Department of
Environment and Conservation
Our environment, our future

Resource Condition Report for a Significant Western Australian Wetland

Hutt Lagoon

2009

Figure 1 – A view across the water body at Hutt Lagoon, coloured pink by alga.

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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 describes the ecological character and condition of Hutt Lagoon, an expansive coastal brine lake in the state's Midwest. Hutt Lagoon was selected as a study site for the IAI RCM project because it is listed in the Directory of Important Wetlands in Australia (DIWA) as an important stop-over for migratory waterbirds (Environment Australia 2001). It is also a proposed Natural Diversity Recovery Catchment, a program of the Department of Environment and Conservation (DEC) that aims to recover and protect significant natural areas, particularly wetlands, from salinity.

1.1. Site Code

Inland Aquatic Integrity Resource Condition Monitoring Project: RCM028.

Directory of Important Wetlands in Australia: WA035.

OzCoasts Estuary ID: 908.

Salinity Action Plan Wetland Biological Survey: SPS189.

Hutt Catchment Survey: HUT012.

1.2. Purpose of Resource Condition Report

This RCR provides a summary of information relevant to the ecology of Hutt Lagoon. 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 lagoon and assist with assessing the effectiveness of management planning and actions at the site.

1.3. Relevant Legislation and Policy

This section provides a summary of the legislation and policy that may be relevant to the management of Hutt Lagoon.

International

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds that may be relevant to Hutt Lagoon. 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 - 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.

Western Australia state 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.

Conservation and Land Management Act 1987

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

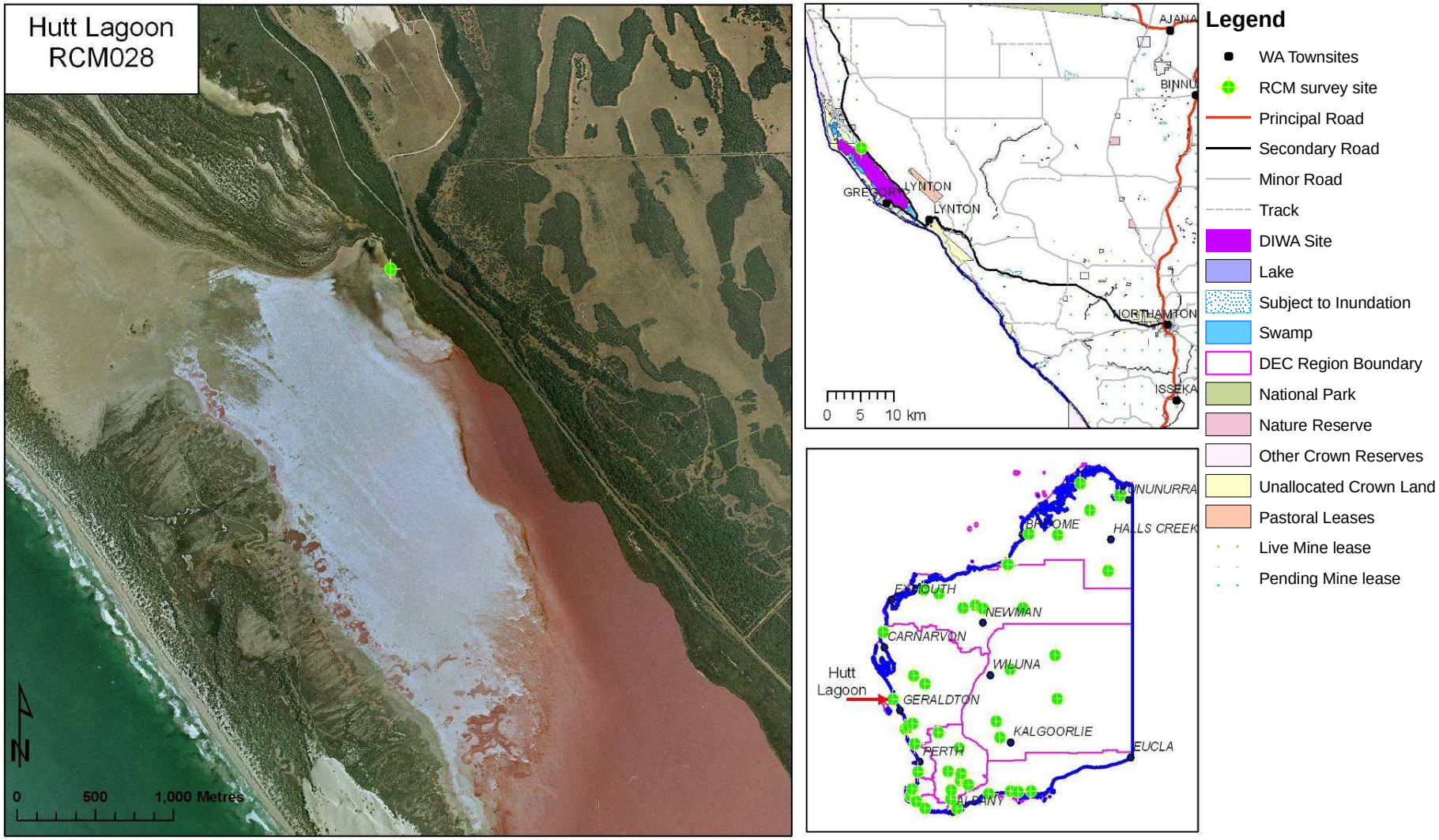

Figure 2 – Aerial photograph showing the position of the survey location at Hutt Lagoon. Also shown, the position of the site relative to surrounding towns (upper insert) and other IAI RCM survey sites (lower insert).

2. Overview of Hutt Lagoon

2.1. Location and Cadastral Information

Hutt Lagoon lies 2 km northeast of Port Gregory and approximately 50 km east-southeast of Kalbarri. The surrounding land is a complex mixture of tenure types, with the southern end of the lake a crown lease and the northern end a 'water feature' that is not vested in any management authority. Unallocated Crown Land lies to the north, south and west of the lagoon as well as forming a bridge across its centre. East of the lagoon is freehold land, mainly used for wheat and sheep farming, but also containing a large garnet mine. There is a shire reserve on the lagoon's south east margin and the Gregory townsite on its south west. The road to Kalbarri (George Grey Drive) runs along the eastern margin of the lagoon (Figure 2, Figure 3).

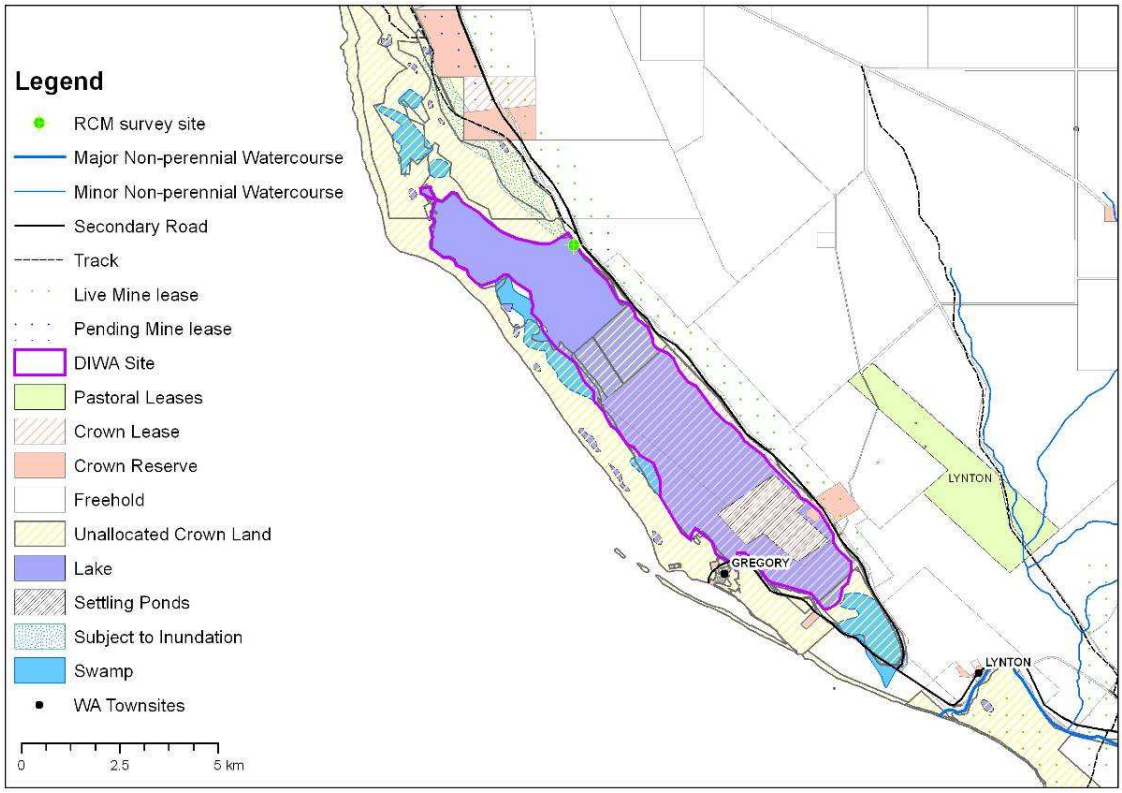

Figure 3 – Tenure of the Hutt Lagoon area.

