ECOLOGICAL CHARACTER DESCRIPTION FOR THE PEEL-YALGORUP RAMSAR SITE

A report to the Department of Environment and Conservation and the Peel-Harvey Catchment Council

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TABLE OF CONTENTS

TABLES

FIGURES

GLOSSARY

Definitions of words associated with ecological character descriptions (DEW 2007).

Administrative Authority	the agency within each Contracting Party charged by the national government with oversight of implementation of the Ramsar Convention within its territory [http://www.Ramsar.org/about/about_glossary.htm].
Adverse conditions	ecological conditions unusually hostile to the survival of plant or animal species, such as occur during severe weather like prolonged drought, flooding, cold, etc (Ramsar Convention 2005).
Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (as defined by Ramsar Convention 2002, Resolution VIII.6).
Baseline	condition at a starting point. For Ramsar wetlands it will usually be the time of listing of a Ramsar site.
Benchmark	a standard or point of reference (ANZECC and ARMCANZ 2000). a pre-determined state (based on the values which are sought to be protected) to be achieved or maintained.
Benefits	benefits/services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	a scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc (Ramsar Convention 2005).
Biological diversity	the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005).
Catchment	the total area draining into a river, reservoir, or other body of water (ANZECC and ARMCANZ 2000).
Change in ecological character	is defined as the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005a, Resolution IX.1 Annex A).
Community	an assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	all the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Community Structure	all the types of taxa present in a community and their relative abundances (ANZECC and ARMCANZ 2000).
Conceptual model	wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003)
Contracting Parties	are countries that are Member States to the Ramsar Convention on Wetlands; 153 as at September 2006. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialized agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice [http://www.Ramsar.org/key_cp_e.htm].
Critical stage	meaning stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers, moulting etc.) which if interrupted or prevented from occurring may threaten long-term conservation of the species. (Ramsar Convention 2005).
Ecological character	is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the variety of benefits to people (Ecosystem Services). (Millennium definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). The phrase "at a given point in time" refers to Resolution VI.1 paragraph 2.1, which states that "It is essential that the ecological character of a site be described by the Contracting Party concerned at the time of designation for the Ramsar List, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).
Ecological communities	any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2005).

Ecosystems	the complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services). (Millennium Ecosystem Assessment 2005).
Ecosystem components	include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002)
Ecosystem services	are the benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food & water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational), and supporting (e.g nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also "Benefits".
Ecologically Sustainable Development	development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ANZECC and ARMCANZ 2000).
Geomorphology	the study of water-shaped landforms (Gordon et al. 1999)
Indicator species	species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2005).
Indigenous species	a species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Introduced (non-native) species	a species that does not originate or occur naturally in a particular country (Ramsar Convention 2005).
Limits of Acceptable Change	the variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed' (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ("the Ramsar List")	the list of wetlands which have been designated by the Ramsar Contracting Partiy in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties [http://www.Ramsar.org/about/about_glossary.htm].
Monitoring	the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management (Ramsar Convention 2002, Resolution VIII.6).
Ramsar	city in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title, "Ramsar Convention on Wetlands" [http://www.Ramsar.org/about/about_glossary.htm].
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values. http://www.Ramsar.org/about/about_glossary.htm
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names "Convention on Wetlands (Ramsar, Iran, 1971)" or "Ramsar Convention" are more commonly used [http://www.Ramsar.org/index_very_key_docs.htm].
Ramsar Information Sheet (RIS)	the form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and conservation measures taken and needed (http://www.Ramsar.org/about/about_glossary.htm).
Ramsar List	the List of Wetlands of International Importance [http://www.Ramsar.org/about/about_glossary.htm].
Ramsar Sites	wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria [http://www.Ramsar.org/about/about_glossary.htm].

Ramsar Sites Database	repository of ecological, biological, socio-economic, and political data and maps with boundaries on all Ramsar sites, maintained by Wetlands International in Wageningen, the Netherlands, under contract to the Convention [http://www.Ramsar.org/about/about_glossary.htm].
Wetlands	are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Finlayson et al. 2001; Ramsar Convention 2002).
Wetland Ecological Risk Assessment	a quantitative or qualitative evaluation of the actual or potential adverse effects of stressors on a wetland ecosystem
Wetland types	as defined by the Ramsar Convention's wetland classification system [http://www.Ramsar.org/ris/key_ris.htm#type].
Wise use of wetlands	is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches[1], within the context of sustainable development[2]" (Ramsar Convention 2005 Resolution IX.1 Annex A). 1. Including inter alia the Convention on Biological Diversity's "Ecosystem Approach" (CBD COP5 Decision V/6) and that applied by HELCOM and OSPAR (Declaration of the First Joint Ministerial Meeting of the Helsinki and OSPAR Commissions, Bremen, 25-26 June 2003). 2. The phrase "in the context of sustainable development" is intended to recognize that whilst some wetland development is inevitable and that many developments have important benefits to society, developments can be facilitated in sustainable ways by approaches elaborated under the Convention, and it is not appropriate to imply that 'development' is an objective for every wetland.

EXECUTIVE SUMMARY

The Peel-Yalgorup wetland system, in south-western Australia, is located approximately 80 km south of Perth within the Swan Coastal Plain bioregion. The 26,000 hectare site includes shallow estuarine waters, saline, brackish and freshwater wetlands of the Peel Inlet, Harvey Estuary, several lake systems including Lake McLarty and Lake Mealup and the Yalgorup National Park. This ecological character description includes the current Ramsar listed site as well the proposed extension of the site, which encompasses Goegrup and Black Lakes.

In June 1990, the Peel-Yalgorup wetland system was designated a "Wetland of International Importance" under the Ramsar Convention on Wetlands. As a Contracting Party to the Ramsar Convention, the Australian Government has accepted a number of obligations with regards to the management of listed wetlands; one of which is to manage listed wetlands in a manner that maintains their "ecological character".

Describing the ecological character of any wetland ecosystem is central to effective management, as the description forms the benchmark against which management planning and actions are set. This includes a description of the benchmark condition for future assessment and monitoring activities. The specific objectives relevant to the Peel-Yalgorup site are to produce a comprehensive description of the ecological character that:

1. Describes the critical components, processes and benefits/services of the wetland found at the Peel-Yalgorup Wetlands Ramsar site and the relationships between them;
2. Develops a conceptual model for the Peel-Yalgorup wetlands that describes the 'ecological character' in terms of components, processes and benefits/services and the relationships between them;
3. Quantifies the limits of acceptable change for the critical components, processes and benefits/services of the wetland;
4. Identifies, using existing knowledge, nutrient water quality objectives that will support the maintenance of critical components, processes and benefits/services in the Peel-Harvey Estuarine system component of the Ramsar site; and
5. Identifies actual or likely threats/risks to the ecological components, processes or services of the Peel-Yalgorup wetlands Ramsar site.

The Peel-Yalgorup Ramsar site meets the following six criteria for listing as a wetland of international importance:

Criterion 1: The site includes the largest and most diverse estuarine complex in south-western Australia and also particularly good examples of coastal saline lakes and freshwater marshes.

Criterion 3: The site is one of only two locations in south-western Australia and one of very few in the world where living thrombolites occur in inland waters.

Criterion 4: The site supports an array of species and communities during critical life stages including: large numbers of migratory birds; breeding of waterbirds, fish, crabs and prawns; drought refuge for waterbirds, fish and invertebrates; and waterfowl such as Shelducks and Musk Ducks during moulting.

Criterion 5: The site comprises the most important area for waterbirds in south-western Australia, supporting in excess of 20,000 waterbirds annually, with greater than 150,000 individuals recorded at one time (February 1977). Numbers exceeding 20,000 birds have been recorded in all comprehensive surveys conducted in the 1990s in the Peel-Harvey Estuary.

Criterion 6: According to the 4th edition of Waterbird Population Estimates, the site regularly supports 1% of the population of: Red-necked Avocet, Red-necked Stint, Red-capped Plover, Hooded Plover, Black-winged Stilt, Banded Stilt, Curlew Sandpiper, Sharp-tailed Sandpiper, Fairy Tern, Musk Duck, Grey Teal, Australasian Shoveler, Australian Shelduck and Eurasian Coot.

Criterion 8: The Peel-Yalgorup Ramsar Site is important as a nursery and/or breeding and/or feeding ground for at least 50 species of fish as well as the commercially significant Blue Swimmer Crab and Western King Prawn. In addition, the Peel-Harvey Estuary is a migratory route for the Pouched Lamprey (*Geotria australis*).

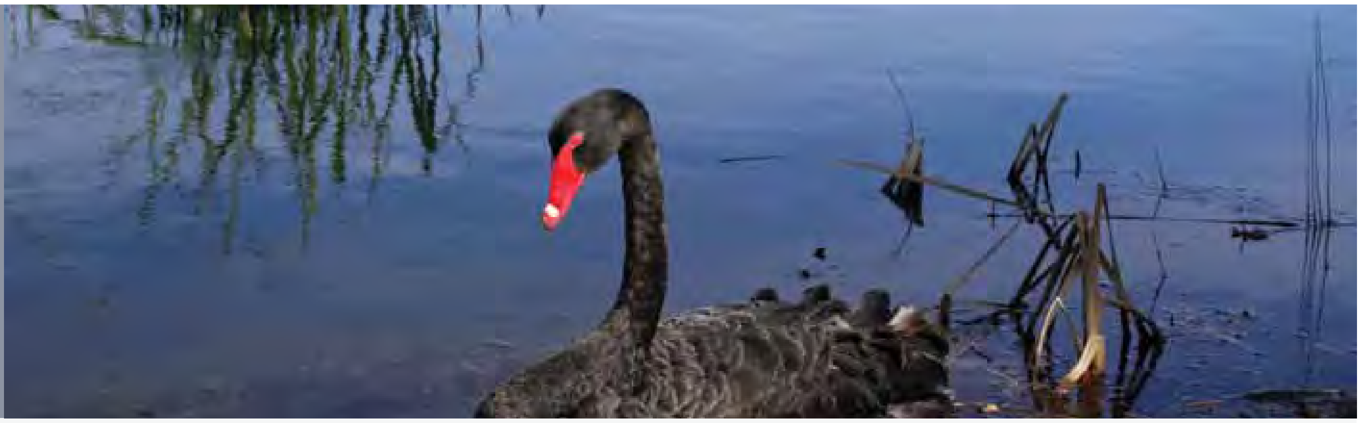
The Peel-Yalgorup site is large and complex, as a consequence, the wetlands within the site have been grouped according to location and wetland type to describe their ecological character:

- Peel Inlet and Harvey Estuary
- Yalgorup Lake System
- McLarty Lake System
- Goegrup and Black Lakes

A summary of the ecological character of the Peel-Yalgorup Ramsar site (at the time of listing) is provided in Table E1.

Table E1: Summary of the ecological character of the Peel-Yalgorup Ramsar site at the time of listing

COMPONENT	SUMMARY DESCRIPTION
PEEL-HARVEY ESTUARY (1990)	
Geomorphology	Shallow “bar-built” estuary Narrow connection to the Indian Ocean (Mandurah Channel) Organic sediments (black ooze)
Hydrology	Highly seasonal freshwater inflows from direct precipitation and rivers Limited tidal exchange with the Indian Ocean Limited groundwater inflows
Water Quality	High concentrations of nutrients (eutrophic) from catchment Seasonal variability in salinity Stratification and deoxygenation of bottom waters
Acid Sulfate Soils	Monosulphidic black ooze Exposed via dredging
Phytoplankton	Winter diatom blooms Spring *Nodularia* blooms in the Harvey Estuary
Benthic Plants	Excessive growth of green macroalgae (*Cladophora* and/or *Chaetomorpha*) in the Peel Inlet Smothering of seagrass
Littoral Vegetation	Samphire communities around the shorelines Paperbark communities in the Harvey River delta
Invertebrates	Commercially significant taxa include blue swimmer crabs and western king prawns Diverse communities in the estuary and the intertidal zones
Fish	Estuarine and marine species Migratory route for some species
Birds	High diversity and abundance of waterbirds Regularly supports > 20,000 waterbirds (maximum recorded 150,000 individuals) Breeding recorded for twelve species Regularly supports > 1 % of the population of eleven species
YALGORUP LAKES (1990)	
Geomorphology	Shallow depressional wetlands No defined surface water inflow or outflow channels
Hydrology	Highly seasonal freshwater inflows predominantly from groundwater No surface water outflows
Water Quality	Brackish to hypersaline conditions Seasonal salinity cycles Low nutrient concentrations Some lakes exhibit stratification Highly alkaline (calcium and bicarbonate)



COMPONENT	SUMMARY DESCRIPTION
Benthic Microbial Community	Thrombolites in Lake Clifton Cyanobacterial algal mats across the sediment surface in some lakes
Flora	Small buffer zones Some areas of paperbark communities
Fauna	Significant site for waterbirds Large numbers of Shelduck and Black Swans annually 1% of population of Banded Stilt, Red-necked Stint, Hooded Plover, Shelduck and Musk Duck Breeding of eight species
LAKES MCLARTY AND MEALUP (1990)	
Geomorphology	Shallow depressional wetlands No defined surface water inflow or outflow channels
Hydrology	Highly seasonal freshwater inflows predominantly from groundwater No natural surface water outflows (although there are drains present)
Water Quality	Fresh to brackish conditions Alkaline
Flora	Typha across parts of each lake Sedges on the margins Paperbark community at higher elevations
Fauna	Important habitat for freshwater invertebrates Provides habitat for a large diversity and number of waterbirds Breeding recorded for 12 species of waterbird
LAKES GOEGRUP AND BLACK (2007)	
Geomorphology	Riverine wetlands on the Serpentine River Goegrup within the river Black connected to Goegrup by a narrow channel
Hydrology	Highly seasonal freshwater inflows predominantly from river flows Tidal influence for the Indian Ocean via the Peel Inlet
Water Quality	Seasonal cycle of salinity High concentrations of nutrients Low dissolved oxygen concentrations
Flora	High phytoplankton biomass Samphire at low elevations in the littoral zone Paperbark communities at high elevations
Fauna	Data deficient Supports waterbirds

The Peel-Yalgorup site was first listed under the Ramsar convention as a wetland of international importance in 1990. Since that time there have been a number of changes in the surrounding catchment and to the wetlands. There has been a substantial increase in the population of Mandurah, which has nearly doubled to around 70,000 people since the time of listing. This has put increased pressure on the wetlands in the Ramsar site in terms of recreational use, nutrient and contaminant loads, groundwater extraction and urban development, including the development of canals within the estuary. All of these have the potential to impact on the ecological character of the site. However, the single most influential factor was the construction of the Dawesville Channel, a large artificial connection to the Indian Ocean, designed to decrease the nutrient accumulations and algal problems in the Peel-Harvey Estuary, which opened in April 1994.

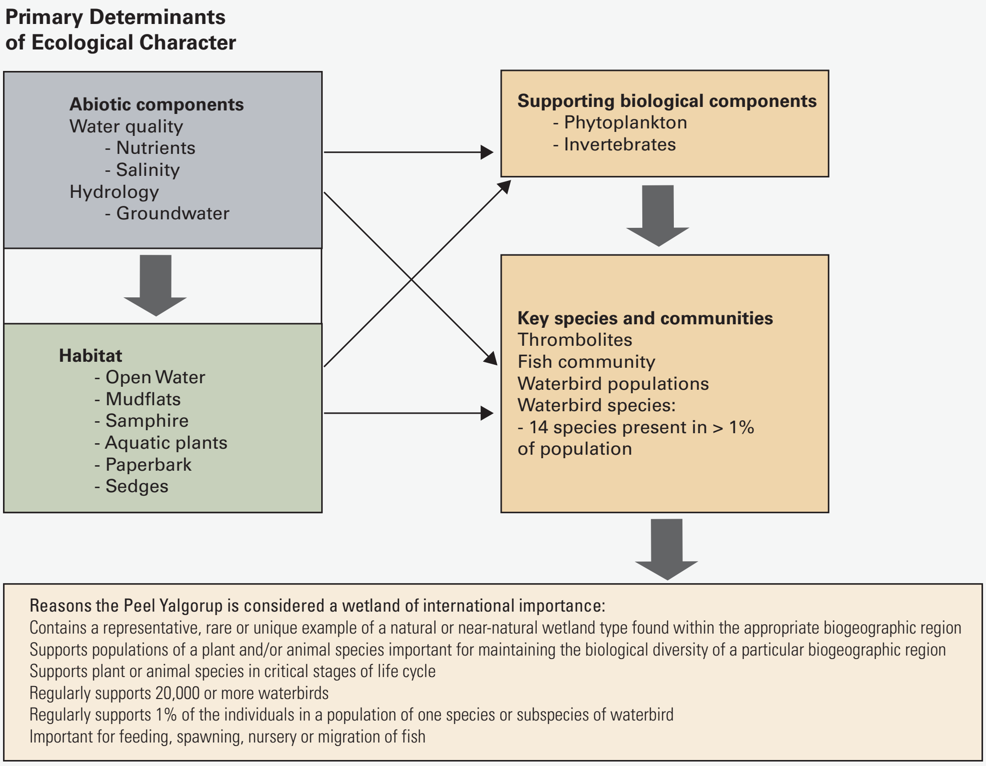
The increased connection to the marine environment has resulted in fundamental and permanent changes to ecological components of the Peel-Harvey Estuary. Attributes such as hydrology and water quality have changed significantly and had effects on the biotic components of the system. While there can be no doubt that the Peel-Yalgorup remains a wetland of international importance and that it continues to meet the Ramsar criteria under which it was listed (Lane *et al.* 2002), management of the system must be consistent with this new environment. For this reason, the current ecological character description based on changes summarised in Table E2, is the benchmark against which future change should be measured.