2.2. IBRA Region

Hutt Lagoon lies within the Geraldton Hills subregion of the Geraldton Sandplains Interim Biogeographic Regionalisation of Australia (IBRA) region. This subregion incorporates the southern end of the Carnarvon Basin and northern end of the Perth Basin. It features exposed areas of Permian/Silurian siltstone and Jurassic sandstones, mostly overlain by sandplain, alluvial plains, and coastal limestone. The vegetation consists primarily of proteaceous heath with emergent *Banksia* and *Actinostrobus* with York Gum woodlands on alluvial plains and *Acacia* scrub on limestone (Desmond and Chant 2002).

2.3. Climate

The nearest Bureau of Meteorology weather station to Hutt Lagoon is at Geraldton, approximately 80 km to the south (Bureau of Meteorology 2009). Weather conditions at Hutt Lagoon do not typically differ appreciably from those at Geraldton.

Geraldton experiences a Mediterranean climate with mild, wet winters and hot, dry summers. It receives a mean annual rainfall of 449.7 mm with approximately 70% falling between May and August (Figure 4). Mean annual evaporation at Geraldton is approximately 2,445 mm.

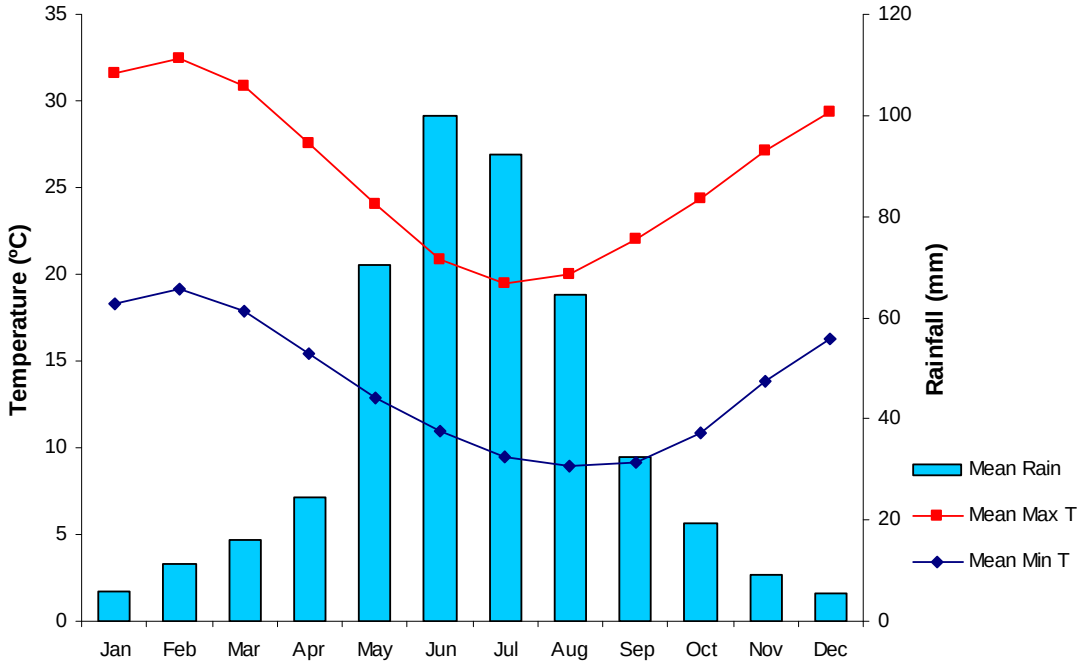

Figure 4 – Climatic means for Geraldton, approximately 80 km southeast of Hutt Lagoon.

In the nine months preceding the IAI RCM survey, which was conducted on the 9th of October 2008, Geraldton received 326.4 mm of rain. The majority of this (239.2 mm) fell between April and July but approximately 8 mm fell in the month preceding the survey.

2.4. Wetland Type

Hutt Lagoon is a macroscale elongate sumpland aligned northwest to southeast, parallel to the coast. It neighbours macroscale elongate floodplains (to the northwest and southeast) that include more than twenty microscale elongate sumplands such as Utcha Swamp (Jaensch 1992).

The Directory of Important Wetlands in Australia (Environment Australia 2001) describes the Hutt Lagoon as a 'brackish to saline lagoon (or marsh) with one or more relatively narrow connections with the sea (type B10). The Hutt Lagoon System also includes 'intertidal marshes' (type B8), 'non-tidal freshwater forested wetlands' (type B12), and 'estuarine waters' (type B6).

2.5. Directory of Important Wetlands in Australia Criteria

Hutt Lagoon is designated as a wetland of national importance under criteria 1 and 6 of the Directory of Important Wetlands in Australia. These criteria are as follows:

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

  Hutt Lagoon is a good example of a coastal brine lake.

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

  Hutt Lagoon is of cultural significance to the local Aboriginal people and of historical significance as an early centre of European settlement in WA.

2.6. Values of Hutt Lagoon

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 consumptive uses of Hutt Lagoon.

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. For example, firewood may be exchanged for money, or another commodity.

Hutt Lagoon contains the world's largest microalgae production plant, a 250 ha series of artificial ponds used to farm *Dunaliella salina.* This microalga gives Hutt Lagoon its pink colouring and is used to produce beta-carotene, a natural food-colouring agent and source of vitamin A. Water for the farm is pumped into the ponds from the ocean.

Hutt Lagoon also provides a commercial supply of *Artemia* brine shrimp. *Artemia* are a specialty feed used by prawn and fish farmers and the aquarium fish trade.

c. Ecosystem services

There are many naturally occurring phenomena that bring enormous benefit to mankind. For example, 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. Hutt Lagoon is a good example of a coastal brine lake and is an important stop-over for migratory waders. It may also play an important role in the hydrology of the area and provides a large area of habitat for native flora and fauna.

d. Amenity

Amenity describes features of the natural environment that make life more pleasant for people. For example, pleasant views, shade or wind shelter from a stand of trees. Hutt Lagoon is valued for the amenity it provides. The pink colouration of the lake has scenic value because it is not commonly found elsewhere. Tourism operators recommend visitation of the site at sundown to observe colour changes in the lagoon at sunset (Total Travel 2009).

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 can also be considered 'control' sites that allow us to benchmark other, altered habitats.

Research on commercial production of beta-carotene at brine lakes has been conducted at Hutt Lagoon. Hutt Lagoon has also been part of two previous biological surveys conducted by DEC: the Salinity Action Plan Biological Survey of the South-west Agricultural Zone and the Hutt Catchment Survey. This history of previous research increases the scientific value of the lagoon.

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.

Hutt Lagoon is used by the local community as a recreation site. The stunning contrast of the pink lagoon with the blue ocean provides countless opportunities for photographers. Nearby Sanford's House is of cultural significance and is a tourist attraction. It was built by convicts in 1853 and may be viewed across Hutt Lagoon.

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. Although Hutt Lagoon itself has no documented spiritual significance to the local Aboriginal people, there are several sites of significance in its near vicinity. These include Utcha Well, Hutt River and two burial sites (Department of Indigenous Affairs 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. Every lost taxon or ecosystem represents a lost opportunity. The alga, *Dunaliella salina*, is under development by the pharmaceutical industry as a potential cancer treatment. Research has shown that the type of beta-carotene contained in the algae is up to ten times more effective at preventing the development of cancerous cells than ordinary beta-carotene (Hieber *et al.* 2000). Microalgae, such as that found in Hutt Lagoon, may also be potentially used for biodiesel production (Tan 2008).

The intent of nature conservation is usually to maintain the ecosystem services, scientific uses, educational uses and potential for future uses at a given site. Doing so is likely to have positive effects on the amenity, recreational uses 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, part of Hutt Lagoon is used for beta-carotene research and production, and is highly 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 Hutt Lagoon

The objective of the Hutt Lagoon 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 Hutt Lagoon'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 results of the 2008 IAI RCM survey of Hutt Lagoon.

Component	Summary description
Geomorphology	Macroscale elongate sumpland situated parallel to the coast at the junction of the Perth and Carnarvon Basins, in sediments of mainly marine origin
Hydrology	Newly formed lagoon supplied by rainfall, surface inflow from several minor creeks and groundwater seepage
Water Quality	Brine, poikilohaline (228.3 mS/cm)
Phytoplankton	Pink alga *Dunaliella salina*
Benthic Plants	None
Littoral Vegetation	Low open shrubland (samphire) and sedgeland surrounded by open heathland
Invertebrates	Low diversity but high compared to other highly saline wetlands
Fish	None seen
Waterbirds	None seen

3.1. Geology and Soils

Hutt Lagoon is situated at the junction of the Perth and Carnarvon Basins. This area is characterised by exposed areas of Permian/Silurian siltstone and Jurassic sandstone and sediments of marine origin (Desmond and Chant 2002).