Table E2: Changes in the ecological character of the Peel-Yalgorup Ramsar site since listing. (Note that as Lakes Goegrup and Black have yet to be listed this section is not applicable to these wetlands)

COMPONENT	SUMMARY DESCRIPTION
PEEL-HARVEY ESTUARY (2007)	
Geomorphology	Dawesville Channel
Hydrology	Increased exchange with the Indian Ocean Changed tidal regime
Water Quality	Nutrient concentrations in the water column decreased Salinity conditions more marine (temporally and spatially) Stratification reduced
Acid Sulfide Soils	Monosulphidic black ooze Exposed via dredging Selenium risk
Phytoplankton	Decreased phytoplankton biomass No *Nodularia* blooms recorded in the Harvey Estuary
Benthic Plants	Decreased macroalgal biomass Increased extent of seagrass
Littoral Vegetation	Changes to samphire – data deficient Deterioration of tree health in the Harvey Estuary
Fish	Increase in marine species Decrease in Cobbler Possible decrease in estuarine species
Birds	No evidence of change in abundance or diversity
YALGORUP LAKES (2007)	
Hydrology	Changes to lake levels – data deficient Potential decrease in groundwater inflows
Water Quality	Salinity and nutrient increases – data deficient Potential increase in nutrients in Lake Clifton and increases in salinity
Benthic Microbial Community	Some evidence in breakdown of microbial mats Thrombolite condition – data deficient
Fauna	Some changes to fish populations in Lake Clifton and recorded fish kills No evidence of change in abundance or diversity of waterbirds
LAKES MCLARTY AND MEALUP (2007)	
Hydrology	Changes to lake levels – data deficient for McLarty Increase in duration of dry periods at Lake Mealup Potential decrease in groundwater inflows
Water Quality	Salinity and nutrient increases – data deficient for Lake McLarty Increases in nutrients and acidification of Lake Mealup
Flora	Loss of sedges and rushes at Lake McLarty
Fauna	Some evidence of an increase in shorebirds at Lake McLarty Anecdotal evidence of waterbird declines at Lake Mealup

The attributes that are central to maintaining the ecological character of a Ramsar site have been described as "primary determinants". In the context of the Peel-Yalgorup Ramsar site primary determinants have been defined as those components and processes that are crucial to the maintenance of the components and processes for which the site has been listed. This includes the abiotic components of water quality and hydrology as well as habitat to maintain key species and communities (Figure E1).

Figure E1: Primary determinants of ecological character at the Peel-Yalgorup site.



The major threatening activities, the threatening processes they induce and the potential impacts to the Peel-Yalgorup site have been identified (Figure E2). The major threatening activities, which could impact on the ecological character of the Peel-Yalgorup Ramsar site, are:

- Agricultural activities in the catchment;
- Altered hydrology
- Urban and peri-urban development;
- Commercial and recreational fishing;
- Recreation; and
- Climate change.

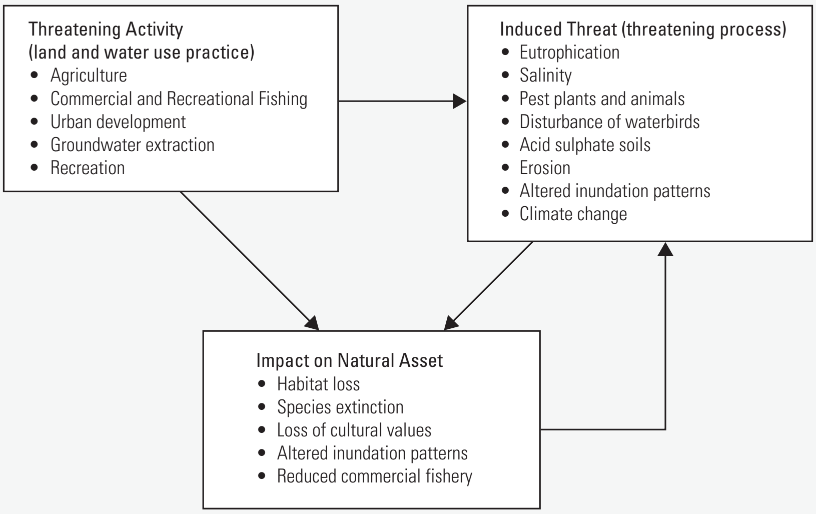


Figure E2: Threatening activities, induced threats and impacts to ecological character.

"Limit of acceptable change" is the terminology used under the Ramsar Convention to set limits on how much key aspects of the ecology of the site can change without risking the ecological character. The setting of limits of acceptable change is a complex and difficult task and is heavily reliant on good baseline or background data. Limits of acceptable change for the Peel-Yalgorup site have been determined based on existing data and guidelines and have been set at a number of time scales (Figure E3). Short-term limits of acceptable change (with a corresponding intensive monitoring program) have been set for measures for which change can be detected in the short term (e.g. water quality). Conversely for other measures, for which change may take longer periods to detect, longterm limits have been set. Finally the key biological components are considered. For most of these, quantitative limits of acceptable change are difficult to determine, either due to a lack of baseline data, inherent high levels of natural variability, or in the case of many waterbird species, factors outside the site affecting their distribution and abundance observed at the site. For this reason, although strict "limits of acceptable change" cannot be set for these components, they form an important element of the monitoring program. Outcomes of the monitoring program are to be reviewed for broad trends and the information used to review and refine the limits of acceptable change for the site.

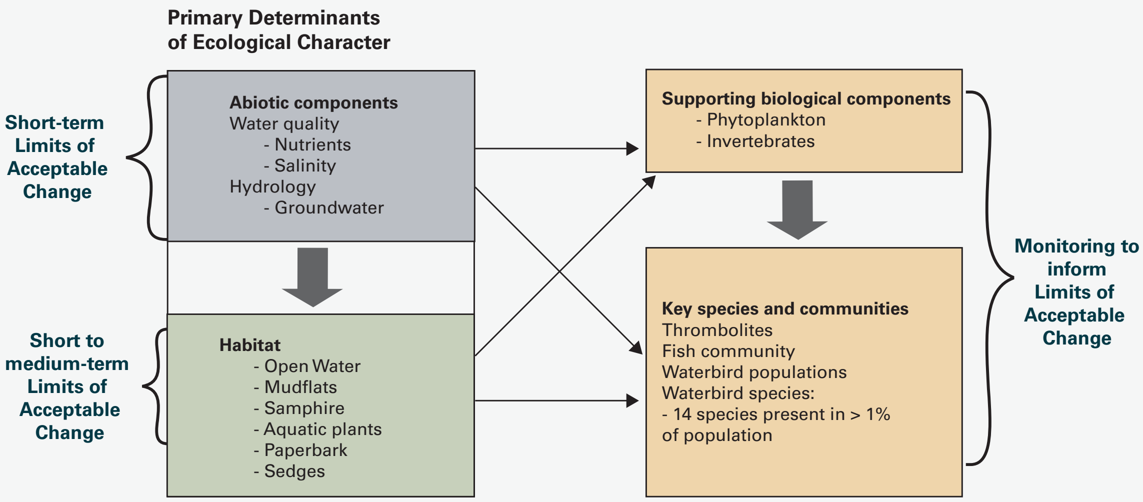


Figure E3: Hierarchical system for setting limits of acceptable change.

The key knowledge gaps that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table E3.

Table E3: Key knowledge gaps

COMPONENT/PROCESS	KNOWLEDGE GAP
PEEL-HARVEY ESTUARY	
Water Quality – Acid sulfate soils	The effect on water quality (pH and contaminant concentrations – selenium) is not known or understood
Phytoplankton	Extent, frequency, duration and distribution of algal blooms in the Peel Inlet and Harvey Estuary from 2002 to current
Aquatic Plants	Community composition, distribution and temporal patterns of seagrass and macroalgal communities within the estuary
Littoral vegetation	Current extent and condition of salt marsh vegetation
	Current extent and condition of paperbark communities
Fish	Current community composition and abundance of fish communities
Waterbirds	There has been no systematic survey and reporting of abundance, species composition or breeding and there is insufficient data to determine spatial and temporal trends or habitat usage
YALGORUP LAKES	
Hydrology	There is little information on the water levels within the lakes and the inflowing of groundwater
Water Quality	There is no comprehensive data on water quality (salinity or nutrients) of the lakes upon which trends could be assessed
Aquatic plants	There is no recent information on the extent and condition of aquatic plants in the lakes
Fish	Black Bream in Lake Clifton pose an unknown threat to the thrombolites. Their feeding patterns and effect on the thrombolites are not known
Waterbirds	Trends in waterbird populations at the lakes
LAKES MCLARTY AND MEALUP	
Hydrology	There is little information on the water levels within the lakes and the inflowing of groundwater
Water quality	There is limited data on water quality (salinity or nutrients) from the lakes
Flora	Extent and distribution of sedgelands is not currently known In addition the impact of cattle grazing on the system is not known
	The extent and condition of the paperbark community upon which many bird species are reliant for roosting and nesting is not known
Waterbirds	There is no systematic data on waterbirds from the lakes upon which trends in breeding, abundance and habitat usage could be assessed
LAKES GOEGRUP AND BLACK	
Hydrology	The hydrology of the two lakes is poorly documented
Water quality	There is little data on water quality (salinity or nutrients) from the lakes themselves
Fish	Current community composition and abundance of fish communities
Waterbirds	There is insufficient data to determine spatial and temporal trends or habitat usage

To address these knowledge gaps and inform against the limits of acceptable change the monitoring needs for the Peel-Yalgorup site have been documented and prioritised. This includes monitoring of the following across the site:

- Hydrology (surface and groundwater);
- Water quality;
- Phytoplankton;
- Aquatic plants;
- Littoral vegetation;
- Fish; and
- Waterbirds

In addition to the required monitoring; there are a number of areas where there is incomplete understanding of processes and threats. While these may not require the establishment of monitoring programs, there is a need for research or investigations to enable the site to be managed to maintain ecological character. Specifically these are:

1. Acid Sulfate Sediments – High Priority
2. Threats to the Thrombolites at Lake Clifton – High Priority
3. Cattle Grazing at Lakes McLarty and Mealup – High Priority

Effect of vegetation changes on non-wading waterbirds at Lake McLarty – Medium Priority

1. INTRODUCTION

1.1 CONTEXT/SITE DETAILS

The Peel-Yalgorup wetland system was designated a "Wetland of International Importance" under the Ramsar Convention on Wetlands in June 1990. The *Ramsar Convention on Wetlands, especially as waterfowl habitat* was ratified in Ramsar, Iran in 1971. Commonly referred to as the Ramsar Convention, with wetlands listed under the Convention called Ramsar sites, there are 153 Contracting Parties including Australia. As a Contracting Party the Australian Government has accepted a number of obligations with regards to the management of listed wetlands. This includes management that promoted the conservation, wise and sustainable use, compatible with the maintenance of natural features of the wetland ecosystems. These obligations (Convention Articles 3.1 and 3.2) have been interpreted by signatory governments to equate to an undertaking to manage wetlands so as to maintain their "ecological character".

Describing the ecological character of any wetland ecosystem is central to effective management, as the description forms the benchmark against which management planning and actions are set. This includes a description of the benchmark condition for future assessment and monitoring activities. In 1990 the Peel-Yalgorup site was listed as an excellent example of a representative, rare or unique wetland type, for supporting regional biodiversity and being a significant site for waterbirds. As part of the nomination process a Ramsar Information Sheet (RIS) was compiled, providing a description of the site, the criterion for which the site was listed, and supporting information. A summation of this information for the Peel-Yalgorup Ramsar site is provided in Table 1 below.

The Peel-Yalgorup system is adjacent to the City of Mandurah and also within the Shires of Murray, Waroona and Harvey, Western Australia. The Peel-Yalgorup Ramsar site includes shallow estuarine waters, saline, brackish and freshwater wetlands of the Peel Inlet, Harvey Estuary, several lake systems including Lake McLarty and Lake Mealup and the Yalgorup National Park. The site is geomorphically complex and biologically diverse. Large populations of waterbirds utilise the estuary and lakes and there is a diversity of fish, aquatic invertebrates and fringing salt marsh vegetation. In addition, the system contains rare microbial communities in the form of thrombolites.

As early as the 1970s and continuing through to the early 1990s, the system suffered the effects of eutrophication, predominantly due to inputs of phosphorus from the catchment. This resulted in an increase in algal growth, and of particular concern, blooms of the potentially toxic cyanobacterium, *Nodularia*. The results of investigations in the 1980s concluded that a reduction in nutrient loads from the catchment would be insufficient to alleviate the problem in an acceptable time, and that improved catchment management should be complemented by increasing nutrient loss to the ocean. As a consequence, the Dawesville Channel was commissioned, and this opening to the Indian Ocean was opened in 1994.

This resulted in significant changes to the system with a decrease in nutrient concentrations in the estuary (but not flowing in from the catchment) and a corresponding decline in phytoplankton. Salinity has become more marine and tidal fluctuations increased, which has affected fauna such as fish and invertebrates as well as fringing samphire and paperbark communities.

Management of Peel-Yalgorup Ramsar site is not only affected by the continuing loading of nutrients from the three main river systems, but also by its proximity to the fast developing City of Mandurah. Canal developments, increased recreational and commercial pressure all must be considered in the management of this system.

Although, technically, this ecological character description (ECD) should extend only to the areas currently under the Ramsar listing, the Department of Environment and Conservation and the Peel-Harvey Catchment Council have requested that the ECD description be expanded to include two wetlands currently outside the Ramsar boundary. Goegrup and Black Lakes lie to the north of the current Ramsar boundary, but are hydrologically connected to the site. It is the intention of State agencies to propose an extension to the Ramsar boundary to include these two waterbodies.

Table 1: Site details for the Peel-Yalgorup Ramsar site taken from the Ramsar Information Sheet (2007).

Site Name	Peel-Yalgorup System, Western Australia
Location in coordinates	Latitude: 32° 32' S to 33° 06' S Longitude: 115° 37' E to 115° 47' E
General location of the site	The Peel-Yalgorup system is in the City of Mandurah and the Shires of Murray, Waroona and Harvey (local authorities), Western Australia. Biogeographic region: Swan Coastal Plain. The original areas nominated comprised: Peel Inlet (south of the old Mandurah Estuary Bridge) and Harvey Estuary; Nature Reserves adjoining the eastern and southern sides of Peel Inlet; Nature Reserves adjoining the eastern and southern sides of Harvey Estuary; most of Lake McLarty; Lake Mealup; and the waters (principally Lakes Clifton, Preston, Boundary, Pollard, Martins Tank, Yalgorup, Hayward and Newnham) and lands of Yalgorup National Park. The site was extended in 2001 to include seven additional areas, most of which were recent additions to the conservation reserve system.
Area	26,530 hectares
Date of Ramsar site designation	Originally nominated in June 1990 Site was extended in 2001
Ramsar/DIWA Criteria met by wetland	Ramsar criteria 1, 3, 4, 5, 6 and 8.
Management authority for the site	The water in the estuary is non-tenured crown land, and managed by the Department of Water. The majority of all other lake, ex-direct freehold, national parks, state forest and reserves are vested with the WA Conservation Commission and are managed by the Department of Environment and Conservation. A number of lesser foreshore reserves are managed by a variety of agencies including the Shire of Murray, City of Mandurah, the Department of Water, and the Water Corporation. There are also a number of smaller parcels that remain vacant crown land. All areas are Zoned as Regional Open Space or Waterways under the Peel Region Planning Scheme, giving stricter planning controls by the WA Planning commission.
Date the ECD applies	1990 and current
Status of Description	This represents the first ECD for the site
Date of Compilation	December 2007
Name(s) of compiler(s)	Jennifer Hale on behalf of DEC and PHCC all enquires to Michael Coote, DEC, 17 Dick Perry Ave, Technology Park, Kensington, WA 6983, Australia, (Tel: +61-8-9334-0479; Fax: +61-8-9334-0199; email: Michael.Coote@dec.wa.gov.au).
References to the Ramsar Information Sheet (RIS)	Peel-Yalgorup System, Western Australia – 36 RIS compiled by the Western Australian Department of Conservation & Land Management (DCLM) in 1990; updated by Roger Jaensch, Wetlands International - Oceania, on behalf of DCLM in 1998, and by DCLM staff in 2000 and 2003. Electronic version: http://www.environment.gov.au/cgi-bin/wetlands/report.pl Updated by Jennifer Hale on behalf of DEC and PHCC 2007
References to Management Plan(s)	At time of printing the management plan was yet to be finalised.

1.2 PURPOSE OF ECOLOGICAL CHARACTER DESCRIPTIONS

The Ramsar Convention has defined "ecological character" and "change in ecological character" as (Ramsar 2005):

"Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time"

And

"…change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service."

In order to detect change it is necessary to establish a benchmark for management and planning purposes. Ecological character descriptions (ECD) form the foundation on which a site management plan and associated monitoring and evaluation activities are based. The legal framework for ensuring the ecological character of all Australian Ramsar sites is maintained is the *Environment Protection and Biodiversity Act, 1999* (the EPBC Act) (see Figure 1). As mentioned above a Ramsar Information Sheet is prepared at the time of designation. However whilst there is some link between the data used for listing a site (based on the various criteria) the information in an RIS does not provide enough detail on the interactions between ecological components, processes and functions to constitute a comprehensive description of ecological character. In response to the short fall, the Australian and state/territory governments have developed the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEW 2007).