The Lagoon itself lies on Quaternary deposits of alluvium, colluvium and dune and beach sands (white calcareous and quartzose sands) (Witt 1997). Coastal dunes 0.3 - 1 km wide, with a maximum elevation of 13 m, separate Hutt Lagoon from the Indian Ocean. A plateau of approximately 100 m elevation, which includes 8 km of cliff, is near the inland edge of the site (Jaensch 1992).

3.2. Hydrology

Hutt Lagoon was probably once the estuary of Hutt River but became cut off from the ocean and was eventually completely separated from the river by a sandbar. The Hutt River now flows into the ocean 2 km southeast of Hutt Lagoon. The lagoon's water is supplied only by direct precipitation, surface inflow from several minor creeks off the plateau and seepage of groundwater (especially from coastal dunes). Its depth is highly seasonal, reaching a maximum of 1 m (Jaensch 1992).

3.3. Water Quality

Hutt Lagoon is naturally highly saline (>150 g/L) and sodium chloride dominated (Table 2. The water is usually clear (colour <20 TCU and turbidity <30 NTU), though it may become more turbid under prolonged windy conditions. Water pH is slightly alkaline (7.26 to 8.05). Nitrogen concentration is fairly high (total filterable nitrogen [TFN] 2,200 – 3,300 µg/L), being in the upper quartile of almost 2000 values recorded by DEC Science Division at sites state-wide. Phosphorus levels are low (TFP <50 µg/L)).

The total concentration of nitrogen (4,800 µg/L) was well above the 1,500 µg/L proposed trigger value for concern in southwestern Australian wetlands (ANZECC/ARMCANZ 2000). Although some nutrients are added to the water by the algae farm, the amount of nitrogen would be quite

low as high levels of nitrogen reduce beta-carotene formation. Furthermore, the algae, which are harvested, would take up most of the nitrogen supplied (M. Borowtizka, pers.comm.). Therefore, the elevated nitrogen levels are unlikely a result of the algae farm and may be attributed to fertiliser leaching from nearby farms. Nutrient levels are typically elevated in salt lakes, so this may not be of great concern but should be monitored.

Table 2 – Water quality parameters measured at Hutt Lagoon by the Salinity Action Plan Wetland Biological survey, Hutt Catchment survey and IAI RCM survey.

	SAP survey SPS189 Jul 1999	Hutt survey HUT012B Sep 2007	RCM survey RCM028 Nov 2008
pH	8.02	8.05	7.26
Alkalinity (mg/L)	145	250	180
TDS (g/L)	180	190	320
Turbidity (NTU)	3.9	29	31
Colour (TCU)	2.5	17	210
Total nitrogen (ug/L)			4800
Total phosphorus (ug/L)			140
Total soluble nitrogen (ug/L)	2200	2300	3300
Total soluble phosphorus (ug/L)	10	40	20
Chlorophyll (ug/L)	3.5	4.5	3.5
Na (mg/L)	69600	51800	123000
Mg (mg/L)	3000	4450	6750
Ca (mg/L)	965	372	764
K (mg/L)	1230	1640	2450
Cl (mg/L)	110000	84800	208000
SO_4 (mg/L)	6470	7520	12000
HCO_3 (mg/L)	177	305	220
CO_3 (mg/L)	1	0.5	0.5

3.4. Phytoplankton

The pink alga *Dunaliella salina* is abundant in Hutt Lagoon (Jaensch 1992).

3.5. Benthic Plants

There were no aquatic plants in the lagoon adjacent to the transect site.

3.6. Littoral Vegetation

The vegetation of Hutt Lagoon consists of low samphire shrubland in periform or latiform arrangement, with sedgeland present at seepage sites (Jaensch 1992). The samphire communities of Hutt Lagoon have been recognised as a rare feature with 'known special values in relation to landscape, ecosystem, species and genetic values' (Desmond and Chant 2002). The surrounding areas support open healthland which includes River Red Gum (*Eucalyptus camaldulensis*) (Jaensch 1992).

A single vegetation transect was established on the northeastern side of Hutt Lagoon (Table 3).

Table 3 –Attributes of the Hutt Lagoon vegetation transect.

Datum		39730
Zone		50
Easting		226653
Northing		6887171
Length		30 m
Bearing		170
Wetland state		Full
Soil state (%)	Dry	0
	Waterlogged	50
	Inundated	50
Substrate (%)	Bare	70
	Rock	0
	Cryptogam	0
	Litter	0
	Trash	0
	Logs	0
Time since last fire		fire unlikely here
Community condition		Natural
Upper Stratum	Cover (%)	-
	Height (m)	-
Mid Stratum	Cover (%)	-
	Height (m)	-
Ground Cover	Cover (%)	35
	Height (m)	<0.3

Transect RCM028-R1

This vegetation transect was established within 5 m of the water's edge. Soil was waterlogged at the time of survey with 50% of the ground covered by standing water. Vegetation was dominated by *Sarcocornia quinqueflora* low open samphire shrubland (35% cover, <0.3 m tall) with scattered individuals of *Triglochin striata* (Figure 5). There were no other plant species recorded along the transect (Table 4).

The overall community condition was considered 'natural' (Table 10 in Appendix 1).

Further from the water's edge the vegetation distinctly changed to *Juncus kraussii* closed rushland, amongst which the weed *Cyperus laevigatus* occurred in abundance (Figure 6). The vegetation then graded into *Baumea juncea*, *Gahnia trifida* closed sedgeland, amongst which *Typha domingensis*, *Samolus repens* var. *paucifolius* and *Apium prostratum* occurred in low abundance. *Acacia rostellifera* and *Myoporum insulare* tall shrubland dominated the dunes further upland of the lagoon.

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

G1+ ^*Sarcocornia quinqueflora*, *Triglochin striata*\samphire shrub, forb\1\i.

Figure 5 – *Sarcocornia quinqueflora* along vegetation transect RCM028-R1.

Figure 6 – Distinct vegetation boundary between *Sarcocornia quinqueflora* open shrubland (right) and *Juncus kraussii* closed rushland (left).

Table 4 – Plant taxa recorded along transect RCM028-R1 (in order of dominance).

Genus	Species	Height (m)	Stratum[1]	Growth Form
Sarcocornia	*quinqueflora*	0.3	G1	Chenopod
Triglochin	*?striata*	0.2	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 (ESCAVI 2003).
? Limited confidence in identification

3.7. Aquatic Invertebrates

Hutt Lagoon is highly saline and this is reflected in the very low diversity of aquatic invertebrates present. The aquatic invertebrates of the lagoon have been surveyed in three different projects: SAP Biological Survey of the South-west Agricultural Zone (spring 1999), Hutt Catchment Survey (spring 2007) and for the Resource Condition Monitoring Project (spring 2008). In these projects,

twelve, eighteen and ten species were collected respectively at salinities of 180, 190 and 320 g/L (Table 5). A total of thirty-three species have been collected (Table 6), indicating that the total known richness is increasing with additional sampling effort. Invertebrate richness, recorded at other sites with salinities between 150 and 320 g/L during past DEC projects, have ranged from naught to nine, suggesting the Hutt aquatic invertebrate diversity counts are comparatively high.

Table 5 – **Aquatic invertebrate diversity of Hutt Lagoon as sampled by the Salinity Action Plan Wetland Biological Survey, the Hutt Catchment Survey and the Inland Aquatic Integrity Resource Condition Monitoring project.**

Diversity measure	**SAP survey site SPS189 July 1997**	**Hutt Catchment Survey HUT012B Sep 2007**	**RCM Survey RCM028 Sep 2008**
Total invertebrate species richness	12	18	-
Macroinvertebrate species richness	9	5	9
Total invertebrate family richness	10	14	-
Macroinvertebrate family richness	8	7	7


Austrochiltonia subtenuis

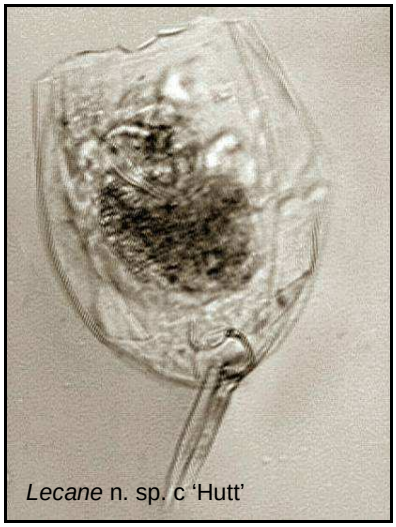
Lecane n. sp. c 'Hutt'

Figure 7– **Two of the aquatic invertebrate taxa collected at Hutt Lagoon.**

Most species found in Hutt Lagoon are well-known and widespread halophiles, such as the chironomid *Tanytarsus barbitarsus*, amphipod *Austrochiltonia subtenuis* (Figure 7) and ostracod *Mytilocypris mytiloides*. Crustaceans and diptera account for almost all taxa, with a small number of rotifers, one record of a water mite, one lepidopteran, one nematode plus an unidentified hydrophilid beetle larvae. Three species have marine affinities, though they have not been formally identified as marine species. These are the ostracod *Paradoxostoma* sp., and copepods *Robertsonia* sp. and Lourinidae sp. The only other records of these species are from Lake MacLeod in Western Australia.