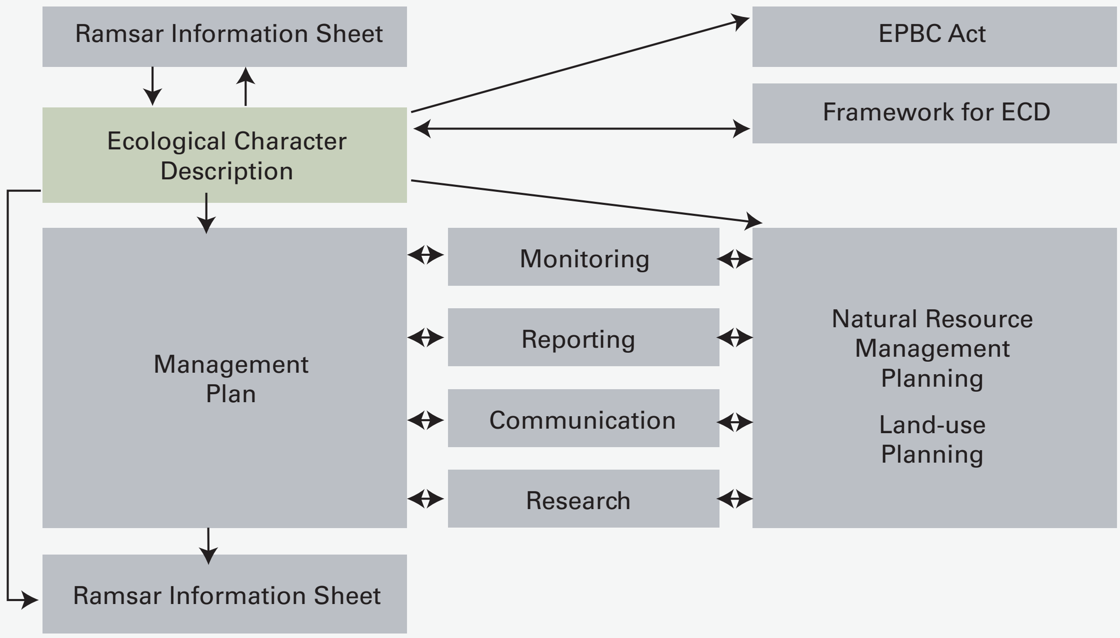


Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEW, 2007).

Wetlands are highly dynamic environments at the interface between terrestrial and aquatic ecosystems and are diverse systems supporting a wide range of species and numerous ecosystem services and values. They are also considered one of the most threatened ecosystems globally. Fully documenting the attributes and threats to wetlands via an ECD is a fundamental part of managing wetlands successfully. The Ramsar Convention states that assessment of ecological character *"should be linked to the Ramsar criterion or criteria fulfilled by the site at the time of designation for the Ramsar List. Use of the criteria indicates certain benefits and values of the wetland which might be lost as a result of change in the ecological character"* (Ramsar Convention 1996). However, it is recognised that the assessment of ecological character should go beyond the key elements for which a site was listed *"since significant degradation of wetland functions and values might occur without any of the designated Ramsar criteria being contravened*" (Ramsar Convention 1996).

This framework emphasises the importance of describing and quantifying the ecosystem components, processes and benefits/services of the wetland and the relationship between them. It is also important that information is provided on the benchmarks or ecologically significant limits of acceptable change that would indicate when the ecological character has or is likely to change.

McGrath (2006) detailed the general aims of an ECD as follows:

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Cth):

a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and

b) To formulate and implement planning that promotes:

i) Conservation of the wetland; and

ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.

2. To assist in fulfilling Australia's obligation under the Ramsar Convention – "to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference."

3. To supplement the description of the ecological character contained in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.

4. To assist the administration of the EPBC Act, particularly:

a) To determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or

b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.

5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.

6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

As of December 2007, a Ramsar Management Plan for the Peel-Yalgorup Ramsar site is yet to be finalised. It is important to note that the ECD is not the Management Plan: only a component. The development of a management plan is a separate process. The progress taken to get to the point of providing a description of the ecological character of the Peel-Yalgorup system is illustrated in Figure 2.

In addition to the Ramsar driven process of site management, a significant number of other planning programs and initiatives also impact on the management of the Ramsar site. The description of the ecological character of the Peel-Yalgorup provides a synthesis of the key attributes of the wetland ecology and function thus ensuring improved decision making and management of this important site. The management plans and initiatives listed below may or may not give direct consideration to Ramsar management requirements, although most would adhere to the concepts of wise use and conservation that underpin Ramsar management.

Management Plans and Initiatives

- Yalgorup National Park Management Plan 1995-2005
- Peel Regional Park Plan (in prep)
- City of Mandurah Foreshore Reserves Management Plans
- Water Quality Improvement Plan (CCI Project)
- Economic Development and Recreation Management Plan for the Peel Waterways 2004
- Eastern Estuary Environmental Assessment "State of Play"
- Lake McLarty Management Plan (draft)
- Draft Peel-Harvey Catchment Plan for NRM (2004)
- Serpentine River Management Plan (Water and Rivers Commission, 1998)
- Management Strategy for the Peel Inlet and Harvey Estuary System (1989)
- Guidance for the Assessment of Environmental Factors No. 28, Protection of Lake Clifton Catchment (EPA)
- Peel Cultural Landscape assessment project
- Goegrup and Black Lakes Action Plan 2006
- Coastal and Lakelands Planning Strategy Dawesville - Binningup
- Fertiliser Action Plan
- Water Sensitive Urban Design Technical Guidelines

1.3 OBJECTIVES OF THE PEEL-YALGORUP ECOLOGICAL CHARACTER DESCRIPTION

The specific objectives of the ecological character description for the Peel-Yalgorup site are to produce a comprehensive description of the ecological character that:

1. Describes the critical components, processes and benefits/services of the wetland found at the Peel-Yalgorup Wetlands Ramsar site at the time of Ramsar listing and the relationships between them;
2. Develops a conceptual model for the Peel-Yalgorup wetlands that describes the 'ecological character' in terms of components, processes and benefits/services and the relationships between them;
3. Quantifies the limits of acceptable change for the critical components, processes and benefits/services of the wetland;
4. Identifies, using existing knowledge, nutrient water quality objectives that will support the maintenance of critical components, processes and benefits/services in the Peel-Harvey Estuarine system component of the Ramsar site; and
5. Identifies actual or likely threats/risks to the ecological components, processes or services of the Peel-Yalgorup wetlands Ramsar site.

1975 Ramsar Convention on Wetlands in force in Australia

Australia agrees to:
- nominate suitable wetlands to the List of Wetands of International Importance
-to maintain the ecological character of these sites and monitor their condition

1990 Australia designates the Peel-Yalgorup System

Australia designates the Peel-Yalgorup system as a Wetland of International Importance

Australia has an obligation to maintain the ecological character of the Ramsar site

1999 Commonwealth Environment Protection and Biodiversity Conservation Act, enacted

This Act enshrines in Commonwealth law the requirements to:
- maintain the ecological character of Ramsar sites
-prepare a management plan for a Ramsar site based on the Australian Ramsar Management Principles

2001 Peel-Yalgorup Ramsar Site expanded

The exsiting Ramsar boundary is expanded to include an additional seven conservation areas.

2007 ECD for the Peel Yalgorup Ramsar Site

This is a fundamental step in the development of a management plan for the Ramsar site.
The ECD describes the character of the site for the time of listing (1990) and current conditions (2007).

2008 Management Plan for the Peel-Yalgorup Ramsar Site

Currenty being developed.
Will use the ECD as a benchmark and guide to maintaining the ecological character of the Ramsar Site.

2008 Peel-Yalgorup Ramsar Site expanded

Proposed further expansion of the site to include Goegrup and Black Lakes.

Figure 2: Ramsar listing pathway for the Peel-Yalgorup site.

1.4 RELEVANT LEGISLATION AND POLICIES

This section provides a brief listing of the legislation and policy that is relevant to the description of the ecological character of the Ramsar site. There is a significant amount of legislation, particularly at the state/local level, relevant to the management of the site which will be documented more fully in the management plan for the site and as such is not repeated here.

International

Ramsar convention

The Convention on Wetlands, otherwise known as the Ramsar Convention, came into being in Ramsar Iran in 1971 and was ratified in 1975. It provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands. Wetlands of international importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and or hydrology

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds which are relevant to the Peel-Yalgorup Ramsar site. 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 - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation

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

The EPBC Act regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance, which includes the ecological character of a Ramsar wetland (EPBC Act 1999 s16(1)). An action that will have or is likely to have a significant impact on a Ramsar wetland is subject to environmental assessment and approval under the EPBC Act. An 'action' includes a project, a development, an undertaking or an activity or series of activities (http://www.environment.gov.au/epbc/index.html).

The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles (EPBC Act 1999 s335) which are set out in Schedule 6 of the Environment Protection and Biodiversity Conservation Regulations 2000. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention. Some matters protected under the EPBC Act are not protected under local or state/territory legislation, and as such, many migratory birds are not specifically protected under State legislation (though they are in Western Australia). All species listed under international treaties JAMBA, CAMBA and CMS are covered by the Act. Threatened species and communities listed under the EPBC Act may also occur, or have habitat in the Ramsar site. The Regulations also cover matters relevant to the preparation of management plans, environmental assessment of actions that may affect the site, and the community consultation process (http://www.environment.gov.au/epbc/matters/Ramsar.html).

Australian Heritage Council Act 2003

The Peel-Harvey estuarine system has been placed on the Register for National Estate. The Australian Heritage Council Act protects places of National and Commonwealth significance.

Western Australia state policy

Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992 (Western Australian EPA website, accessed May 2007 http://www.epa.wa.gov.au/)

This policy sets out the environmental quality objectives for the Estuary which if achieved will rehabilitate the Estuary and protect the Estuary from further degradation; and to outline the means by which the environmental quality objectives for the Estuary are to be achieved and maintained.

Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (Western Australian EPA website, accessed May 2007 http://www.epa.wa.gov.au/)

This policy aims to protect the environmental values of lakes on the Swan Coastal Plain. The EPP was gazetted in 1992, together with Miscellaneous Plan No. 1815, which depicted lakes protected under the policy. The EPP made the filling, draining, excavating, polluting and clearing of these lakes an offence unless authorised by the EPA. The policy was subject to a statutory review in 1999. On 23 August 2006 the Minister for the Environment announced to Parliament that he will not approve the revised draft Environmental Protection (Swan Coastal Plain Wetlands) Policy 2004. The 1992 Lakes EPP remains in force.

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife and all fauna in Western Australia is protected under section 14 of the *Wildlife Conservation Act 1950*. The Act establishes licensing frameworks for the taking and possession of protected fauna and also 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.

Town Planning Management Act 1928: Statement of Planning Policy No 2.1 (The Peel-Harvey Coastal Plain Catchment) 2003

This policy relates to land use in the Peel-Harvey Coastal Plain Catchment with the objectives of the policy being:

To improve the social, economic, ecological, aesthetic, and recreational potential of the Peel-Harvey Coastal Plain Catchment.

- To ensure that changes to land use within the Catchment to the Peel-Harvey Estuarine system are controlled so as to avoid and minimise environmental damage.
- To balance environmental protection with the economic viability of the primary sector.
- To increase high water-using vegetation cover within the Peel-Harvey Coastal Plain Catchment.
- To reflect the environmental objectives in the Draft Environmental Protection Policy (Peel-Harvey Estuarine System) 1992.
- To prevent land uses likely to result in excessive nutrient export into the drainage system.

Western Australian Aboriginal Heritage Act (1972)

There are several important Aboriginal heritage sites around Peel Inlet and Harvey Estuary, which are protected under this act including campsites at the Serpentine River mouth and Island Point, and a ceremonial site at Egg Island (O'Connor et al. 1989 cited in RIS).

1.5 METHODOLOGY

The method used to develop the ecological character description for the Peel-Yalgorup Ramsar Site is based on the nine-step approach provided in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEW 2007). A more detailed description of each of the steps and outputs required is provided in the source document.

1. Introduction to the description, including:
    i. site details
    ii. statement of purpose for description
    iii. relevant legislation
2. Describe the site, including:
    iv. Site location
    v. Maps, images and photographs
    vi. Land tenure
    vii. Ramsar criteria met
    viii. Wetland types
3. Describe the ecological character of the site at the time of its Ramsar listing, including:
    ix. Describe components, processes and benefits/services of the site that most strongly determine the ecological character of the site and the relationship between them
    x. Develop a conceptual model for the wetland
    xi. Articulate natural variability and limits of acceptable change for the critical components, processes and services of the site.
4. Identify actual or likely threats/risks to the site
5. Summarise the knowledge gaps
6. Describe any changes to ecological character since time of listing
7. Make any recommendations for monitoring
8. Identify communication, education and public awareness messages
9. Prepare a Ramsar Information Sheet for the site

2. OVERVIEW OF THE PEEL-YALGORUP RAMSAR SITE

2.1 LOCATION

The Peel-Yalgorup Ramsar site is located in south-western Australia, approximately 80 km south of Perth within the Swan Coastal Plain bioregion. The site covers more than 26,000 hectares and spans four municipal boundaries: City of Mandurah and the Shires of Waroona, Murray and Harvey (Figure 3).

The Swan Coastal Plain bioregion is a long, narrow coastal strip of land extending from Geraldton in the north to Dunsborough in the south. The bioregion is 550 km long and only 6 to 35 km wide. It is bounded to the east by a major fault line, the Darling Escarpment, which separates the low relief coastal plain from the uplands. Over a quarter of the land within the Swan Coastal Plain is wetland and a further 17 % is seasonally water logged palusplain and floodplain (Balla, 1994). Approximately 9600 wetlands covering 362,000 ha within the bioregion have been mapped and classified (Semeniuk & Seminiuk, 1995). The Swan Coastal Plain bioregion contains 30 wetland sites of national importance, including the Peel-Yalgorup.

The Peel-Harvey catchment has a total area of 11,378 km^2 and can be divided into three basins based on three river systems: the Harvey, the Serpentine and the Murray that discharge to the Peel-Harvey Estuary. Major land uses include state forest, cropping, and beef cattle (Figure 4). The Harvey and Serpentine catchments are predominantly sandy soils and have been extensively cleared for grazing (cattle, sheep and horses). There are also intensive landuse activities in these catchments including poultry, piggeries and sheep holding yards for the live sheep trade to the Middle East. By contrast, the middle catchment of the Murray River contains extensive areas of state forest, with the upper part of the catchment mostly agricultural.

The low-lying areas of the catchment were once extensive areas of paperbark swamp (Brearley, 2005). Clearing for agriculture began in the 1800s, but the water-logged soils in winter, coupled with the arid summer, proved to be a problem for farmers. In the 1890s an extensive drainage scheme was put in place and there is currently a network of drains across the catchment that divert water both into the estuary and directly to the sea. In the 2000 km^2 of the Swan Coastal Plain there are approximately 4000 km of drains. The largest of these is the Harvey Diversion Drain, which takes a large proportion of the water from the Harvey River catchment and diverts it directly to the Indian Ocean.

The Peel region has a rapidly growing population particularly in the City of Mandurah, which has nearly doubled in population over the period 1995 to 2005 (URS, 2007). This has lead to expansion in urban areas and in particular a large increase in urban waterside development and canals within and adjacent to the Ramsar site.

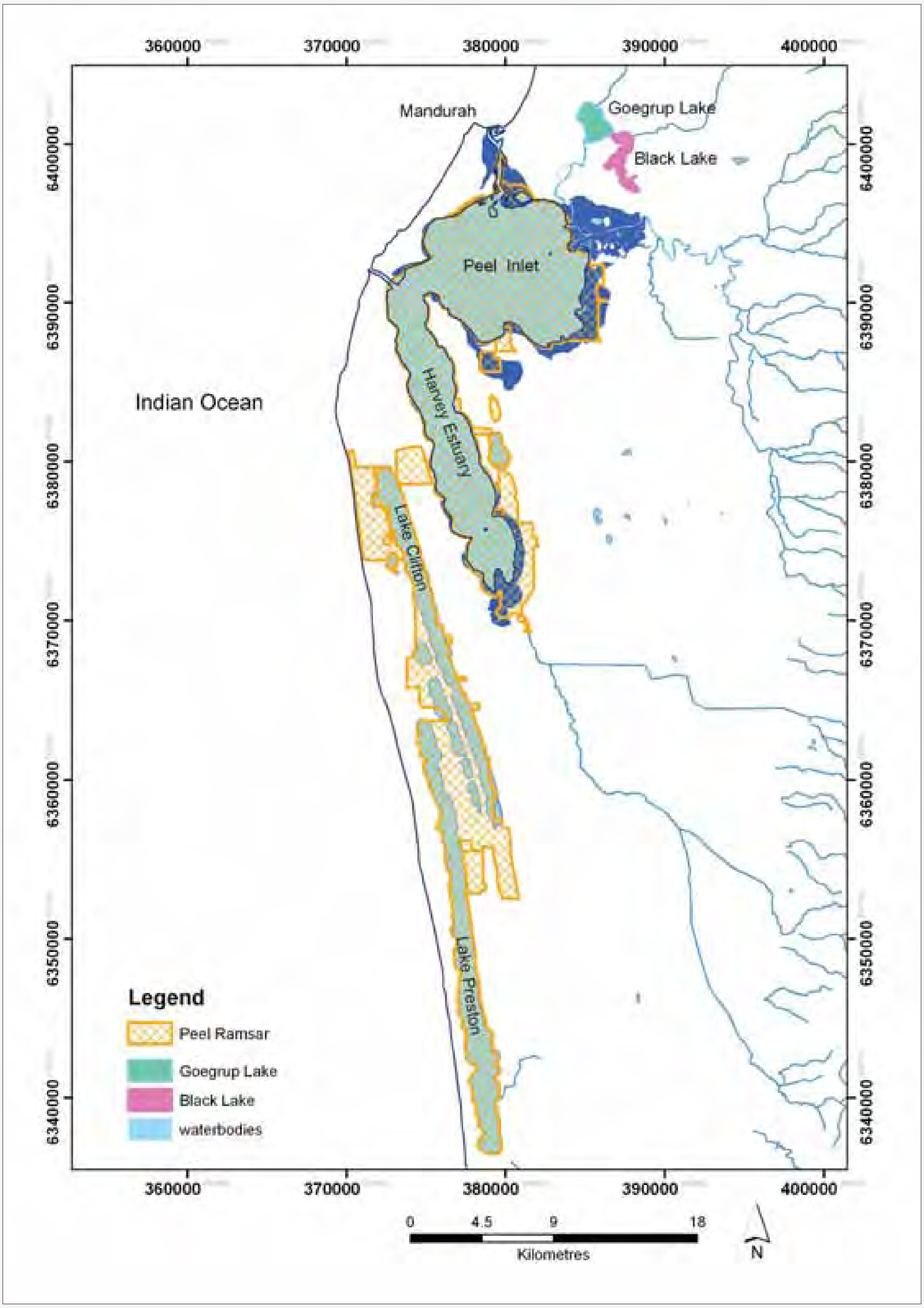


Figure 3: Peel-Yalgorup Ramsar site showing the location of the proposed extension wetlands Goegrup and Black Lakes.