The *Artemia* brine shrimps are believed to be anthropogenic introductions to Australia. Those from Hutt Lagoon have been identified as *Artemia parthenogenetica* in the past on the basis that that males have never been found, though there are disagreements about the identity of *Artemia* in Australia (Ruebhart *et al.* 2008). This species has undoubtedly been present in Hutt Lagoon for at least two decades. The ecological effects of this introduction are unknown but

A. parthenogenetica is unlikely to have replaced endemic *Parartemia* as they inhabit inland salt lakes rather than coastal lagoons. *Artemia* and other crustaceans are a significant food resource for wading birds.

One of the rotifers, *Lecane* n. sp. c 'Hutt' (Figure 7) is thus far known only from Hutt Lagoon but has only been recorded once (during the SAP survey) and is suspected to have been simply a contracted specimen of *Lecane grandis*.

The species collected during the RCM project are representative of what has been found in the past, but includes first records of the widespread dipteran families Ephydridae and Dolichopodidae.

Table 6 – Aquatic invertebrate species collected at Hutt Lagoon*.

Class	Order	Family	LowestID	SAP survey SPS189	Hutt survey HUT012B	RCM survey RCM028
Nematoda	-	-	Nematoda	+		
Rotifera	Ploimida	Lecanidae	Lecane grandis	+		
			Lecane sp. nov. c (Hutt Lagoon) (SAP)	+		
Arachnida	Parasitiformes	-	Mesostigmata		+	
Crustacea	Anostraca	Artemiidae	Artemia sp.	+	+	1,2,3
	Ostracoda	Cyprididae	Australocypris insularis		+	
			Diacypris spinosa		+	
			Mytilocypris mytiloides		+	
		Paradoxostomidae	Paradoxostoma sp.		+	
	Copepoda	Centropagidae	Calamoecia clitellata		+	
		Cyclopidae	Halicyclops ambiguus		+	
			Mesocyclops brooksi		+	
			Apocyclops dengizicus		+	
		Canthocamptidae	Mesochra baylyi		+	
		Diosaccidae	Robertsonia sp.		+	
		Ameiridae	Nitocra sp. 5 (SAP)	+		
		Lourinidae	Lourinidae		+	
	Amphipoda	Ceinidae	Austrochiltonia subtenuis		+	1,2
	Isopoda	Philosciidae	Philosciidae	+		
Insecta	Coleoptera	Dytiscidae	Hydroglyphus leai			
			Necterosoma penicillatus			
		Hydrophilidae	Helochares tatei			
			Hydrophilidae	+	+	
	Diptera	Ceratopogonidae	Culicoides sp.	+	+	
		Stratiomyidae	Stratiomyidae	+		1
		Dolichopodidae	Dolichopodidae			1
		Ephydridae	Ephydridae			2
			Ephydridae sp. 6 (SAP)	+		1,2
		Muscidae	Muscidae sp. A (SAP)	+		1,2
		Chironomidae	Procladius paludicola	+		
			Orthocladiinae sp. P (SAP)	+		3
			Tanytarsus barbitarsis	+	+	1,3
	Lepidoptera	-	Lepidoptera		+	
	Odonata	Lestidae	Austrolestes annulosus			
			Austrolestes psyche			

* The SAP and HUT sample 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 were replicate 15 m benthic sweeps (bare sediment) using a net with 250 µm mesh.
+ Presence in SAP and HUT samples, numbers indicate presence in samples 1, 2 or 3 of the RCM sampling.
Shading indicates microinvertebrates (not identified for RCM project)

3.8. Fish

No fish were sighted during the 2008 IAI RCM survey. There are no previous records of fish at Hutt Lagoon.

3.9. Waterbirds

No waterbirds were sighted during the 2008 IAI RCM survey. However, waterbird surveys have previously been conducted at Hutt Lagoon as part of the SAP Biological Survey of the South-west Agricultural Zone (SPS) and Hutt Catchment Survey (HUT) (Table 7).

The Royal Australasian Ornithologists Union (now Birds Australia) conducted waterbird surveys in the Hutt Lagoon System, in 1984 and 1985 (Jaensch *et al.* 1988). These surveys recorded six species of waterbirds at Hutt Lagoon, including up to 100 Red-capped Avocets. Around 1,000 shorebirds were counted at Hutt Lagoon in November 1986. Many of these were migratory species, indicating the wetland is an important migration stop-over, particularly for waders (Jaensch 1992).

Table 7 – Waterbirds observed by the Department of Environment and Conservation at Hutt Lagoon (numbers indicate abundance).

		Project and Date of Survey	
Common name	**Latin name**	**SPS 21/07/1999**	**HUT 15/09/2007**
Australian Shelduck	*Tadorna tadornoides*	9	24
Banded Stilt	*Cladorhynchus leucocephalus*		77
Black-winged Stilt	*Himantopus himantopus*	4	51
Grey Teal	*Anas gracilis*	4	22
Gull-billed Tern	*Gelochelidon nilotica*	3	
Little Grassbird	*Megalurus gramineus*		5
Pacific Black Duck	*Anas superciliosa*		12
Red-capped Plover	*Charadrius ruficapillus*	23	4
Red-necked Avocet	*Recurvirostra novaehollandiae*	12	96
* Ruddy Turnstone	*Arenaria interpres*		1
Silver Gull	*Larus novaehollandiae*	5	6
Swamp Harrier	*Circus approximans*	2	

* Listed under Migratory Bird Agreements JAMBA, CAMBA and ROKAMBA

3.10. Terrestrial Vertebrates

Kangaroos were sighted at Hutt lagoon. No evidence of other fauna was observed during the 2008 IAI RCM survey.

4. Interactions between Ecological Components at Hutt Lagoon

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

Hale and Butcher (2007) justified the equivalence of Ramsar nomination criteria and primary determinants of ecological character. This justification may also be extended to nomination for the

Directory of Important Wetlands in Australia, as the criteria are very similar. Accordingly, the primary determinants of ecological character at Hutt Lagoon are the characteristics that contribute to the site, namely:

- being a good example of a coastal brine lake; and
- having outstanding historical and cultural significance.

Table 8 summarises the interactions between key components and processes at Hutt Lagoon. 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.

For a diagrammatic representation of the interactions and processes occurring within Hutt Lagoon, refer to the conceptual models of a wave-dominated estuary in Ryan *et al*. (2003).

Table 8 – The relationship between the services and benefits delivered by Hutt Lagoon and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Productive Value Beta-carotene production	*Dunaliella salina*	Fauna communities (grazers)	Water chemistry Salinity Temperature Turbidity	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation
Productive Value *Artemia* supply	*Artemia* sp.	Algae food source (e.g. *Dunaliella salina*)	Water chemistry Salinity Temperature Turbidity	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation
Opportunity Value Potential future use of unique flora and fauna, e.g., as anti-cancer agent	Endemic flora Endemic fauna	Pollinators Food sources	Habitat extent and distribution Hydrological regime Fire regime Water quality	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation Grazing by livestock and introduced pest animals Weeds Predation by introduced fauna
Ecosystem Service Value It is a good example of a wetland type occurring within a biogeographic region in Australia	Coastal brine lake geomorphology	Vegetation communities Aquatic invertebrate assemblages Phytoplankton	Hydrological regime Water quality	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Siltation Grazing by livestock or introduced pest animals Weeds Erosion

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Amenity Value Pink colouring of the waterbody	*Dunaliella salina*	Fauna communities (grazers)	Water chemistry Salinity Temperature Turbidity	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation
Recreational Value Bird watching Picnicking Photography Sight seeing	Landscape amenity Waterbird populations Vegetation communities	Invertebrate populations (food source) Phytoplankton (food source) Vegetation communities	Water chemistry Salinity Temperature Turbidity Soils	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation Grazing by livestock and introduced pests Weeds Predation by introduced fauna Loss of migratory bird populations due to offsite factors
Spiritual Value Outstanding historical or cultural significance	Geomorphology of lake and surrounds Native flora and fauna communities Association with European settlers and Aboriginal people	Flora and fauna populations Pollinators and food sources for above	Soils Hydrology Water quality	Overexploitation by aquaculture Altered hydrology due to climate change, water extraction or catchment perturbation Erratic weather conditions due to climate change Siltation Grazing by livestock and introduced pests Weeds Predation by introduced fauna Erosion

5. Threats to the Ecology of Hutt Lagoon

The ambition for conservation management at Hutt Lagoon is to maintain those elements of the ecology that resulted in its nomination as a DIWA site. The critical components of the ecology are the geomorphologic, hydrologic and water quality factors that make the lake a suitable stopover for migratory birds. 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 communities that inhabit it and the threatening processes that face these. Also of importance are the elements of the system that contribute to its cultural and scientific values. These are the same as the above listed influences on the primary determinants of ecological character, with the addition of landscape amenity.

Threats to Hutt Lagoon must be considered in relation to their likelihood of causing failure of the above management goal for the lake. 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 9. In summary, failure to achieve the management goal for Hutt Lagoon is most likely to result due to impacts associated with aquaculture, mining, and agriculture. Weeds, grazing and eutrophication of the water body are also significant threats.