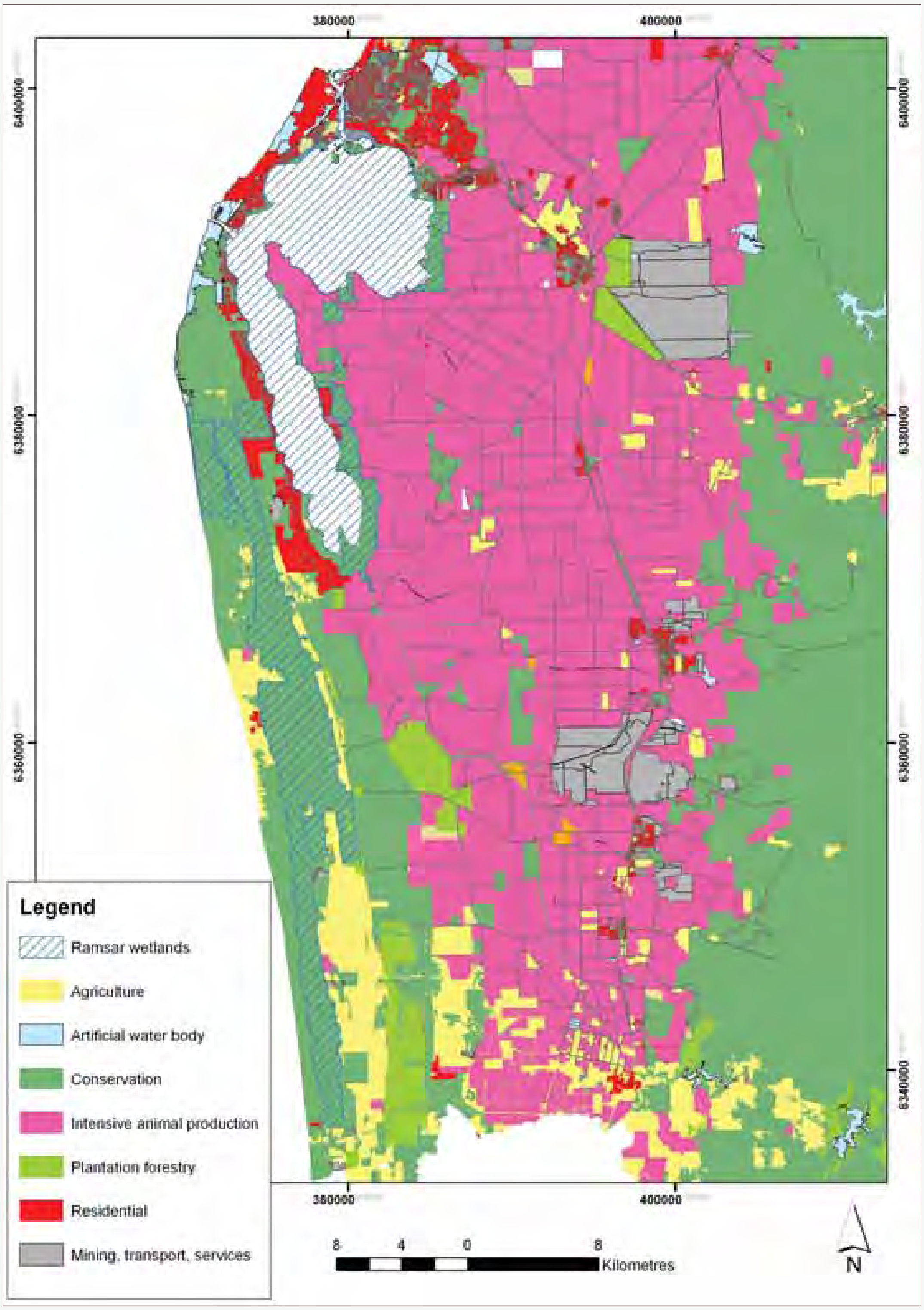


Figure 4: Land use in the Peel-Harvey Catchment

2.2 CLIMATE

The Peel-Yalgorup site has a Mediterranean climate with hot dry summers (December to February) cool wet winters (June – August). Unlike the rest of Australia, the climate of the south-west of Western Australia is relatively stable with annual rainfall and temperature ranges varying little from year to year (IOCI, 2002). The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and wind as these all fundamentally affect wetland hydrology and the water budget.

Rainfall varies across the catchment, with higher rainfall (1400mm per year) falling in the east on the Darling Escarpment, than on the coast. The rainfall at the site (as indicated by the station at Mandurah) is approximately 880 mm per year on average (1989 to 2001) and the variability over the past 50 years is shown in (Figure 5). Rainfall is highest in June, with 80% of rainfall between May and October (Figure 6).

Temperatures range from hot in summer (maximum average of 30° C in February) and mild in winter (average maximum 17° C in July). Average minimum winter temperatures are approximately 9° C (Figure 7).

The western coast of Australia is characterised by high winds, and Perth is the windiest Australian city (IOCI, 2002). Winds in the Mandurah area are 12 to 16 km/hour on average and generally higher in the afternoon than in the morning. There is little annual pattern, with similar average wind speeds year round (Figure 8).

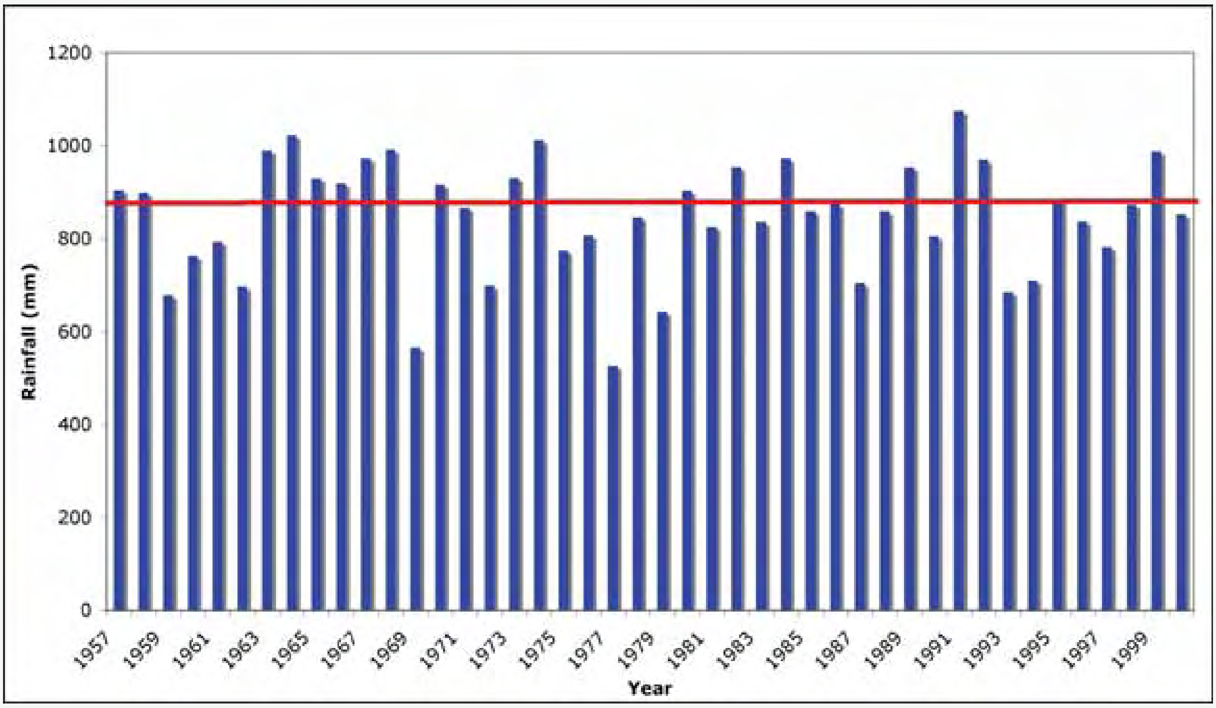


Figure 5: Annual rainfall at Mandurah 1957 to 2001 with long term mean indicated in red (Bureau of meteorology).

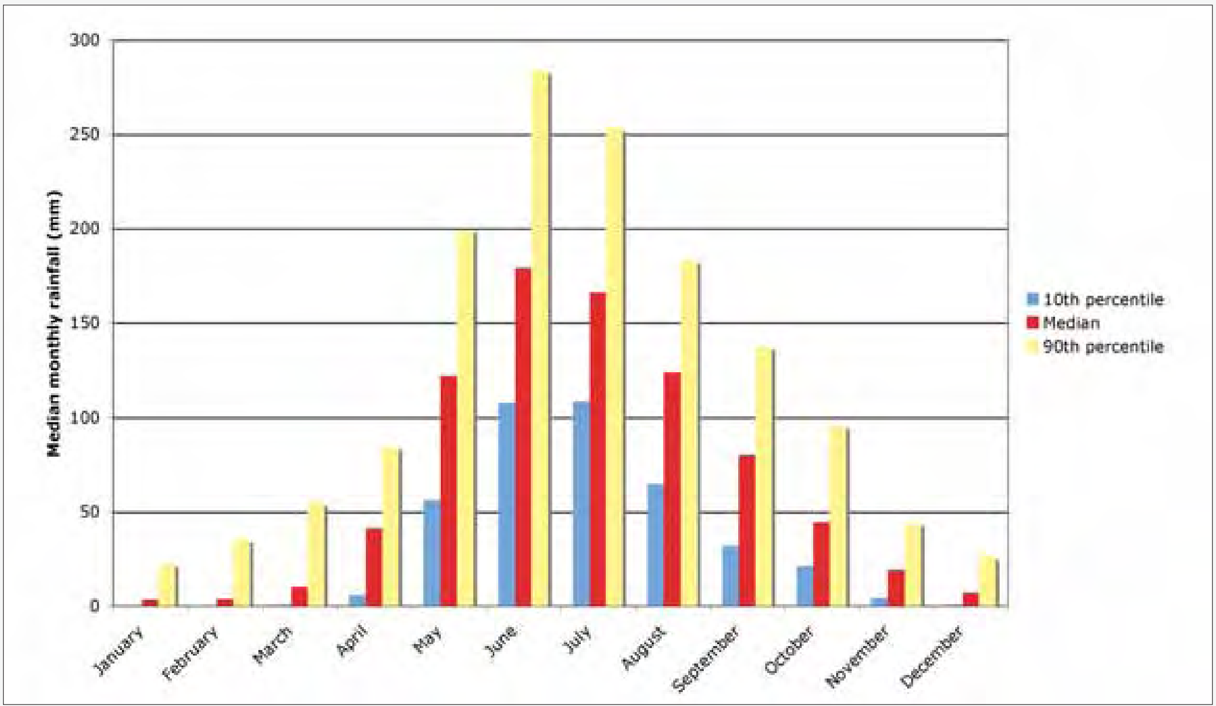


Figure 6: Median (10th and 90th percentile) monthly rainfall at Mandurah (1889–2001; Bureau of meteorology).

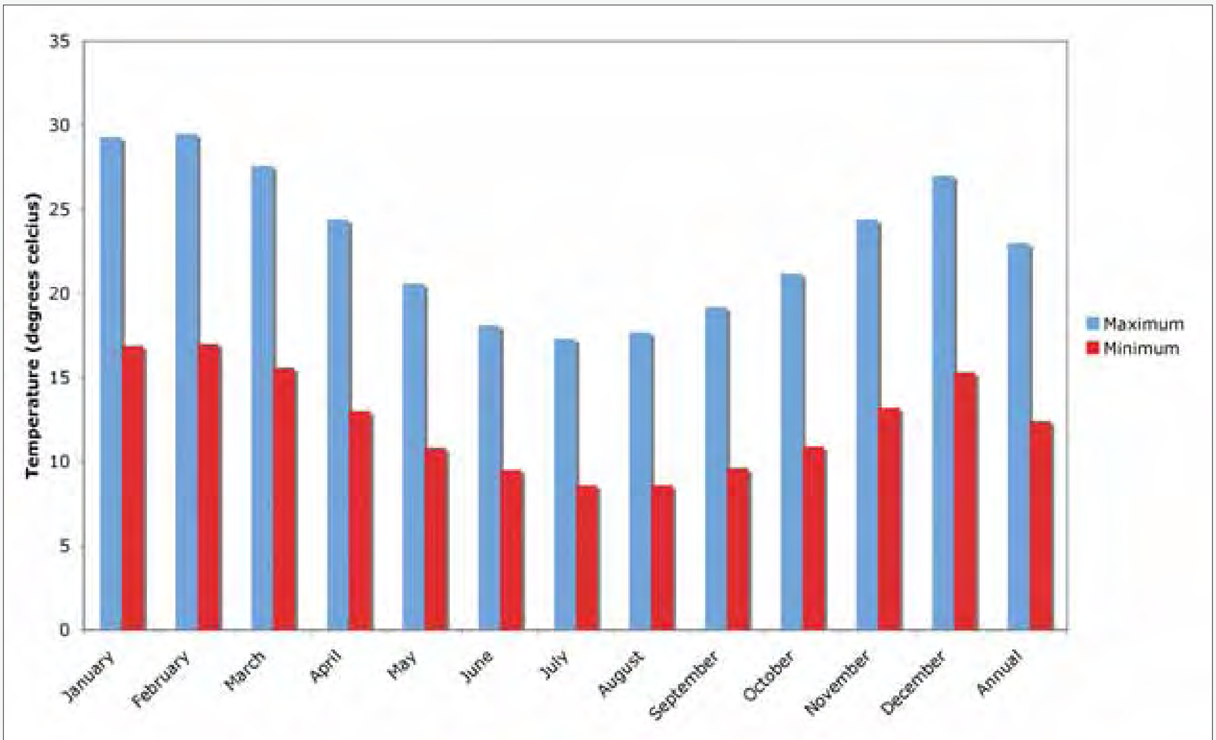


Figure 7: Mean maximum and minimum monthly temperatures at Mandurah (1900–1985; Bureau of meteorology).

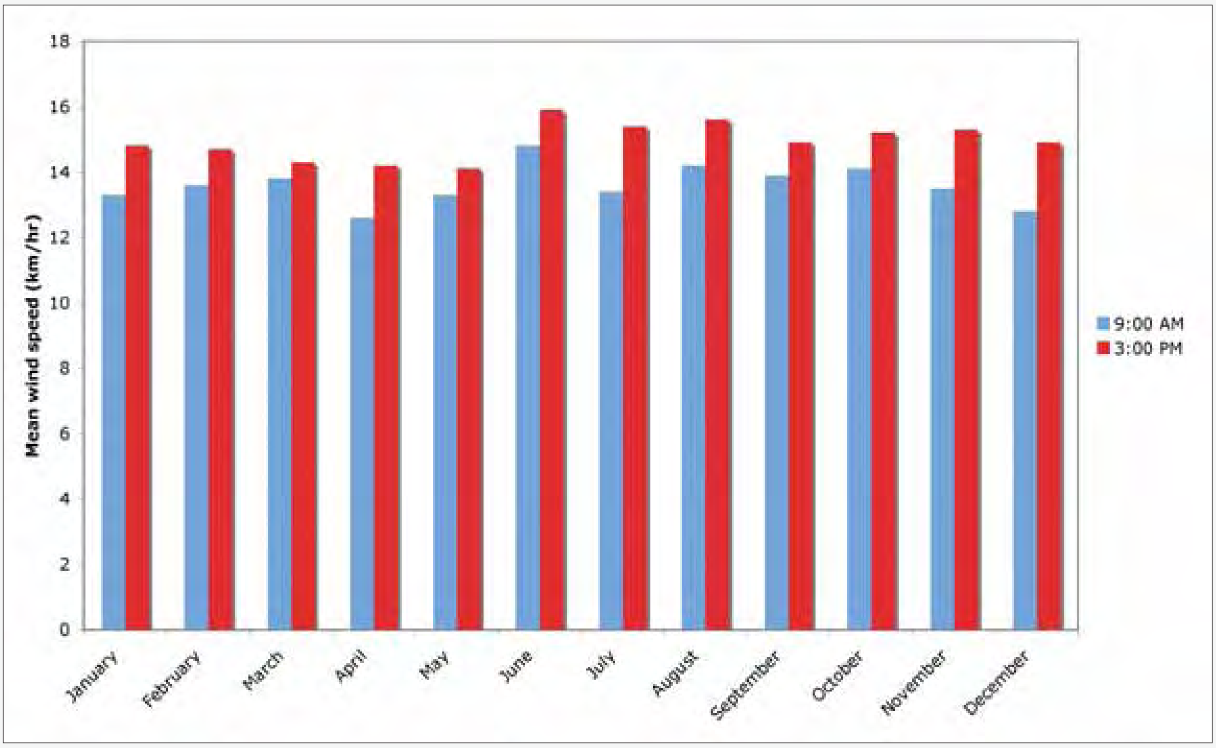


Figure 8: Mean wind speed at Mandurah (1965–1985; Bureau of meteorology).