There are two industries operating either on or near Hutt Lagoon. These are the *Dunaliella. salina* farm, which extracts beta-carotene, and the 'Hose Mine', an open-cut garnet mine immediately to the east of the lagoon. Both of these industries have the potential to alter the hydrology and water quality of Hutt Lagoon if not managed appropriately.

Algae farm

Hutt Lagoon is dominated by the *Dunaliella salina* farm and processing facility. Natural betacarotene and other carotenoids are recovered from the algae, purified, refined and concentrated and then dispatched for further processing. These processes utilise no petrochemical solvents and are said to be environmentally sustainable (Curtain 2000; Cognis undated).

The operation of the algae farm significantly alters the hydrology of Hutt Lagoon. Seawater is supplied to the farm by pumping it from the ocean via a pump house located south of Port Gregory. Used water is discharged into the lagoon. The farm consists of holding pens constructed by creating linear mounds from the lagoon's substrate.

The impacts of the algae farm are likely to increase significantly if a proposed expansion of the farm area goes ahead. This would see the total pond area increase from 250 ha to 850 ha (Borowitzka 1998). This would bring the total area occupied by the algae farm to a third of the wetland, significantly altering its ecology and causing significant soil disturbance.

Garnet Mine

A garnet mine operates on the eastern side of Hutt Lagoon, on the opposite side of the road. Called 'the Hose Mine', it began operations in 1998 with a planned mine life of 30 years (URS Australia 2007). The mine obtains up to 429 ML of water per year from a superficial groundwater aquifer. The proximity of an environmentally sensitive wetland (Utcha Swamp) and a seawater aquifer 'wedge' nearby, combined with the relatively low rainfall, places the sustainability of the groundwater resource at risk. Groundwater draw down could cause seawater intrusion and impact upon Utcha Swamp. The mine's Water Resource Management Operation Strategy outlines a groundwater monitoring program addressing these issues. Monitoring includes weekly records of water levels and salinities at Utcha Swamp, monthly records of monitoring bore water levels and abstraction volumes, salinities and water levels in all (operating) production bores, and annual monitoring of salinity and major ion analysis of groundwater from all production bores and from Utcha Swamp directly. However, the mining company does not appear to monitor any impacts the operation of the mine may have on Hutt Lagoon, despite its close proximity to the lagoon.

Potential for further aquaculture development

An area to the east and south of Hutt Lagoon, north of Hutt River has been identified by the Department of Fisheries as a potential site for further development of land-based aquaculture (Kolkovski and Machin 2004). The area, dubbed Lynton, comprises a coastal area of about 3 km^2 of cleared agricultural land. Lynton is considered one of the best sites in the mid-west coastal region for land-based aquaculture. If development were to proceed at the site, issues related to the use and discharge of sea water would need to be resolved. Two options for discharging used water have been proposed: northwards to Hutt Lagoon and southwards to Hutt River. Draining used water into the lagoon would increase the concentration of nutrients in the waterbody. The current nutrient levels are already elevated and further enrichment of the water body is undesirable.

Agriculture

Land adjacent to Hutt Lagoon is currently being used for agriculture, particularly cereal cropping. The soils of the area are sandy, highly hydraulically transmissive and prone to aeolian erosion. It is likely that elevated nutrient levels in Hutt Lagoon are a consequence of fertiliser use on surrounding farmland.

Causeway

The main access road to port Gregory has been built on land reclaimed across the southern section of Hutt lagoon. This has altered the hydrology of the wetland by impeding surface water flow. The road may also be contributing pollutants to the lagoon via surface run-off.

Threats to vegetation

Several threats to the vegetation of Hutt Lagoon have been identified (Desmond and Chant 2002). These include grazing pressure, exotic weeds (particularly wild oats and lupins) and changes to hydrology. Specifically, altered flow regimes are affecting riparian vegetation due to a rising watertable. The condition of the vegetation of the Hutt Lagoon System was assessed by the Biodiversity Audit of Western Australia as fair, but declining.

Climate Change

Climate change is expected to affect Hutt Lagoon. The Geraldton area has already experienced a decrease in rainfall over the last 30 years (Bureau of Meteorology 2003), and this trend is expected to continue (CSIRO 2001). Longer periods of drought are expected with more severe weather events. The impacts of this on the ecology and geomorphology of Hutt Lagoon are difficult to predict and should be monitored. It is possible that climate change may lead to alteration in wetland extent, water quality and vegetation.

Table 9 – Threat assessment for Hutt Lagoon.

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 Hutt Lagoon, thus ensuring it remains a suitable migratory stopover for waterbirds and retains its cultural and scientific values.

Threat category	Management issue	Probability that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Altered biogeochemical processes	Hydrological processes, particularly salinity	0.1	0.1	Hutt Lagoon is located within a highly disturbed catchment, where significant clearing has occurred for agriculture. The nearby garnet mine may also be affecting the hydrology of the area. The algae farm uses seawater rather than groundwater.
	Carbon cycle and climate change	0.05	0.05	A drying climate with decreased rainfall is predicted. The impacts of this are difficult to predict but may lead to some alteration in the composition of vegetation.
Impacts of introduced plants and animals	Environmental weeds	0.1	0.05	Weeds have been identified as one of the primary threats to the ecology of the Hutt Lagoon, particularly wild oats and lupins (Desmond and Chant 2002).
	Herbivory, wallowing and trampling by introduced species	0.02	0.01	Grazing has been identified as a potential threat.
Impacts of problem native species	Overgrazing by native species	0.01	0.01	Grazing has been identified as a potential threat.
Impacts of disease	Plant pathogens	0	0	No impacts evident.
Detrimental regimes of physical disturbance events	Fire regimes	0	0	The vegetation communities of Hutt Lagoon are not particularly fire prone.
	Drought	0.01	0.01	Possible longer periods of drought as a result of climate change are predicted for the area. The impacts of this difficult to predict but may lead to some alteration in the composition of vegetation.
	Flood	0.01	0.01	Major flooding does not occur often in the Northern Agricultural region. While it is not known how the frequency of flooding will be affected by climate change, this is unlikely to be a significant threat.

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 pollution	Herbicide, pesticide or fertiliser use and direct impacts	0.2	0.1	Agriculture is occurring adjacent to Hutt Lagoon and pollution from the spread of fertilisers or herbicides may be responsible for elevated nitrogen levels in the lagoon.
Impacts of competing land uses	Recreation management	0.01	0	Recreational usage of Hutt Lagoon is low impact and unlikely to have any deleterious impacts.
	Nutrient enrichment of water body	0.2	0.1	Hutt Lagoon contained high levels of nitrogen, which may be the result of excess nutrient input from surrounding agriculture or from processes within the algae farm or garnet mine. It may also be a result of run-off from the causeway to Port Gregory. However, nutrient levels are frequently elevated in salt lakes and this may be a natural occurrence.
	Urban and industrial development	0.3	0.1	An area immediately southeast of Hutt Lagoon has been identified as a potential site for further development of aquaculture.
	Consumptive uses	0	0	No evidence of consumptive uses of Hutt Lagoon.
	Illegal activities	0	0	No evidence of any threat.
	Mines and quarries	0.1	0.05	A nearby garnet mine may be impacting on hydrology in the area.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	0.01	0.01	Hutt Lagoon is well-connected to extensive areas of natural or near-natural environment. Populations are likely to self-supporting in this setting. Off-site impacts on migratory birds could potentially reduce their population size to unsustainable levels, but this could not be addressed at a site level.

6. Knowledge Gaps and Recommendations for Future Monitoring

Considering the significant productive usage of Hutt Lagoon, it is strongly advised that long-term monitoring of the wetland is established. The RCM and SAP surveys conducted by DEC have provided baseline data on the ecological character of Hutt Lagoon. Ongoing surveillance is required to establish any impacts the algae farm and garnet mine are having on the wetland. This will become even more important if expansion of the algae ponds or further development of aquaculture or mining is pursued. Particular attention should be paid to the water chemistry (especially nitrogen and salinity) and how this is affected by the supply and drainage of sea-water into Hutt Lagoon.

Vegetation should also be monitored for impacts resulting from agricultural practices or altered hydrology. The impacts of weeds, grazing and soil erosion should be considered. Changes in the extent and composition of plant communities should be recorded, as these could indicate degradation of the ecosystem. Recovery actions have previously been recommended for the plant assemblages at Hutt Lagoon. These include (Desmond and Chant 2002):

- habitat protection through reserves, on other State lands and on private lands;
- fencing for exclosure of feral herbivores;
- feral animal control of rabbits and goats;
- weed control for critical habitats; and
- fire management, especially for species with juvenile periods of greater than 5 - 8 years.

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Appendix 1 – Vegetation Condition

Table 10 – 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
	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

Appendix 2 – Herbarium Plant Records

Plant specimens submitted to the Western Australian Herbarium:
Triglochin ?striata (RCM028-R1-02)

Table 11 – Herbarium Records for Hutt Lagoon.