2.3 LAND TENURE

The water in the estuary is non-tenured crown land, and managed by the Department of Water. The majority of all other lake, ex-direct freehold, national parks, state forest and reserves are vested with the WA Conservation Commission and are managed by the Department of Environment and Conservation. A number of lesser foreshore reserves are managed by a variety of agencies including the Shire of Murray, City of Mandurah, the Department of Water, and the Water Corporation. There are also a number of smaller parcels that remain vacant crown land. All areas are Zoned as Regional Open Space or Waterways under the Peel Region Planning Scheme, giving stricter planning controls by the WA Planning commission.

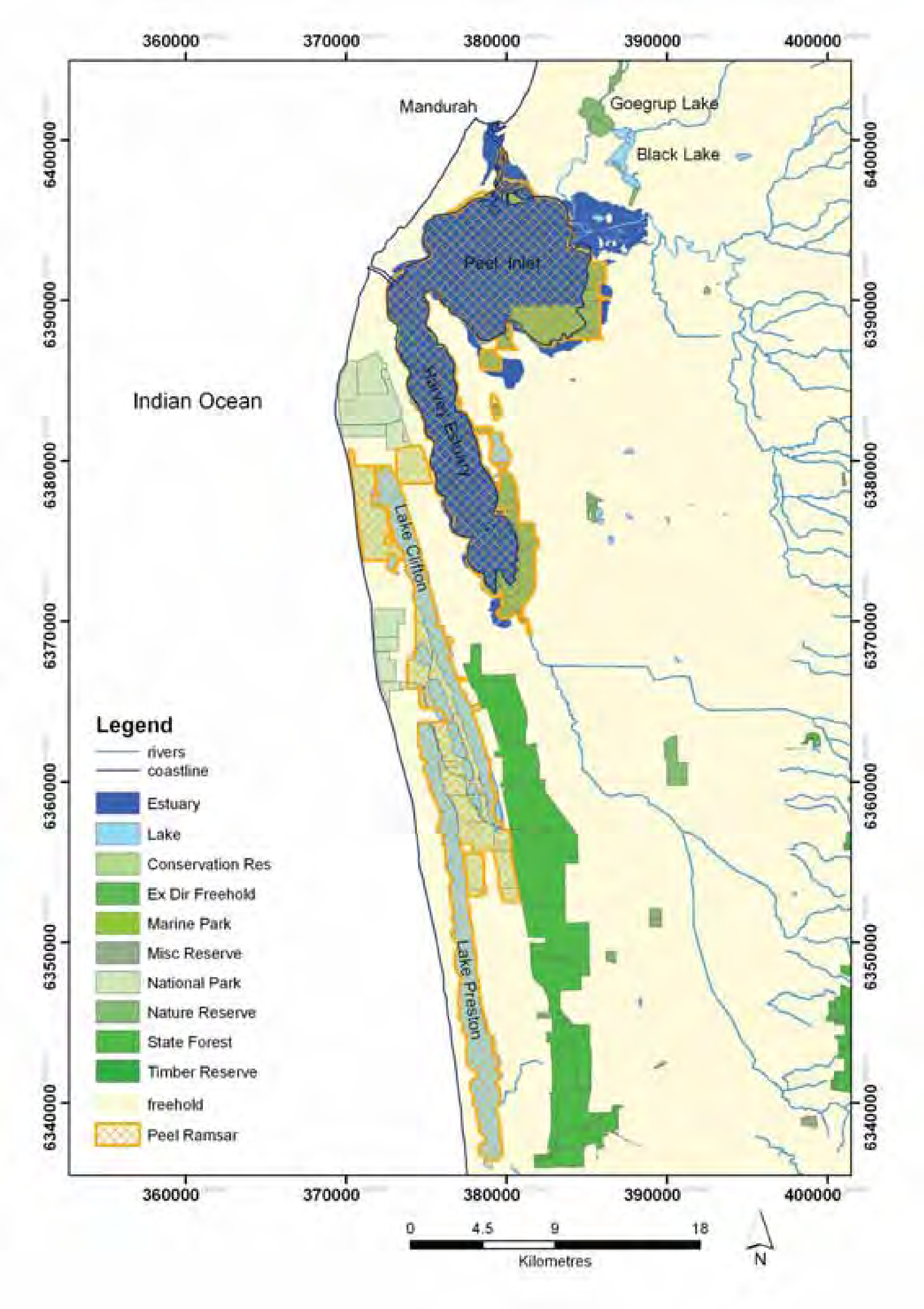


Figure 9: Land tenure within and adjacent to the Peel-Yalgorup Ramsar site.

2.4 RAMSAR CRITERIA

2.4.1 CRITERIA UNDER WHICH THE SITE WAS DESIGNATED (1990)

At the time that the Peel-Yalgorup system was first nominated as a Wetland of International Importance, there were six criteria against which a wetland site could qualify (Table 2). At this time, the Peel-Yalgorup site was considered to meet four of these criteria as follows (Ramsar Information Sheet, 2003):

Criterion 1: The site includes the largest and most diverse estuarine complex in south-western Australia and also particularly good examples of coastal saline lakes and freshwater marshes.

Criterion 3: The site is one of only two locations in south-western Australia and one of very few in the world where living thrombolites (a type of microbialite, superficially similar in appearance to stromatolites) occur in hyposaline water.

Criterion 5: The site comprises the most important area for waterbirds in south-western Australia, supporting in excess of 20,000 waterbirds annually, with greater than 150,000 individuals recorded at one time (February 1977).

Criterion 6: The site regularly supports 1% of the population of six shorebirds: Red-necked Avocet (*Recurvirostra novaehollandiae*), Red-necked Stint (*Calidris ruficollis*), Red-capped Plover (*Charadrius ruficapillus*), Black-winged Stilt *(Himantopus himantopus)*, Caspian Tern *(Sterna caspia)* and Fairy Tern *(Sterna nereis)*.

Table 2: Criteria for Identifying Wetlands of International Importance. Criteria for which the Peel-Yalgorup was listed are highlighted in green.

NUMBER	BASIS	DESCRIPTION
GROUP A. SITES CONTAINING REPRESENTATIVE, RARE OR UNIQUE WETLAND TYPES		
Criterion 1		A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
GROUP B. SITES OF INTERNATIONAL IMPORTANCE FOR CONSERVING BIOLOGICAL DIVERSITY		
Criterion 2	Species and ecological communities	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	Species and ecological communities	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	Species and ecological communities	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Waterbirds	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6	Waterbirds	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

2.4.2 CURRENT SITUATION AND ADDITIONAL CRITERIA MET

In 1996, an additional two criteria (criteria 7 and 8) were adopted by the Ramsar Convention in Brisbane and a ninth criterion was added at the 9th Ramsar Conference in Uganda in 2005. In addition, there has been a revision of population estimates for birds (http://www.wetlands.org/event.aspx?id=318e62d4-b171-4f99-b77f-fda289041f6a), which influences the application of criterion 6; and additional data has been collected for the site.

Therefore, a revision and update of the Ramsar Information Sheet has been undertaken as a part of this ecological character description (Appendix C), which includes an assessment of the Peel-Yalgorup Ramsar site against the nine Ramsar criteria (Table 3). In deciding if the site qualifies under criterion six (regularly supports 1% of the individuals in a population of one species of waterbird), an approach consistent with the Ramsar Convention has been adopted (see Appendix D).

It should be noted that the criteria have been applied only to values captured inside the boundary of the current Ramsar site. This excludes the proposed extension of Goegrup and Black Lakes. Should theses wetlands be formally included in the Ramsar site, a revised Ramsar Information Sheet and assessment should be under taken.

Table 3: Criteria for Identifying Wetlands of International Importance (Adopted by the 7th (1999) and 9th (2005) Meetings of the Conference of the Contracting Parties). Criteria for which the Peel-Yalgorup currently qualifies are highlighted in green.

NUMBER	BASIS	DESCRIPTION
GROUP A. SITES CONTAINING REPRESENTATIVE, RARE OR UNIQUE WETLAND TYPES		
Criterion 1		A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
GROUP B. SITES OF INTERNATIONAL IMPORTANCE FOR CONSERVING BIOLOGICAL DIVERSITY		
Criterion 2	Species and ecological communities	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	Species and ecological communities	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	Species and ecological communities	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Waterbirds	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6	Waterbirds	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Fish	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Fish	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Criterion 9	Other taxa	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

An assessment against each of the criteria for the Peel-Yalgorup Ramsar Site is as follows:

Criterion 1: The site includes the largest and most diverse estuarine complex in south-western Australia and also particularly good examples of coastal saline lakes and freshwater marshes. This criterion was met at designation in 1990 and continues to be met at present.

Criterion 2: In the Australian context, it is recommended that this criterion should only be applied with respect only to nationally threatened species/communities, listed under the EPBC Act 1999. Only one waterbird species, Australian Painted Snipe, is usually applicable and while there is suitable habitat for the Australian Painted Snipe at this Ramsar site there are no records from the Peel-Yalgorup. Species included in the IUCN Red List as vulnerable or endangered could also be considered in this criterion: a relevant species in this context is the Australasian Bittern (globally Endangered), which formerly occurred and possibly bred at Lake McLarty (and also Mealup) but which seems to have become locally extinct with the demise of extensive sedgeland in that wetland. There may be future occasional occurrences of Australasian Bittern from sedgey habitats within the Ramsar site but regular and/or substantial occurrence would be a pre-requisite for Criterion 2 to be met. (It is interesting to note that the stromatolite community at Lake Richmond is listed as a threatened ecological community whereas the stromatolite community at the Yalgorup Lakes is not so listed.) Therefore, this criterion probably was met (with respect to Australasian Bittern) at the date of listing but is not met at present.

Criterion 3: The site is one of only two locations in south-western Australia and one of very few in the world where living thrombolites occur in inland waters. This criterion was met at designation in 1990 and continues to be met at present.

Criterion 4: The basic description of this criterion implies a number of common functions/roles that wetlands provide and the following apply at Peel-Yalgorup Ramsar site, in most if not all cases both at the date of listing and at present:

- the critical life stage of migration: annual use by large numbers of many species of migratory animals;
- the critical life stage of drought refuge: seasonal influx of large numbers of waterbirds from dried out wetlands in surrounding areas, and periodic massive influx from wider regions during drought;
- the critical life stage of breeding: regionally and nationally significant colonies of cormorants occurred in the 1980s in paperbark swamp in "Carraburmup Swamp Nature Reserve" (Jaensch et al. 1988) on the south-east side of Peel Inlet (and part of the Ramsar site) and small breeding colonies of pelicans breed now and then on islets in Peel Inlet; in addition, the Yalgorup Lakes are a significant site bioregionally for breeding of Hooded Plover (Birds Australia 2006);
- breeding also applies to fishes, crabs and prawns; and
- the critical life stage of moulting: shelducks and Musk Ducks that congregate on the open waters of the Ramsar site outside the breeding season are engaging in moult (hence, the birds are flightless for a short period).

Therefore this criterion was met at the date of listing and continues to be met.

Criterion 5: The site comprises the most important area for waterbirds in south-western Australia, supporting in excess of 20,000 waterbirds annually, with greater than 150,000 individuals recorded at one time (February 1977). Numbers exceeding 20,000 birds have been recorded in all comprehensive surveys conducted in the 1990s in the Peel-Harvey Estuary. Therefore, this criterion was met at designation in 1990 and continues to be met at present.

Criterion 6: Applying the method detailed in Appendix 3, this criterion is clearly met for a number of waterbirds (both international and Australian). For the majority of these species it is likely that the site met this criterion both at the time of listing and currently. According to the 4th edition of Waterbird Population Estimates, the site regularly supports 1% of the population of:
Red-necked Avocet,
Red-necked Stint,
Red-capped Plover,
Hooded Plover
Black-winged Stilt,
Banded Stilt
Curlew Sandpiper
Sharp-tailed Sandpiper
Fairy Tern
Musk Duck
Grey Teal
Australasian Shoveler
Australian Shelduck
Eurasian Coot.

The 4th edition of Waterbird Population Estimates (WPE; Wetlands International 2006) applies the range 10,000 to 100,000 to the Australian population of the Caspian Tern and, by the WPE methodology (using the upper limit), this equates to a 1% threshold of 1000. With maximum numbers < 500, the site does not support 1% of the population of this species.

Criterion 7: This criteria is very difficult to apply and given the paucity of data from the site it is unable to be determined if this criterion would be met.

Criterion 8: The Peel-Yalgorup Ramsar Site is important as a nursery and/or breeding and/or feeding ground for at least 50 species of fish and the Peel-Harvey Estuary is a migratory route for the Pouched Lamprey *(Geotria australis)*. Therefore, this criterion was met at designation in 1990 and continues to be met at present.

Criterion 9: The application of this criterion relies on estimates of the total population of non-bird species. In the case of the Peel-Yalgorup this would require population estimates of fish and crustacean species. This criterion cannot be assessed based on current information.

2.5 WETLAND TYPES

The Peel-Yalgorup site contains a wide range of wetland types and includes inland and marine components. Under the Ramsar wetland classification system, there are nine main types of wetlands within the site:

Marine/Coastal:

- *Estuarine waters;* permanent water of estuaries and estuarine systems of deltas.
- *Intertidal mud, sand or salt flats.*
- *Intertidal marshes;* includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes

Inland:

- *Permanent freshwater lakes (over 8 ha);* includes large oxbow lakes.
- *Seasonal/intermittent freshwater lakes (over 8 ha);* includes floodplain lakes.
- *Permanent saline/brackish/alkaline lakes.*
- *Permanent freshwater marshes/pools;* ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
- *Seasonal/intermittent freshwater marshes/pools* on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
- *Shrub-dominated wetlands;* shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
- *Freshwater, tree-dominated wetlands;* includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.

The wetlands within the site can be grouped according to geographic location and broad type into the following groups:

Peel Inlet and Harvey Estuary – Marine/Coastal, dominated by "Estuarine Waters" with areas of "Intertidal mud and sand flats" and "Intertidal marshes"

Yalgorup Lake System – Inland, dominated by "Permanent saline/brackish lake"

McLarty Lake System – Inland, dominated by "Permanent and seasonal freshwater lakes over 8 ha"

Goegrup and Black Lakes – Inland, dominated by "Permanent freshwater lakes over 8 ha"

These groupings have been used for the subsequent ECD and in particular descriptions of ecosystem components and processes.

2.6 SYSTEM SERVICES AND BENEFITS

Ecosystem benefits and services are defined under the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). This includes benefits that directly affect people such as the provision of food or water resources as well as indirect ecological benefits.

The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) defines four main categories of ecosystem services:

1. **Provisioning services** – the products obtained from the ecosystem such as food, fuel and fresh water;
2. **Regulating services** – the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation;
3. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics; and
4. **Supporting services** – the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time.

The key ecosystem benefits and services of the Peel-Yalgorup Ramsar site are outlined in Table 4. The relationships between ecological components and processes and these benefits and services are explored in section 5. Ecological services and benefits form the majority of an ecological character description and Sections 3–9 focus on these components, processes and services. However, the Peel-Yalgorup Ramsar site is also economically and culturally significant. A brief description of these services and benefits is provided in section 2.6.1.

Table 4: Ecosystem benefits and services for the Peel-Yalgorup Ramsar site.

CATEGORY	DESCRIPTION
PROVISIONING SERVICES - PRODUCTS OBTAINED FROM THE ECOSYSTEM SUCH AS FOOD, FUEL AND FRESH WATER	
Wetland products	Commercial fisheries for a number of species of fish, as well as prawns and crabs
REGULATING SERVICES - BENEFITS OBTAINED FROM THE REGULATION OF ECOSYSTEM PROCESSES SUCH AS CLIMATE REGULATION, WATER REGULATION AND NATURAL HAZARD REGULATION	
Pollution control and detoxification	Peel Inlet and Harvey Estuary act as sinks for nutrients from the catchment and a mechanism for discharge to the sea.
Climate regulation	Data deficient – plausible but not documented.
Flood control	The site acts as a receiver of drainage water from the surrounding floodplain.
CULTURAL SERVICES - BENEFITS PEOPLE OBTAIN THROUGH SPIRITUAL ENRICHMENT, RECREATION, EDUCATION AND AESTHETICS	
Recreation and tourism	The Peel Inlet and Harvey Estuary are important recreational fisheries.
	Passive recreational activities such as bird watching occur both in the estuarine and wetland areas within the site.
	The Peel Inlet and Harvey Estuary are important for water based recreational activities and water sports such as boating.
Spiritual and inspirational	The wetlands and estuarine areas are spiritually significant for the Nyoongar and contain a number of specific culturally significant sites.
	The site has inspirational, aesthetic and existence values at regional, state and national levels.
Scientific and educational	The Peel Inlet and Harvey Estuary are the sites of long-term monitoring dating back several decades
	Lake Clifton represents one of very few places at which thrombolites can be studied.
SUPPORTING SERVICES - SERVICES NECESSARY FOR THE PRODUCTION OF ALL OTHER ECOSYSTEM SERVICES SUCH AS WATER CYCLING, NUTRIENT CYCLING AND HABITAT FOR BIOTA. THESE SERVICES WILL GENERALLY HAVE AN INDIRECT BENEFIT TO HUMANS OR A DIRECT BENEFIT OVER A LONG PERIOD OF TIME	
Biodiversity	As evidenced by the listing of the Peel-Yalgorup site as a wetland of international importance. The system provides a wide range of biodiversity values including: Supporting a wide range of ecological communities Supporting a number of regionally, nationally and internationally threatened species Supporting a high diversity of species (flora and fauna); and Supporting a bioregionally unique community (thrombolites)
Nutrient cycling	The Peel-Yalgorup system plays a large role in the recycling and discharge of nutrients from the surrounding catchment.
	Carbon sequestration – data deficient but plausible

2.6.1 CULTURAL, ECONOMIC AND SOCIAL SERVICES AND BENEFITS

Commercial Fishing

The Peel-Harvey estuary is an important commercial and recreational fishery. Commercial species include King George Whiting, Black Bream, Cobbler, Blue Swimmer Crabs and Western King Prawns. It is estimated that the commercial fishing operations in the estuary are worth about $1 million a year in fish (URS 2007).