Search Coordinates: NW corner 28.0432°S, 114.1558°E ; SE corner 28.2648°S, 114.3737°E

Family	Species	Alien	Cons. Status
Acarosporaceae	*Acarospora citrina*		
Agyriaceae	*Trapeliopsis psammophila*		
Aizoaceae	*Carpobrotus* sp.		
Aizoaceae	*Mesembryanthemum crystallinum*	Y	
Aizoaceae	*Tetragonia decumbens*	Y	
Aizoaceae	*Tetragonia implexicoma*		
Amaranthaceae	*Ptilotus chortophytum*		P1
Amaranthaceae	*Ptilotus drummondii*		
Amaranthaceae	*Ptilotus eriotrichus*		
Amaranthaceae	*Ptilotus gaudichaudii* subsp. *parviflorus*		
Amaranthaceae	*Ptilotus helichrysoides*		
Amaranthaceae	*Ptilotus manglesii*		
Amaranthaceae	*Ptilotus* sp. Geraldton (R. Davis 10952)		
Amaranthaceae	*Ptilotus villosiflorus*		
Anthericaceae	*Caesia* sp. Wongan (K.F. Kenneally 8820)		
Anthericaceae	*Thysanotus manglesianus*		
Apocynaceae	*Alyxia buxifolia*		
Asteraceae	*Argyroglottis turbinata*		
Asteraceae	*Brachyscome iberidifolia*		
Asteraceae	*Brachyscome pusilla*		
Asteraceae	*Cephalosorus carpesioides*		
Asteraceae	*Dittrichia graveolens*	Y	
Asteraceae	*Erymophyllum tenellum*		
Asteraceae	*Gilberta tenuifolia*		
Asteraceae	*Gnephosis tenuissima*		
Asteraceae	*Hyalosperma glutinosum* subsp. *glutinosum*		
Asteraceae	*Lawrencella davenportii*		
Asteraceae	*Myriocephalus occidentalis*		
Asteraceae	*Olearia homolepis*		
Asteraceae	*Ozothamnus* sp. Geraldton (J. Brooker & M. Weir 913)		P1
Asteraceae	*Podolepis lessonii*		
Asteraceae	*Podotheca gnaphalioides*		
Asteraceae	*Rhodanthe chlorocephala* subsp. *rosea*		
Asteraceae	*Sonchus hydrophilus*		
Asteraceae	*Symphyotrichum squamatum*	Y	
Asteraceae	*Waitzia acuminata* var. *albicans*		
Asteraceae	*Waitzia nitida*		
Asteraceae	*Waitzia podolepis*		
Bonnemaisoniaceae	*Asparagopsis taxiformis*		
Boraginaceae	*Echium plantagineum*	Y	
Boraginaceae	*Halgania argyrophylla*		
Boraginaceae	*Halgania sericiflora*		
Bryaceae	*Rosulabryum billarderi*		
Caesalpiniaceae	*Labichea lanceolata* subsp. *lanceolata*		

Family	Species	Alien	Cons. Status
Caesalpiniaceae	*Senna glutinosa* subsp. *chatelainiana*		
Candelariaceaa	*Candelaria* sp.		
Candelariaceaa	*Candelariella vitellina*		
Caulerpaceae	*Caulerpa sedoides* forma *germinata*		
Chenopodiaceae	*Atriplex canescens*	Y	
Chenopodiaceae	*Atriplex cinerea*		
Chenopodiaceae	*Atriplex isatidea*		
Chenopodiaceae	*Atriplex paludosa* subsp. *baudinii*		
Chenopodiaceae	*Chenopodium murale*	Y	
Chenopodiaceae	*Rhagodia latifolia* subsp. *recta*		
Chenopodiaceae	*Rhagodia preissii* subsp. *obovata*		
Chenopodiaceae	*Sarcocornia blackiana*		
Chenopodiaceae	*Sarcocornia quinqueflora*		
Chenopodiaceae	*Tecticornia halocnemoides*		
Chenopodiaceae	*Tecticornia indica* subsp. *bidens*		
Chenopodiaceae	*Tecticornia syncarpa*		
Chenopodiaceae	*Tecticornia undulata*		
Chloanthaceae	*Lachnostachys eriobotrya*		
Chloanthaceae	*Pityrodia atriplicina*		
Cladoniaceae	*Cladonia cervicornis* subsp. *verticillata*		
Cladoniaceae	*Cladonia* sp.		
Cladoniaceae	*Heterodea beaugleholei*		
Cladoniaceae	*Heterodea muelleri*		
Cladoniaceae	*Notocladonia cochleata*		
Cladoniaceae	*Thysanothecium hookeri*		
Cladostephaceae	*Cladostephus verticillatus*		
Codiaceae	*Codium spongiosum*		
Colchicaceae	*Burchardia rosea*		
Colchicaceae	*Wurmbea dioica* subsp. *alba*		
Colchicaceae	*Wurmbea monantha*		
Convolvulaceae	*Convolvulus remotus*		
Convolvulaceae	*Wilsonia humilis*		
Cunoniaceae	*Aphanopetalum clematideum*		
Cupressaceae	*Actinostrobus pyramidalis*		
Cupressaceae	*Callitris columellaris*		
Cyperaceae	*Baumea juncea*		
Cyperaceae	*Baumea rubiginosa*		
Cyperaceae	*Cyperus laevigatus*	Y	
Cyperaceae	*Gahnia trifida*		
Cyperaceae	*Isolepis congrua*		
Cyperaceae	*Lepidosperma striatum*		
Cyperaceae	*Lepidosperma tenue*		
Cyperaceae	*Schoenus armeria*		
Cyperaceae	*Schoenus clandestinus*		
Cyperaceae	*Schoenus rigens*		
Cyperaceae	*Schoenus* sp.		
Cyperaceae	*Schoenus subfascicularis*		
Cystoseiraceae	*Caulocystis uvifera*		
Dasypogonaceae	*Acanthocarpus canaliculatus*		
Dasypogonaceae	*Acanthocarpus preissii*		
Dasypogonaceae	*Acanthocarpus* sp.		
Dasypogonaceae	*Lomandra hastilis*		
Dasypogonaceae	*Lomandra maritima*		

Family	Species	Alien	Cons. Status
Deuteromycotina	*? Lepraria* sp.		
Deuteromycotina	*Leprocaulon* sp.		
Dicranaceae	*Campylopus introflexus*		
Dilleniaceae	*Hibbertia desmophylla*		
Dilleniaceae	*Hibbertia glabrisepala*		
Dilleniaceae	*Hibbertia hypericoides*		
Dilleniaceae	*Hibbertia spicata*		
Droseraceae	*Drosera humilis*		
Droseraceae	*Drosera macrantha* subsp. *macrantha*		
Droseraceae	*Drosera neesii* subsp. *borealis*		
Droseraceae	*Drosera omissa*		
Epacridaceae	*Astroloma* sp. Kalbarri (D. & B. Bellairs 1368)		
Epacridaceae	*Leucopogon* sp. Mid West (J.S. Beard 7388)		
Epacridaceae	*Leucopogon* sp. Port Gregory (C. Page 33)		P1
Epacridaceae	*Lysinema ciliatum* forma N of Perth (N. Sammy s.n. 15/8/1985)		
Epacridaceae	*Lysinema ciliatum*		
Euphorbiaceae	*Adriana urticoides* var. *urticoides*		
Euphorbiaceae	*Beyeria cinerea*		
Euphorbiaceae	*Euphorbia drummondii* subsp. *drummondii*		
Euphorbiaceae	*Euphorbia tannensis* subsp. *eremophila*		
Euphorbiaceae	*Euphorbia terracina*	Y	
Euphorbiaceae	*Phyllanthus calycinus*		
Euphorbiaceae	*Stachystemon nematophorus*		R
Frankeniaceae	*Frankenia* aff. *pauciflora*		
Frankeniaceae	*Frankenia confusa*		P2
Frankeniaceae	*Frankenia pauciflora*		
Goodeniaceae	*Dampiera altissima*		
Goodeniaceae	*Dampiera incana* var. *incana*		
Goodeniaceae	*Dampiera linearis*		
Goodeniaceae	*Dampiera oligophylla*		
Goodeniaceae	*Dampiera* sp.		
Goodeniaceae	*Goodenia hassallii*		
Goodeniaceae	*Lechenaultia floribunda*		
Goodeniaceae	*Lechenaultia linarioides*		
Goodeniaceae	*Scaevola anchusifolia*		
Goodeniaceae	*Scaevola kallophylla*		P4
Goodeniaceae	*Scaevola oldfieldii*		P3
Goodeniaceae	*Scaevola phlebopetala*		
Goodeniaceae	*Scaevola porocarya*		
Goodeniaceae	*Scaevola* sp.		
Goodeniaceae	*Scaevola spinescens*		
Goodeniaceae	*Scaevola thesioides* subsp. *thesioides*		
Goodeniaceae	*Scaevola virgata*		
Goodeniaceae	*Verreauxia reinwardtii*		
Gyrostemonaceae	*Gyrostemon racemiger*		
Gyrostemonaceae	*Tersonia cyathiflora*		
Haemodoraceae	*Anigozanthos humilis x manglesii*		
Haemodoraceae	*Anigozanthos kalbarriensis*		
Haemodoraceae	*Anigozanthos manglesii* subsp. *quadrans*		
Haemodoraceae	*Conostylis aculeata* subsp. *septentrionora*		
Haemodoraceae	*Conostylis aurea*		
Haemodoraceae	*Conostylis prolifera*		

Family	Species	Alien	Cons. Status
Haemodoraceae	*Conostylis stylidioides*		
Halimediaceae	*Halimeda cuneata*		
Heppiaceae	*Heppia* sp.		
Hydatellaceae	*Trithuria australis*		P2
Hymeneliaceae	*Aspicilia calcarea*		
Iridaceae	*Moraea setifolia*	Y	
Iridaceae	*Patersonia occidentalis* var. *occidentalis*		
Juncaceae	*Juncus kraussii* subsp. *australiensis*		
Juncaginaceae	*Triglochin* sp. A Flora of Australia (G.J. Keighery 2477)		
Lamiaceae	*Hemigenia pimelifolia*		P2
Lamiaceae	*Prostanthera scutata*		P1
Lamiaceae	*Teucrium* sp. Hutt River (W.H. Butler 54)		P1
Lauraceae	*Cassytha racemosa* forma *racemosa*		
Lecanoraceae	*Clauzadeana macula*		
Lecanoraceae	*Lecanora* sp.		
Lecanoraceae	*Lecanora sphaerospora*		
Lecidiaceae	*Lecidea ochroleuca*		
Lecidiaceae	*Lecidea* sp.		
Lecidiaceae	*Toninia glaucocarpa*		
Lecidiaceae	*Toninia* sp.		
Lichinaceae	*? Paulia* sp.		
Lichinaceae	*Paulia* sp.		
Lobeliaceae	*Isotoma hypocrateriformis*		
Lobeliaceae	*Lobelia alata*		
Lobeliaceae	*Lobelia heterophylla*		
Lobeliaceae	*Lobelia rhytidosperma*		
Loranthaceae	*Amyema miraculosa* subsp. *miraculosa*		
Malvaceae	*Alyogyne coronopifolia*		
Malvaceae	*Alyogyne hakeifolia*		
Malvaceae	*Alyogyne huegelii* var. *huegelii*		
Malvaceae	*Lawrencia viridigrisea*		
Menyanthaceae	*Villarsia congestiflora*		P3
Mimosaceae	*Acacia ? scirpifolia*		
Mimosaceae	*Acacia alata* var. *biglandulosa*		
Mimosaceae	*Acacia alata* var. *biglandulosa* (Peduncles glabrous)		
Mimosaceae	*Acacia andrewsii*		
Mimosaceae	*Acacia ashbyae*		
Mimosaceae	*Acacia idiomorpha*		
Mimosaceae	*Acacia lasiocarpa* var. *lasiocarpa*		
Mimosaceae	*Acacia latipes* subsp. *licina*		P3
Mimosaceae	*Acacia pelophila*		P1
Mimosaceae	*Acacia pulchella* var. *glaberrima*		
Mimosaceae	*Acacia ridleyana*		P3
Mimosaceae	*Acacia rostellifera*		
Mimosaceae	*Acacia saligna* subsp. *lindleyi*		
Mimosaceae	*Acacia scirpifolia*		
Mimosaceae	*Acacia spathulifolia*		
Mimosaceae	*Acacia sphacelata* subsp. *sphacelata*		
Mimosaceae	*Acacia tetragonophylla*		
Mimosaceae	*Acacia ulicina*		
Molluginaceae	*Macarthuria australis*		
Myoporaceae	*Eremophila decipiens* subsp. *decipiens*		
Myoporaceae	*Eremophila glabra* subsp. *albicans*		

Family	Species	Alien	Cons. Status
Myoporaceae	*Eremophila glabra* subsp. *carnosa*		
Myoporaceae	*Eremophila glabra*		
Myoporaceae	*Eremophila microtheca*		P4
Myoporaceae	*Myoporum insulare*		
Myoporaceae	*Myoporum montanum*		
Myrtaceae	*Calothamnus blepharospermus*		
Myrtaceae	*Calothamnus homalophyllus*		
Myrtaceae	*Calothamnus* sp.		
Myrtaceae	*Calytrix depressa*		
Myrtaceae	*Calytrix ecalycata* subsp. *ecalycata*		P3
Myrtaceae	*Calytrix fraseri*		
Myrtaceae	*Calytrix harvestiana*		P2
Myrtaceae	*Chamelaucium micranthum*		
Myrtaceae	*Chamelaucium* sp.		
Myrtaceae	*Darwinia pauciflora*		
Myrtaceae	*Darwinia virescens*		
Myrtaceae	*Eremaea brevifolia*		
Myrtaceae	*Eremaea ebracteata*		
Myrtaceae	*Eremaea ebracteata* var. *ebracteata*		
Myrtaceae	*Eucalyptus arachnaea*		
Myrtaceae	*Eucalyptus arachnaea* subsp. *arachnaea*		
Myrtaceae	*Eucalyptus blaxellii*		R
Myrtaceae	*Eucalyptus camaldulensis* var. *obtusa Blakely*		
Myrtaceae	*Eucalyptus dolichocera*		
Myrtaceae	*Eucalyptus kochii* subsp. *borealis*		
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*		
Myrtaceae	*Eucalyptus oldfieldii*		
Myrtaceae	*Eucalyptus oraria*		
Myrtaceae	*Hypocalymma angustifolium*		
Myrtaceae	*Hypocalymma longifolium*		R
Myrtaceae	*Melaleuca bisulcata*		
Myrtaceae	*Melaleuca cardiophylla*		
Myrtaceae	*Melaleuca concreta*		
Myrtaceae	*Melaleuca coronicarpa*		
Myrtaceae	*Melaleuca radula*		
Myrtaceae	*Melaleuca rhaphiophylla*		
Myrtaceae	*Melaleuca viminea*		
Myrtaceae	*Melaleuca viminea* subsp. *viminea*		
Myrtaceae	*Phymatocarpus porphyrocephalus*		
Myrtaceae	*Pileanthus rubronitidus*		
Myrtaceae	*Pileanthus vernicosus*		
Myrtaceae	*Scholtzia* aff. *umbellifera*		
Myrtaceae	*Scholtzia laxiflora*		
Myrtaceae	*Scholtzia* sp. Geraldton (A. Strid 20714)		
Myrtaceae	*Scholtzia* sp. Yerina Springs (N. Hoyle 517)		
Myrtaceae	*Scholtzia spatulata*		
Myrtaceae	*Thryptomene baeckeacea*		
Myrtaceae	*Verticordia chrysantha*		
Myrtaceae	*Verticordia chrysanthella*		
Myrtaceae	*Verticordia densiflora* var. *roseostella*		P3
Myrtaceae	*Verticordia oculata*		
Myrtaceae	*Verticordia spicata* subsp. *spicata*		
Najaceae	*Najas marina*		

Family	Species	Alien	Cons. Status
Nyctaginaceae	*Commicarpus australis*		
Onagraceae	*Oenothera drummondii*	Y	
Orchidaceae	*Caladenia* aff. *vulgata*		
Orchidaceae	*Caladenia flava* subsp. *maculata*		
Orchidaceae	*Caladenia flava* subsp. *flava*		
Orchidaceae	*Caladenia hoffmanii*		R
Orchidaceae	*Caladenia longicauda* subsp. *borealis*		
Orchidaceae	*Caleana major*		
Orchidaceae	*Cyanicula amplexans*		
Orchidaceae	*Diuris* aff. *laxiflora*		
Orchidaceae	*Diuris laxiflora*		
Orchidaceae	*Diuris recurva*		P4
Orchidaceae	*Drakaea concolor*		R
Orchidaceae	*Microtis brownii*		
Orchidaceae	*Paracaleana minor*		
Orchidaceae	*Prasophyllum elatum*		
Orchidaceae	*Prasophyllum fimbria*		
Orchidaceae	*Prasophyllum macrotys*		
Orchidaceae	*Pterostylis sanguinea*		
Orchidaceae	*Pterostylis* sp. Geraldton (S.D. Hopper 3349)		R
Orchidaceae	*Thelymitra antennifera x macrophylla*		
Papilionaceae	*Bossiaea spinescens*		
Papilionaceae	*Chorizema racemosum*		
Papilionaceae	*Cristonia biloba*		
Papilionaceae	*Daviesia divaricata* subsp. *lanulosa*		
Papilionaceae	*Gastrolobium ebracteolatum*		
Papilionaceae	*Gastrolobium oxylobioides*		
Papilionaceae	*Gastrolobium propinquum*		P1
Papilionaceae	*Glycine canescens*		
Papilionaceae	*Gompholobium tomentosum*		
Papilionaceae	*Jacksonia arenicola*		
Papilionaceae	*Jacksonia cupulifera*		
Papilionaceae	*Jacksonia rigida*		
Papilionaceae	*Kennedia prostrata*		
Papilionaceae	*Leptosema aphyllum*		
Papilionaceae	*Lotus australis*		
Papilionaceae	*Melilotus indicus*	Y	
Papilionaceae	*Mirbelia depressa*		
Papilionaceae	*Mirbelia spinosa*		
Papilionaceae	*Swainsona canescens*		
Parmeliaceae	*Parmelia* sp.		
Parmeliaceae	*Xanthoparmelia prodomokosii*		
Parmeliaceae	*Xanthoparmelia amplexula*		
Parmeliaceae	*Xanthoparmelia congesta*		
Parmeliaceae	*Xanthoparmelia exillima*		
Parmeliaceae	*Xanthoparmelia isidiigera*		
Parmeliaceae	*Xanthoparmelia lineola*		
Parmeliaceae	*Xanthoparmelia notata*		
Parmeliaceae	*Xanthoparmelia reptans*		
Parmeliaceae	*Xanthoparmelia tasmanica*		
Parmeliaceae	*Xanthoparmelia verisidiosa*		
Parmeliaceae	*Xanthoparmelia xanthomelanoides*		P2
Peltulaceae	*Peltula* cf. *euploca*		