Recreation and tourism

The Peel-Harvey Estuary and Yalgorup Lakes represent important recreational and tourist sites. Tourism in the Peel region contributes approximately $150 million annually to the region, with both domestic and international visitors. The most popular recreational and tourism activities associated with the Ramsar site include: bushwalking, birdwatching, camping, fishing, boating, crabbing, water skiing, canoeing and swimming (URS 2007).

Indigenous Values

The Peel-Yalgorup Ramsar site lies within Pinjarup country, a dialect group of the Nyoongar. As with other Indigenous Australians, Pinjarup people were strongly connected to each other, their culture and their country through the Dreaming. In southwest Australia, water is of special significance and the 'Waugal' is the creative and life-giving being associated with all freshwater sources, surface and ground. Although dormant most of the time, the Waugal may cause immense harm if disturbed. Hence all fresh water-bodies may be considered to be highly significant mythological sites, with certain areas having particular significance as a place where the Waugal enters or exits the ground, or where it rests. (Dortch *et al.* 2006).

There are over 356 sites of aboriginal significance in the Peel-Harvey Catchment and 27 specific sites on the Peel-Harvey Estuary have been identified for the proposed heritage trail (Dortch *et al.* 2006). This includes sites of artefact scatter, camp sites, ceremonial sites, fish traps, skeletal remains and sites of mythological significance (Table 5).

Table 5: Some of the significant Aboriginal sites in the Peel-Yalgorup Ramsar site (adapted from Dortch et al. 2006). For a more complete list and descriptions see source document

NAME	TYPE	DESCRIPTION
Peel Inlet	Water source	Fresh-water spring in inlet, accessible to animals.
Point Grey	Skeletal material/burial	Two Aboriginal leaders shot by European settlers and buried here.
Ancient Reef 2	Other	A large pinnacle 2.5 m high protruding 2.5 m from the edge of the estuary. On the opposite side of the estuary is a burial site on a large hill.
Caves Hill	Mythological	A large hill of an ancient reef or limestone.
Lookout Point	Lookout	A high point on the estuary shore where people could see the campfires of other family groups on the western side of the estuary.
Buchanan Scarred Tree	Modified Tree	Scar on old "bluegum" possum tree.
Point Grey	Camp	Traditional camping area on north and west sides of Point Grey used by Aboriginal people until recent decades.
Stony Point	Camp	Camp site
Egg Island Harvey Estuary	Ceremonial	A scrub-covered island on which a stone, the size and shape of an emu egg, had mythological and ceremonial importance. Those who mishandled the stone reputedly fell ill.
Mealup Point Reserve	Wild celery; Quondong tree; Tea-tree; Moss; Peppermint trees; frogs; bandicoots; lizards; mice	Moss-covered limestone ridge provides habitat for small animals, also the Woodatj, a mischievous evil little man
McLarty Reserve	Emu Berry Bush; Kwondong; Cowslip Orchid; Spider Orchid; Swamp banksia; Blue Hovea; Tongue kodong;	Fruiting of emu berry bushes showed when it was time to hunt for emu chicks. Quartz flakes found.

3. WHAT COMPRISED THE PEEL-YALGORUP IN 1990: CRITICAL COMPONENTS AND PROCESSES

The basis of an ECD is the identification, description and where possible, quantification of the critical components and processes of the site. Wetlands are complex ecological systems and the complete list of physical, chemical and biological components and processes for even the simplest of wetlands would be extensive and difficult to conceptualise. A more informative approach is the identification of key or critical components and processes that determine the character of the site. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would result in a significant change in the system. This section documents these critical aspects of the ecology of the Peel-Yalgorup system and the driving forces behind them.

3.1 DRIVERS OF WETLAND ECOLOGY

Climate and geomorphology are accepted as the fundamental drivers of wetland ecology (Mitsch and Gossleink, 2000). They determine where a wetland will be located within the landscape, the type of wetland that it will be and it's hydrological regime. The hydrological regime, in turn, influences wetland biota as well as the chemical components and processes of a wetland (Figure 10).

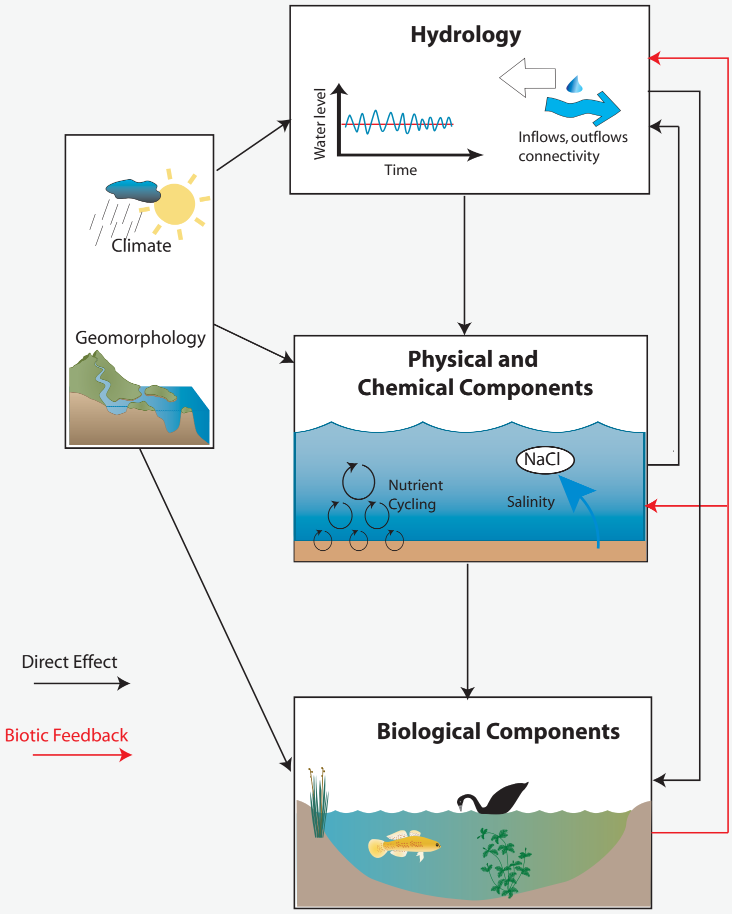


Figure 10: Conceptual model of wetland ecology (adapted from Mitsch and Gosselink, 2000).

3.2 PEEL-HARVEY ESTUARY

The estuarine areas of the Peel-Yalgorup site include the Peel Inlet and Harvey Estuary. The key ecosystem components and processes at the time of listing (1990) are summarised in Table 6 and detailed in sections 3.2.1 to 3.2.11 below.

Table 6: Critical ecosystem components and processes of the Peel-Harvey Estuary.

COMPONENT	SUMMARY DESCRIPTION
Geomorphology	Shallow “bar-built” estuary Narrow connection to the Indian Ocean (Mandurah Channel) Organic sediments (black ooze)
Hydrology	Highly seasonal freshwater inflows from direct precipitation and rivers Limited tidal exchange with the Indian Ocean Limited groundwater inflows
Water Quality	High concentrations of nutrients (eutrophic) from catchment Seasonal variability in salinity Stratification and deoxygenation of bottom waters
Acid Sulfide Soils	Monosulphidic black ooze Exposed via dredging
Phytoplankton	Winter diatom blooms Spring *Nodularia* blooms in the Harvey Estuary
Benthic Plants	Excessive growth of green macroalgae (*Cladophora* and/or *Chaetomorpha*) in the Peel Inlet Smothering of seagrass
Littoral Vegetation	Samphire communities around the shorelines Paperbark communities in the Harvey River delta
Invertebrates	Commercially significant taxa include blue swimmer crabs and western king prawns Diverse communities in the estuary and the intertidal zones
Fish	Estuarine and marine species Migratory route for some species
Birds	High diversity and abundance of waterbirds Regularly supports > 20,000 waterbirds (maximum recorded 150,000 individuals) Breeding recorded for twelve species Regularly supports > 1 % of the population of eleven species

3.2.1 GEOMORPHOLOGY

The Peel-Harvey Estuary lies on the western edge of the Swan Coastal Plain and formed approximately 8,000 years ago. Prior to this, the sea level was approximately 150 m lower than it is today and the Murray and Harvey Rivers joined to flow directly to the Indian Ocean. Rising sea levels led to flooding of the plain and the estuary reached a maximum size approximately 4,000 years ago (when sea levels were 0.5 to 43 m higher than current). Fossils show that at this time the estuary was more marine in nature and dominated by marine fauna (Brearley 2005).

The influx of sediment from the catchment, coupled with decreasing sea levels and the consequent movement of sand on-shore lead to a constriction of flow paths to the sea and the basins became more estuarine. By modern times (and the time of listing under Ramsar) the Peel-Harvey was a bar built estuary with a narrow connection to the Indian Ocean through the 5km long Mandurah Channel. This connection would have naturally opened and closed depending on the patterns of sediment deposition and erosion (Brearley 2005) but dredging of the Mandurah and Sticks Channels to a depth of 1.9 m kept the connection open (Hodgkin *et al*. 1981).

The geomorphology and bathymetry of the Peel-Harvey Estuary during the 1990s is illustrated in Figure 11 and dimensions are provided in Table 7. The Peel Inlet is approximately 10 km in diameter and circular in shape. It is shallow with large areas < 0.5 m in depth at high water and a small central basin of approximately 2 m depth (Hodgkin *et al*. 1981). The Serpentine and Murray rivers discharge into the Inlet from the east on to the shallow shelf. The Harvey Estuary is a long narrow basin (20 km x 2-3 km) that runs roughly parallel to the coast. Similar to the Peel Inlet, it is shallow with large areas < 0.5 m and a deeper (approximately 2 m) central basin. It receives freshwater from the Harvey River to the south and is connected to the Peel Inlet by a narrow deep channel at its northern end.

*Table 7: Dimensions of the Peel-Harvey Estuary (Hodgkin **et al.** 1981)*

MANDURAH CHANNEL		
	Length	5 km
	Width	200 m
PEEL INLET		
	Area	75 km^2
	Volume	11700 GL
HARVEY ESTUARY		
	Area	56 km^2
	Volume	15200 GL

The Peel-Harvey Estuary is covered in approximately 3 m of Holocene sediments from four different sources (Hodgkin *et al*. 1981):

- Older (Pleistocene) soils eroded by wave action;
- Sand, silt, clay and organic matter from the catchment via river inflows;
- Marine sand from tidal currents; and
- Organic material that originated within the basin.

Organic matter has always been a component of the sediments in the estuary and ranged from 0.5 to 5 % (Hodgkin *et al*. 1981). However, at the time of listing there were large areas where surficial sediments were dominated by high carbon content (12%) black mud (ooze) of recent origin from algal material and faecal pellets.

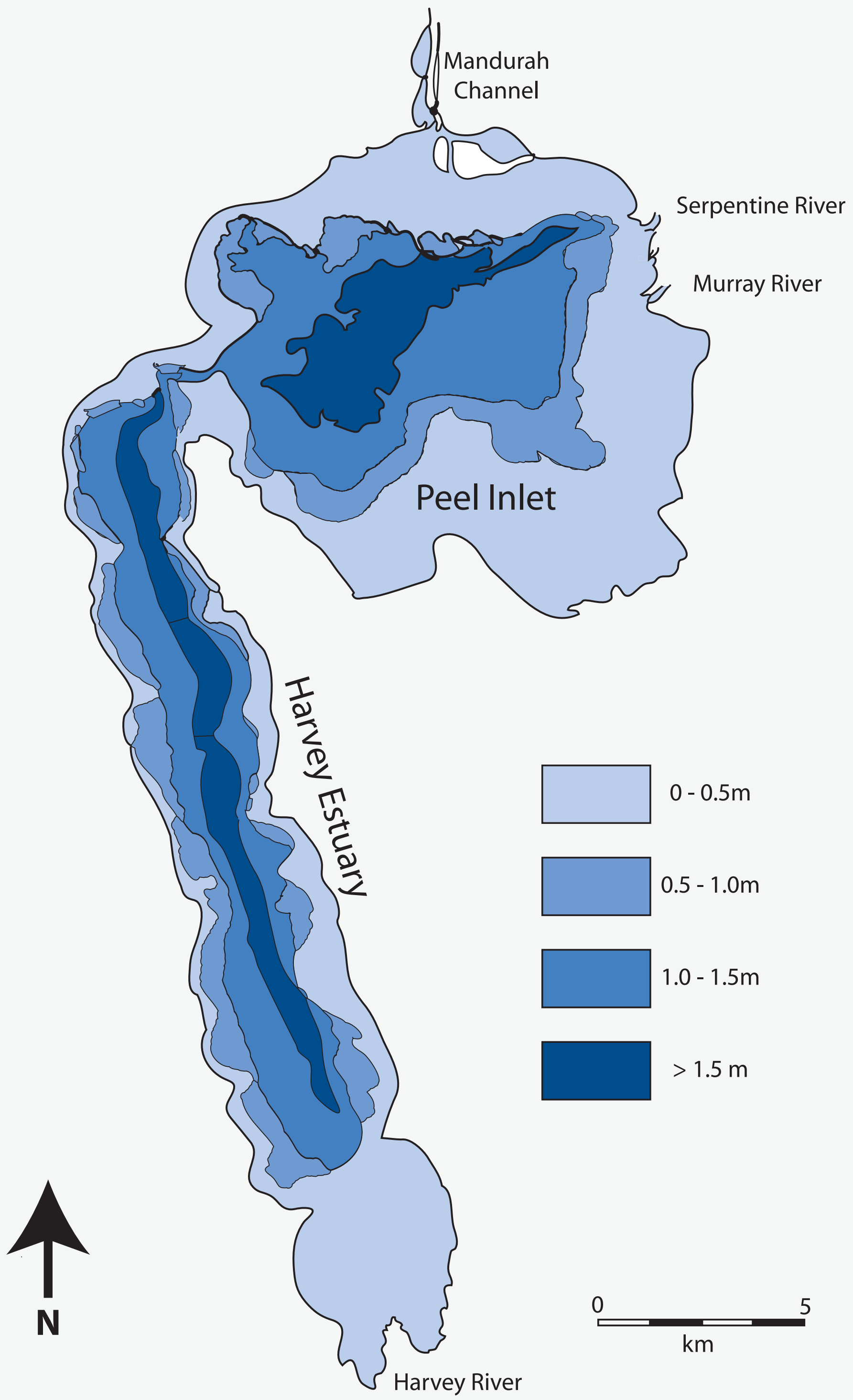


Figure 11: Bathymetry of the Peel-Harvey Estuary (adapted from Town Planning Department 1976).

The geomorphology of the Peel-Harvey Estuary had been modified prior to the time of listing both from the dredging of the Mandurah and Sticks Channel and from the development of canals. The first canal development occurred in the Peel Inlet in the 1970s with an approach channel dredged across the Murray River Delta across an intertidal area at South Yunderup in 1971-1972. In 1989 the channel was deepened and a further canal development was proposed for Mandurah (Damara 2006). Although the South Yunderup canals occupy a relatively small area of the Peel Inlet, this alteration to the geomorphology of the system had effects on sediment and water quality (see relevant sections below).

3.2.2 HYDROLOGY

Climate and geomorphology dictate the hydrology of wetland systems (see Figure 10 above) in terms of both water budgets (water inflows and outflows) and hydroperiod (patterns of inundation). A conceptual water budget of the Peel-Harvey Estuary was developed in the 1970s (Hodgkin *et al.* 1981; Figure 12) and is equally applicable to the estuarine system of the 1990s. This illustrates both the sources and the relative magnitude of inflows and outflows of the system on an annual basis. The major sources of water to the Peel-Harvey at that time were:

- Direct rainfall; and
- Rainfall in the catchment delivered via:
    - Surface water flows (rivers and drains); and
    - Groundwater

The major outflows were evaporation and the discharge of water via tidal exchange through the Mandurah Channel[1].