Family	Species	Alien	Cons. Status
Peltulaceae	*Peltula obscurans*		
Peltulaceae	*Peltula* sp.		
Pertusariaceae	*Ochrolechia* sp.		
Physciaceae	*Buellia* sp.		
Physciaceae	*Physcia ? jackii*		
Physciaceae	*Physcia* sp.		
Physciaceae	*Rinodina ? thiomela*		
Pittosporaceae	*Marianthus bicolor*		
Plumbaginaceae	*Limonium companyonis*	Y	
Poaceae	*Austrodanthonia occidentalis*		
Poaceae	*Austrodanthonia setacea*		
Poaceae	*Austrodanthonia* sp.		
Poaceae	*Austrostipa elegantissima*		
Poaceae	*Austrostipa macalpinei*		
Poaceae	*Austrostipa tenuifolia*		
Poaceae	*Brachypodium distachyon*	Y	
Poaceae	*Cenchrus ciliaris*	Y	
Poaceae	*Ehrharta calycina*	Y	
Poaceae	*Enteropogon ramosus*		
Poaceae	*Eragrostis dielsii*		
Poaceae	*Polypogon monspeliensis*	Y	
Poaceae	*Puccinellia stricta*		
Poaceae	*Sporobolus virginicus*		
Poaceae	*Themeda triandra*		
Polygalaceae	*Comesperma flavum*		
Polygalaceae	*Comesperma integerrimum*		
Portulacaceae	*Calandrinia liniflora*		
Pottiaceae	*Tortella* sp.		
Primulaceae	*Anagallis arvensis* var. *caerulea*	Y	
Primulaceae	*Samolus junceus*		
Primulaceae	*Samolus repens* var. *paucifolius*		
Primulaceae	*Samolus repens*		
Proteaceae	*Adenanthos cygnorum* subsp. *cygnorum*		
Proteaceae	*Banksia fraseri* var. *ashbyi*		
Proteaceae	*Banksia leptophylla* var. *melletica*		
Proteaceae	*Banksia sceptrum*		
Proteaceae	*Banksia sessilis* var. *flabellifolia*		
Proteaceae	*Banksia victoriae*		
Proteaceae	*Conospermum acerosum* subsp. *hirsutum*		
Proteaceae	*Conospermum acerosum* subsp. *acerosum*		
Proteaceae	*Conospermum boreale* subsp. *boreale*		
Proteaceae	*Conospermum stoechadis* subsp. *stoechadis*		
Proteaceae	*Grevillea argyrophylla*		
Proteaceae	*Grevillea biternata*		
Proteaceae	*Grevillea commutata* subsp. *commutata*		
Proteaceae	*Grevillea leucopteris*		
Proteaceae	*Grevillea pinaster*		
Proteaceae	*Grevillea triloba*		P3
Proteaceae	*Hakea circumalata*		
Proteaceae	*Hakea pycnoneura*		
Proteaceae	*Isopogon divergens*		
Proteaceae	*Persoonia acicularis*		
Proteaceae	*Petrophile conifera*		

Family	Species	Alien	Cons. Status
Proteaceae	*Petrophile macrostachya*		
Proteaceae	*Petrophile scabriuscula*		
Proteaceae	*Stirlingia latifolia*		
Proteaceae	*Synaphea recurva*		
Proteaceae	*Synaphea* sp.		
Psoraceae	*Psora crenata*		
Psoraceae	*Psora crystallifera*		
Psoraceae	*Psora decipiens*		
Psoraceae	*Psora* sp.		
Restionaceae	*Chaetanthus aristatus*		
Restionaceae	*Desmocladus asper*		
Restionaceae	*Hypolaena exsulca*		
Restionaceae	*Lyginia imberbis*		
Rhamnaceae	*Blackallia nudiflora*		P3
Rhamnaceae	*Cryptandra arbutiflora* var. *borealis*		
Rhamnaceae	*Cryptandra mutila*		
Rhamnaceae	*Polianthion wichurae*		
Rhamnaceae	*Stenanthemum intricatum*		
Rhizocarpaceae	*Rhizocarpon obscuratum*		
Rhizocarpaceae	*Rhizocarpon* sp.		
Rhodomeliaceae	*Chondrophycus brandenii*		
Rubiaceae	*Opercularia spermacocea*		
Rutaceae	*Boronia cymosa*		
Rutaceae	*Boronia ramosa* subsp. *anethifolia*		
Rutaceae	*Diplolaena geraldtonensis*		
Rutaceae	*Diplolaena grandiflora*		
Rutaceae	*Geleznowia verrucosa*		
Rutaceae	*Geleznowia verrucosa* subsp. *verrucosa*		
Santalaceae	*Santalum acuminatum*		
Sapindaceae	*Diplopeltis huegelii* subsp. *subintegra*		
Sapindaceae	*Diplopeltis petiolaris*		
Sapindaceae	*Dodonaea pinifolia*		
Sapindaceae	*Dodonaea* sp.		
Sapindaceae	*Dodonaea viscosa* subsp. *angustissima*		
Sargassaceae	*Sargassum lacerifolium*		
Sargassaceae	*Sargassum* sp.		
Scytosiphonaceae	*Hydroclathrus clathratus*		
Scytosiphonaceae	*Scytosiphon lomentaria*		
Siphonocladaceae	*Struvea plumosa*		
Siphulaceae	*Siphula coriacea*		
Solanaceae	*Anthocercis genistoides*		
Solanaceae	*Anthocercis ilicifolia* subsp. *ilicifolia*		
Solanaceae	*Anthocercis intricata*		P3
Solanaceae	*Anthocercis* sp.		
Solanaceae	*Solanum americanum*	Y	
Solanaceae	*Solanum lasiophyllum*		
Solanaceae	*Solanum nigrum*	Y	
Solanaceae	*Solanum oldfieldii*		
Solanaceae	*Solanum orbiculatum* subsp. *orbiculatum*		
Solanaceae	*Solanum symonii*		
Stackhouseaceae	*Tripterococcus brunonis*		
Sterculiaceae	*Commersonia gaudichaudii*		
Sterculiaceae	*Guichenotia ledifolia x macrantha*		

Family	Species	Alien	Cons. Status
Sterculiaceae	*Guichenotia quasicalva*		P2
Sterculiaceae	*Guichenotia sarotes*		
Sterculiaceae	*Lasiopetalum angustifolium*		
Sterculiaceae	*Lasiopetalum oldfieldii* subsp. *oldfieldii*		P3
Stylidiaceae	*Levenhookia pusilla*		
Stylidiaceae	*Stylidium elongatum*		
Stylidiaceae	*Stylidium kalbarriense*		
Stylidiaceae	*Stylidium purpureum*		
Stylidiaceae	*Stylidium septentrionale*		
Surianaceae	*Stylobasium australe*		
Teloschistiaceae	*Caloplaca ? montisfracti*		
Teloschistiaceae	*Caloplaca* cf. *tavaresiana*		
Teloschistiaceae	*Caloplaca cranfieldii*		
Teloschistiaceae	*Caloplaca kantvilasii*		
Teloschistiaceae	*Caloplaca kiamae*		
Teloschistiaceae	*Caloplaca lithophila*		
Teloschistiaceae	*Caloplaca montisfracti*		
Teloschistiaceae	*Caloplaca* sp.		
Teloschistiaceae	*Fulgensia ? bracteata*		
Teloschistiaceae	*Fulgensia ? subbracteata*		
Teloschistiaceae	*Fulgensia bracteata*		
Teloschistiaceae	*Fulgensia subbracteata*		
Thelotremataceae	*Diploschistes ? strictus*		
Thelotremataceae	*Diploschistes euganeus*		
Thelotremataceae	*Diploschistes gypsaceus*		
Thelotremataceae	*Diploschistes* sp.		
Thelotremataceae	*Diploschistes strictus*		
Thymelaeaceae	*Pimelea angustifolia*		
Thymelaeaceae	*Pimelea argentea*		
Thymelaeaceae	*Pimelea floribunda*		
Thymelaeaceae	*Pimelea gilgiana*		
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*		
Verrucariaceae	*? Endocarpon* sp.		
Verrucariaceae	*Endocarpon* sp.		
Verrucariaceae	*Placidium* sp.		
Violaceae	*Hybanthus calycinus*		
Vitaceae	*Clematicissus angustissima*		
Zygophyllaceae	*Zygophyllum billardierei*		