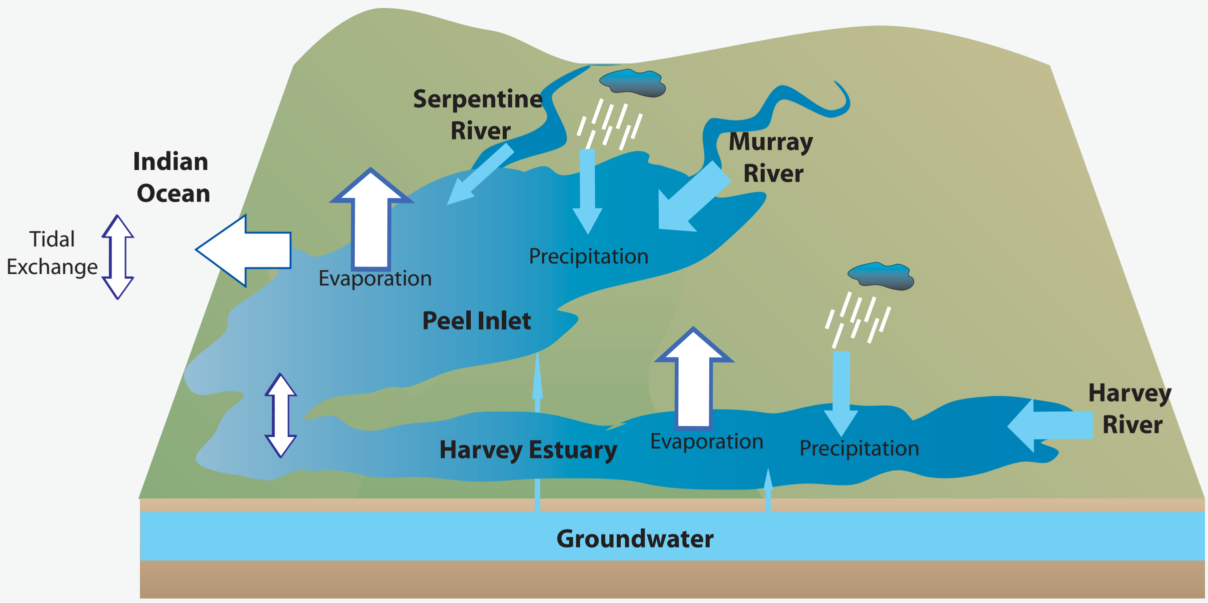


Figure 12: Conceptual water budget of the Peel-Harvey Estuary (adapted from Hodgkin et al. 1981). Blue arrows represent inflows, white arrows represent outflows, and the width of the arrow represents relative magnitude.

Direct rainfall accounts for approximately 15 % of the total inflow of water into the system. With an average rainfall of approximately 880 mm per year (Bureau of Meteorology) across the 75 km^2 of the Peel Inlet and 56 km^2 of the Harvey Estuary, this equates to approximately 115,000 ML per annum. Rainfall is highest in winter and lowest in summer with 80 % of rainfall occurring between May and October (Table 8).

1 Although oceanic exchange acts as both an inflow and an outflow, on an annual basis it is a net outflow (Hodgkin *et al.* 1981).

Table 8: Average monthly inflows (ML) to the Peel Inlet and Harvey Estuary from direct rainfall (calculated from the Bureau of Meteorology data 1900 to 1990).

MONTH	PEEL INLET	HARVEY ESTUARY
January	720	540
February	1,000	750
March	1,500	1,100
April	3,300	2,500
May	9,500	7,100
June	14,000	11,000
July	13,000	9,800
August	9,500	7,100
September	6,400	4,700
October	3,900	2,900
November	1,700	1,300
December	870	650
TOTAL	**65,000**	**50,000**

The rainfall that falls in the catchment is delivered in the short term (days to weeks) by surface water flows in rivers and drains and via longer time scales (years) through groundwater. Groundwater flows to the Peel-Harvey are predominantly from the shallow unconfined aquifer that extends over much of the catchment (URS 2007). Hodgkin *et al.* (1981) calculated the discharge rate of this aquifer and estimated that it contributed approximately 2,000 ML per annum. Although this figure may vary from year to year and seasonally within any given year due to recharge and discharge events in the catchment, as groundwater contributes < 0.5 % of the total inflows these variations are unlikely to significantly affect the hydrology of the system.

River inflows are from three major river systems, the Murray and Serpentine Rivers, which discharge to the Peel Inlet and the Harvey River which discharges to Harvey Estuary. The combined catchment area is approximately 11,300 km^2, of which 6,900 km^2 is within the unregulated Murray River catchment. The Harvey and Serpentine Rivers both contain major dams, as does the Dandalup River (a major tributary of the Serpentine). In addition, water is diverted both into and from the river systems through a network of drains across the catchment. The most significant of these is the Harvey River diversion, which drains the majority of the flow from the Harvey River directly to the sea at Myalup Beach, rather than flowing into the estuary.

The combined surface water inflows from the catchment account for approximately 85% of the total inflows to the system. Most surface flow to the Peel Inlet comes from the Murray River, which on average contributes twice that of the Serpentine. The Harvey River and drains contribute on average 225,000, just over a third of the total river inflows, despite the large amount of water diverted directly to the sea (Table 9).

Table 9: Average annual river flows (ML) from 1977–1988 (McComb and Humphries 1992).

SOURCE	MINIMUM	MAXIMUM	MEAN	% OF RIVER FLOW
Harvey River and drains	86,000	370,000	225,000	36
Serpentine River	50,000	190,000	129,000	21
Murray River	62,000	756,000	264,000	43

Evaporation from the system is high, due to the high summer temperatures and the prevailing wind. Hodgkin *et al.* (1981) estimated evaporation from the Peel-Harvey over a two year period during 1977/78 and 1978/79. As expected a pattern of highest evaporation losses during summer and lowest during winter was reported (Table 10). Average evaporation from the system was approximately 180,000 ML per year, which accounted for up to 50 % of total outflows.

Table 10: Estimated monthly evaporation (mm) for the Peel-Harvey Estuary (Hodgkin et al. 1981)

MONTH	1977/78	1978/79
January	122	127
February	151	159
March	196	186
April	177	180
May	147	137
June	155	138
July	118	86
August	87	80
September	57	47
October	68	59
November	66	67
December	76	63
Total (mm)	1,421	1,330
Volume (ML)	**190,000**	**177,000**

Tidal exchange in 1990 was a result of movement between the Peel Inlet and the Indian Ocean through the Mandurah Channel and the Peel Inlet and the Harvey Estuary through the Grey Channel. There have been a number of investigations into the residence time and flushing rate of the Peel-Harvey Estuary (Hodgkin *et al.* 1981; Dufty and Bowden 1983; Kinhill 1988; and Ryan 1993). These investigations utilised different methods and produced a variety of estimates for annual average residence time for the system, ranging from 75 days (Dufty and Bowden 1983) to 44 days (Kinhill 1988). The results from Hodgkin *et al.* (1981) are provided as indicative residence times for the two basins (Table 11).

Common to the findings of all investigations were:

- Residence times are longer in the Harvey Estuary than the Peel Inlet due to the restricted exchange through Grey Channel;
- The lowest residence time occurs during winter due to climatic conditions and the effects of the river flows; and
- The highest residence times are during summer when water circulation is lowest.

Table 11: Residence times (days) for the Peel Inlet and Harvey Estuary (Hodgkin et al. 1981).

	PEEL INLET	HARVEY ESTUARY
Summer	48	87
Winter	14	20
Annual average	30	40

The restricted tidal exchange through the Mandurah Channel also affected the tidal levels within the estuary. While daily astronomical tides in the Indian Ocean adjacent to the Peel-Harvey Estuary ranged from 20 to 90 cm, the tidal range in the estuary was predominantly < 10 cm (DAL 1997). The water levels in the Peel-Harvey are affected by tides, river flows, oceanic storm surges and barometric pressure. The combination of these factors lead to a range of water levels that occur over different time scales. While daily fluctuations may have been driven by tides, extreme events were the result of river flows and floods in the catchment (oceanic storm surges were ameliorated by the restricted exchange through the Mandurah Channel; DAL 1997). Modelling of water levels based on ambient conditions between 1989 and 1991 indicates a range from a maximum of 53 cm above mean water level to a minimum of 40 cm below mean water level (Table 12). However, it has been estimated that a 1 in 100 year flood event would have raised the water level in the Peel Inlet and Harvey Estuary by 1.8 and 1.3 m, respectively and taken up to 10 days to return to tidal level (DAL, 1997).

Table 12: Model predictions of water levels (cm above Australian Height Datum, AHD) in the Peel-Harvey based on conditions from 1989 to 1991 (adapted from Ryan, 1993).

DESCRIPTION	PEEL INLET	HARVEY ESTUARY
Maximum Level	53	53
Mean High High Water Level	5	4
Mean Water Level	0	0
Mean Low Low Water Level	-5	-5
Minimum Level	-40	-40

3.2.3 WATER QUALITY

Salinity

Hydrological patterns of seasonal freshwater inflows (winter) and seasonal outflows due to evaporation (summer) resulted in strong seasonal trends in salinity in both the Peel Inlet and Harvey Estuary (Figure 13 and Figure 14). During winter and spring when freshwater flows from the rivers were highest, salinity was low. Over the period 1985 to 1991 mean surface water salinity during winter and spring was 19 ppt in the Peel Inlet and 13 ppt in the Harvey Estuary (Hale and Paling 1999). Average salinity in bottom water over the same time period was significantly higher in the Peel Inlet (27 ppt) but only marginally higher in the Harvey Estuary (16 ppt) reflecting the influence of marine water through the Mandurah Channel. This, on occasion, lead to stratification of the water column and effects to dissolved oxygen concentrations (see section on dissolved oxygen below). There were spatial trends on the horizontal plane in winter/spring salinity also evident with near fresh water measurements of < 1 ppt recorded at sites adjacent to river inflows in both the Peel Inlet and Harvey Estuary.

During summer, salinity was significantly higher with mean surface salinity (1985–1991) of 35.5 ppt in the Peel Inlet and 32.5 ppt in the Harvey Estuary (Hale and Paling 1999). During summer the incidences of salinity stratification were reduced with bottom water salinities close to those at the surface. During summer there were occasions in both the Peel Inlet and Harvey Estuary where the salinity became hyper-saline with measurements > 40 ppt common and on occasion > 50 ppt.

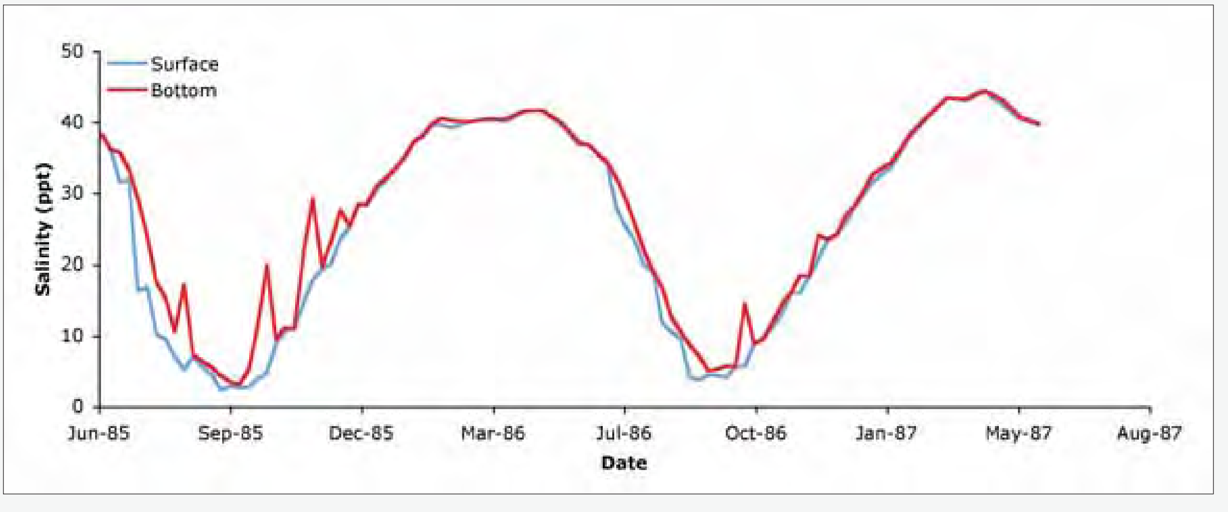


Figure 13: Typical seasonal pattern of salinity in the Harvey Estuary (centre site, June 1985 to August 1987; data from Hale and Paling 1999).

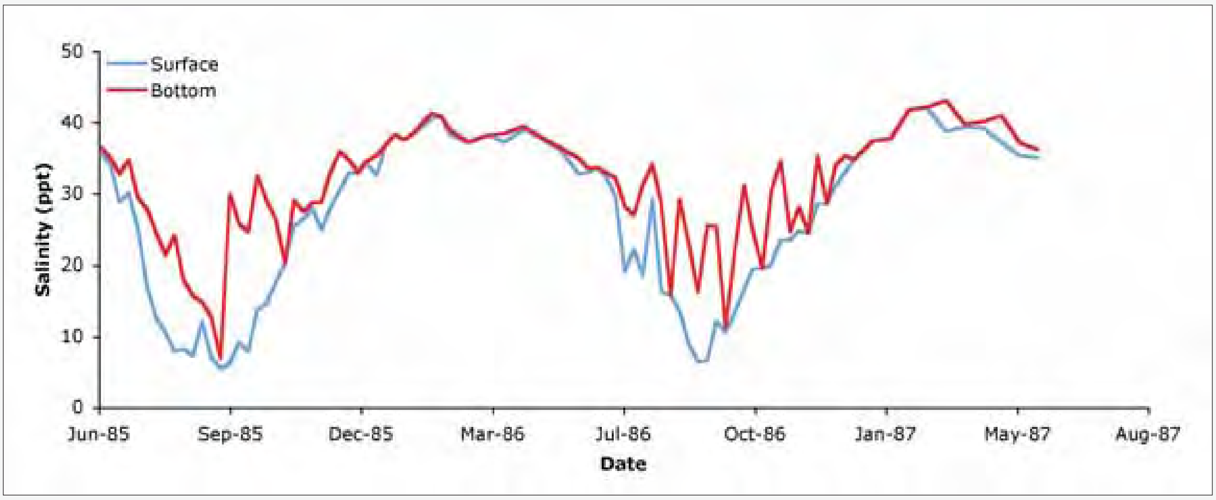


Figure 14: Typical seasonal pattern of salinity in the Peel Inlet (centre site, June 1985 to August 1987; data from Hale and Paling 1999).

Dissolved oxygen

The shallow nature of the Peel-Harvey Estuary, together with the high winds, enhanced diffusion of oxygen from the atmosphere into the water column and as a consequence, the water was generally well oxygenated. Annual cycles of dissolved oxygen predominantly reflected cycles of phytoplankton productivity, with high daytime concentrations during spring and summer (peak phytoplankton biomass). The majority of water quality sampling occurred during daylight hours when phytoplankton would have been photosynthesising and therefore net oxygen producers. However, it is likely that oxygen concentrations at night, when phytoplankton are net consumers of oxygen, would have dropped to very low concentrations.

In addition, the high organic loading to the water and sediment, particularly following growth and decline of phytoplankton and macroalgae, led to the consumption of oxygen as this material decomposed. Salinity induced stratified conditions that occurred in the estuary during calm periods in winter and spring and inhibited the transfer of oxygen into the bottom layer of water. As a consequence, deoxygenation of the bottom waters was a relatively common occurrence. Hale and Paling (1999) reported deoxygenation of waters 1 m above the sediment on average between 10 % and 40 % of sampling events during winter (1985–1991).

Water Clarity

Water clarity varied seasonally due to high turbidity of inflowing waters from rivers, wind induced resuspension of sediment from the water column, and phytoplankton biomass (DAL 1997). In general, the water of the Peel Inlet was clear with light penetration often to the bottom. In contrast, the greater turbidity of the Harvey River and the higher phytoplankton biomass in the Harvey Estuary led to lower water clarity in this basin.

Nutrients

At the time of listing (1990) the Peel-Harvey Estuary had suffered the effects of eutrophication for a number of decades; with large nutrient loads from the catchment, delivered to the estuary via rivers and drains. On average, approximately 1,200 tonnes of nitrogen and 140 tonnes of phosphorus were discharged annually to the estuary over the period 1977 to 1988 (McComb and Lukatelich 1995). The greatest nitrogen load came from the Murray River and was discharged to the Peel Inlet, while the Harvey Estuary received the greatest phosphorus load from the Harvey River and associated drains (Table 13). Due to the seasonality of river flow, 80–90 % of the nutrient loads to the estuary occurred in winter (Hodgkin *et al*. 1981). This discharge of nutrients from river flow led to high concentrations of nitrogen and phosphorus in the water column and sediments of the Peel Inlet and Harvey Estuary.

Table 13: Annual nitrogen and phosphorus loads to the Peel-Harvey Estuary 1977–1988 (McComb and Lukatelich 1995).

	TOTAL NITROGEN LOAD (TONNES/YEAR)			TOTAL PHOSPHORUS LOAD (TONNES/YEAR)		
RIVER	MIN.	MAX.	MEAN	MIN.	MAX.	MEAN
Harvey River and Drains	138	1,115	430	25	133	82
Serpentine River	110	629	250	14	70	43
Murray River	46	2,012	553	3	69	18
Total			**1,233**			**143**

Water column concentrations of dissolved inorganic nutrients (the forms available for plant uptake) were seasonally high in the Peel Inlet and Harvey Estuary. Mean (± standard deviation) concentrations of orthophosphate (PO^4) from 1985 to 1991 during winter were 45 (± 55) µg/L in the Harvey Estuary and 23 (± 28) µg/L in the Peel Inlet. This ranged from a mean of 16 (± 12) µg/L at sites located furthest from the rivers to 80 (± 90) µg/L at sites adjacent to river inflows. Concentrations for the remainder of the year were generally < 10 µg/L (Hale and Paling 1999).

Nitrate-nitrite concentrations followed a similar pattern of high concentrations in winter; 870 (± 460) µg/L in the Peel Inlet and 1,300 (± 580) µg/L in the Harvey Estuary. Concentrations in summer dropped below 10 µg/L in the Peel Inlet and to round 30 µg/L in the Harvey Estuary. Ammonium concentrations were also high during winter with average water column concentrations of 170 (± 200) µg/L in both the Peel Inlet and Harvey Estuary. Peaks of > 1,500 µg/L were recorded at sites closest to river discharges. Concentrations of ammonium were also generally lower during summer, however high concentrations, particularly in bottom waters were often recorded and most likely associated with stratification and release of ammonium from the sediments.

Measurements of particulate nitrogen and phosphorus include inorganic mineral bound nutrients as well as organic nutrients that are contained within microscopic biota such as phytoplankton. Given the high biomass of phytoplankton in the Peel-Harvey Estuary at the time of listing, total nutrient concentrations were dominated by organic nitrogen and phosphorus contained in phytoplankton cells and thus largely reflected the patterns of phytoplankton biomass (see section 3.2.5). Concentrations were highest in spring and summer and higher in the Harvey Estuary than the Peel Inlet. Mean spring concentrations (1985–1991) of organic nitrogen were approximately 2,000 (± 2,000) µg/L in the Harvey Estuary and 1,000 (± 1,000) µg/L in the Peel Inlet. Mean organic phosphorus concentrations over the same time period were 250 (± 250) µg/L in the Harvey Estuary and 100 (± 100) µg/L in the Peel Inlet (Hale and Paling 1999).

Nutrient concentrations and loads were also high in the sediments of the estuary. Hodgkin *et al.* (1981) estimated that the top 1 cm of "black ooze" under the algal beds contained 1,200 tonnes of nitrogen and 130 tonnes of phosphorus. The sediment was thought to be a net sink for nutrients in the system. However, under certain conditions, particularly when the water column is stratified and the dissolved oxygen at the sediment water interface is low, nutrients in the form of orthophosphate and ammonium were released into the water column (Figure 15).

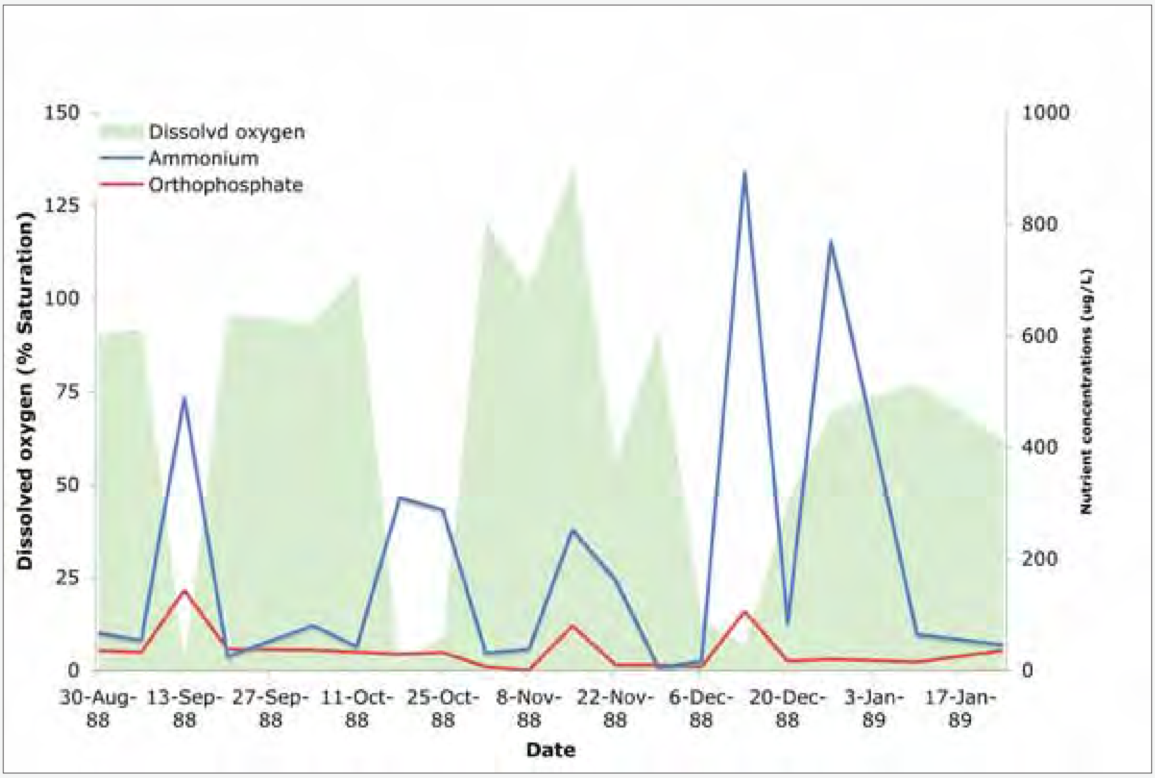


Figure 15: An example of the relationship between dissolved oxygen (shaded green) and release of nutrients from the sediment in the Harvey Estuary (data from Hale and Paling 1999).

3.2.4 ACID SULFATE SOILS

At the time of listing (1990) Acid sulfate soils (ASS) had not been investigated in the Peel-Harvey Estuary. However, recent investigations (Sullivan *et al.* 2006) reported that the mono-sulphidic black ooze in the Peel Inlet can lead to changes in water quality such as acidification, release of contaminants and secondary salinisation if disturbed by activities such as dredging. Given that there are descriptions of "black ooze" in the surficial sediments of the Peel Inlet prior to listing (Hodgkin *et al.* 1981) and that disturbance of sediments from the dredging of the Yunderup canals had also occurred prior to 1990 it can be hypothesised that ASS may have been a component of the ecosystem at that time. However, as there is no information on these sediments from this time, the discussion of this component is contained in section 4.2.3.

3.2.5 PHYTOPLANKTON

The effects of eutrophication lead to excessive growth of phytoplankton and cyclic algal blooms in the estuary. Over the majority of the year, diatoms dominated the phytoplankton community. In summer, this community was often diverse and dominated by *Pleurosigma* with other common genera including *Navicula, Nitschia* and *Rhizoselenia* (Hodgkin *et al.* 1981). In winter, diatom populations bloomed in response to the high loads of nutrients entering the system and the dominance shifted to species of *Rhizoselenia* and *Chaetoceros*.

In the Harvey Estuary, winter diatom blooms were often followed by spring and summer blooms of the cyanobacteria (blue-green algae) *Nodularia spumigena* (Figure 16). These blooms were first recorded in the 1970s and occurred every year there was significant flow (and inflow of nutrients) from the rivers (McComb and Lukatelich 1995). *Nodularia* blooms commenced when temperatures were sufficient for the germination of akinetes (resting stages or spores that remain dormant in the sediment over winter). Blooms would decline in mid summer when salinity increased to 30 ppt or higher.

Nodularia is capable of fixing atmospheric nitrogen and so is more reliant on phosphorus concentrations in the water column for growth. The Harvey Estuary was thought to be a more suitable environment for the growth of *Nodularia* due to the high levels of phosphorus from the Harvey River and the extended period of low salinity compared to the Peel Inlet (McComb and Lukatelich 1995). In addition, the more turbid water in the Harvey Estuary restricted the growth of benthic plants and as such phytoplankton experienced less competition for nutrients in this basin.

*Figure 16: Landsat image showing the extent of a **Nodularia** bloom across the Harvey Estuary in the 1980s.*

Although phytoplankton blooms are a natural occurrence in wetland systems, the frequency and magnitude of blooms in the Peel-Harvey were indicative of a system that was greatly affected by human activities. During the period 1985–1991, phytoplankton biomass (as indicated by chlorophyll *a;* mean ± standard deviation) during winter months was on average 8 (± 10) µg/L in the Peel Inlet and 14 (± 12) µg/L in the Harvey Estuary. However, there were peaks of > 50 µg/L in both basins during this time. During spring and summer over the same period of time mean chlorophyll *a* concentrations were 18 (± 40) µg/L in the Peel Inlet and 125 (± 340) µg/L in the Harvey Estuary, with a peak of > 2,000 µg/L recorded in December 1985 in the Harvey Estuary. The cyclic pattern of phytoplankton biomass in the Harvey Estuary is illustrated in Figure 17.

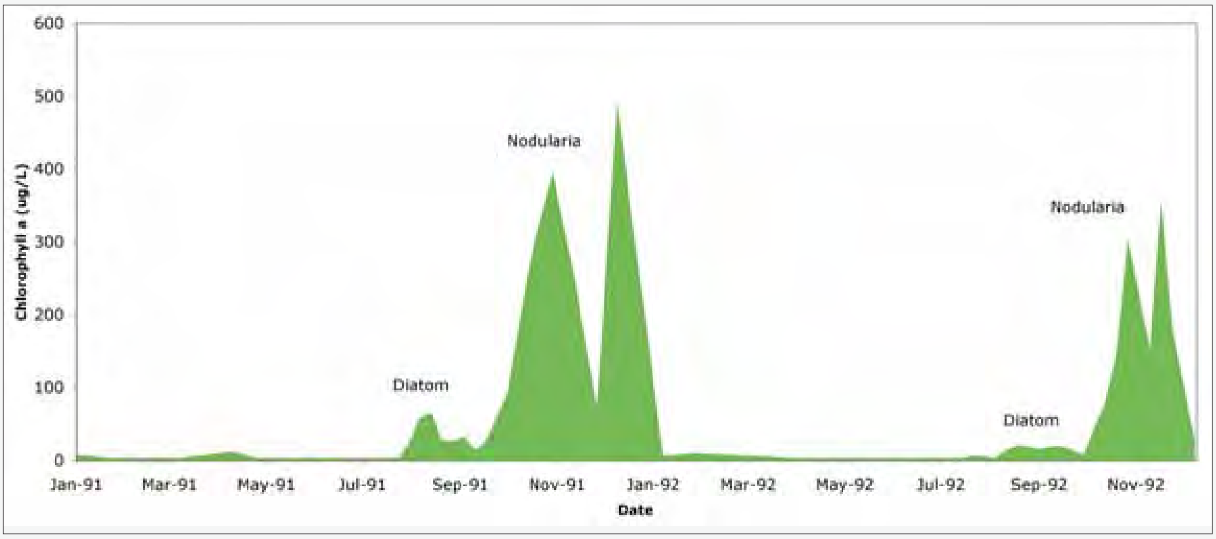


Figure 17: Phytoplankton biomass (as indicated by chlorophyll a concentrations) in the Harvey Estuary 1991–1992

3.2.6 BENTHIC PLANTS

While eutrophication in the Harvey Estuary resulted in increased phytoplankton biomass, in the Peel Inlet, excessive macro-algal biomass was the dominant symptom of nutrient enrichment. During the 1970s, *Cladopora montagnaea* was the dominant taxa (McComb and Lukatelich 1995) and biomass estimates of > 60,000 tonnes dry weight were recorded (Gordon *et al.* 1981).

Cladophora is a green alga, which although filamentous, forms dense sphere shaped clumps 1–3 cm in diameter (Figure 18). This free-floating growth form occurred in large beds across the estuary floor 1–10 cm deep. The lower sections would decompose to form a black ooze over the sediments (Hodgkin *et al.* 1981). Under certain conditions, the *Cladophora* beds would rise to the surface and be driven to the shore by wind and currents, where they formed large rotting masses.

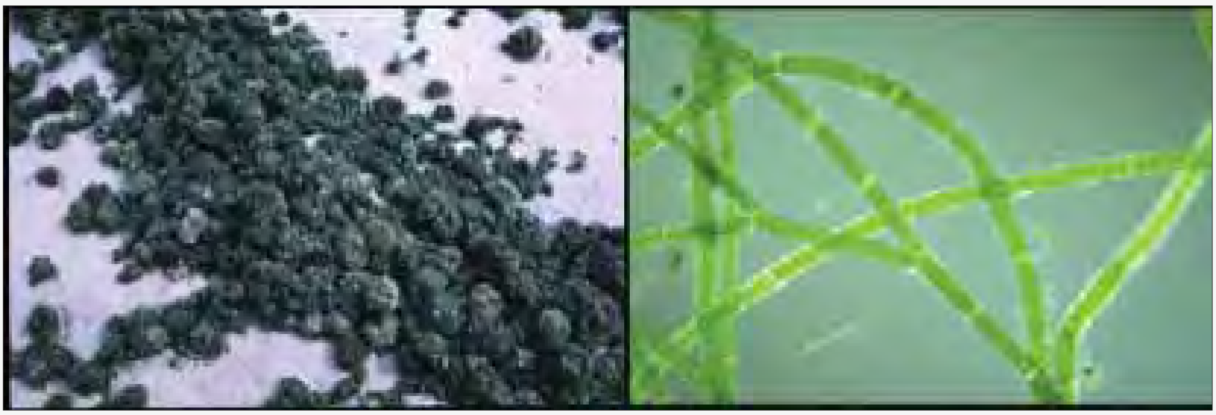


Figure 18: Cladophora showing growth form in balls (left, A. McComb) and filament structure (right, Tsukii, http://protist.i.hosei.ac.jp/PDB2/PCD4817/htmls/53.html).

The growth rate of the macroalgae was highest in summer and lowest in winter with temperature and light the limiting factors during the winter months. Salinity had little effect on growth and laboratory investigations indicated that phosphorus was the factor limiting growth during times of adequate light (McComb and Lukatelich 1995).

Successional changes in macroalgae occurred during the 1980s and other green algae *(Chaetomorpha, Enteromorpha* and *Ulva*) replaced *Cladophora* as the dominant taxa. Mean total biomass (1985–1991) was 10,000–20,000 tonnes dry weight (Wilson *et al.* 1999). Maximum biomass occurred during summer and autumn with > 90% of total biomass comprising of green macroalgae (Chlorophyta). Species richness and diversity were low with an average of only five or six different taxa recorded in any given survey (Wilson *et al.* 1999). Distribution of macroalgae (Figure 19) strongly correlated with water depth with largest beds and growth along the shallow eastern shore of the Peel Inlet.

Seagrass in the estuary was dominated by two species *Ruppia megacarpa* and *Halophila ovalis*. Seagrass would typically germinate in spring, *Ruppia* from seed and *Halophila* from rhizomes. Growth was generally restricted to the shallow margins of the Peel Inlet and average summer biomass (1985–1991) was approximately 2,000 tonnes dry weight (Wilson *et al.* 1999). Seagrass would senesce in the autumn and remain dormant over the winter months when light, temperature and salinity limited growth.

Conditions of high nutrient concentrations generally favoured the growth of green macroalgae over that of seagrass. As a consequence, seagrass distribution and biomass was probably limited by the extensive macroalgal beds, which were observed to smother seagrass growing below (Hodgkin *et al.* 1981).

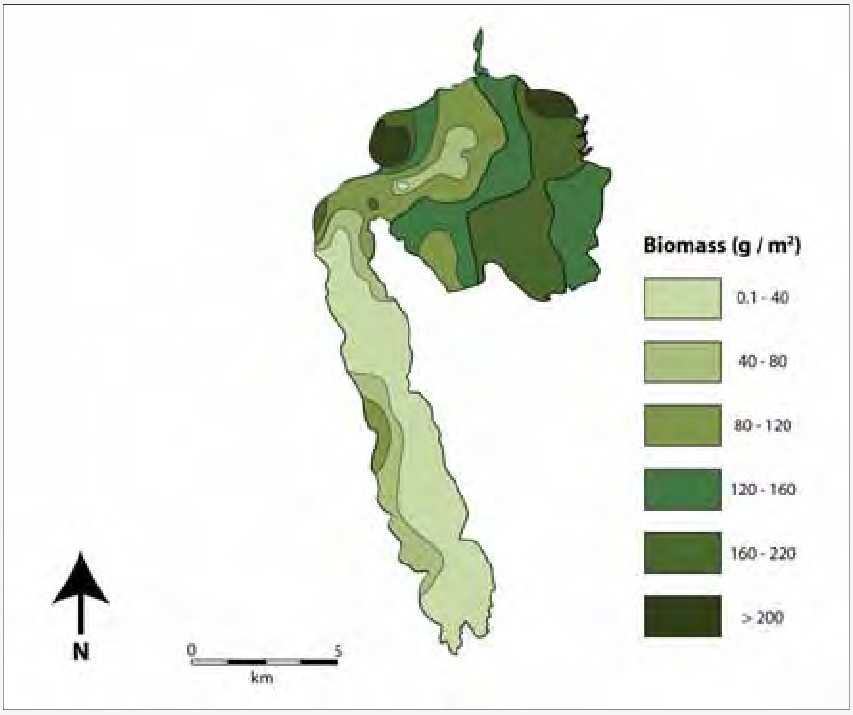


Figure 19: Mean biomass and distribution of macroalgae 1985–1991 (adapted from Wilson et al. 1999).

Another important group of benthic plants is the benthic microalgae or microphytobenthos (MPB). Lukatelich and McComb (1986) investigated the productivity and biomass of MPB in the estuary during the mid 1980s. Their studies indicated that MPB biomass during winter was similar in both basins and approximately 150–160 mg/m^2. During summer, however, biomass of MPB in the Harvey Estuary was twice that in the Peel Inlet with an average of 202 mg/m^2 chlorophyll *a*. Salinity, water column nutrient concentrations and water depth were all factors that influenced productivity and biomass and this explains the decrease in biomass over winter when freshwater inflows lower salinity and decrease water clarity. It is likely that MPB in the Peel Inlet were shaded over summer by the large macroalgal beds and as these were largely absent from the Harvey Estuary there was greater light penetration to the sediment surface in this basin. MPB was an important component in the Harvey Estuary and possibly the most significant primary producer during summer months accounting for approximately 40 times the productivity of the water column except during times of diatom or *Nodularia* blooms (Lukatelich and McComb 1986).

3.2.7 LITTORAL VEGETATION

Tidal salt marshes were (and remain) an important component of the fringing vegetation of the Peel-Harvey Estuary. Hodgkin *et al.* (1981) estimated that there was about 13 km^2 of salt marsh along the shoreline of the Peel-Harvey Estuary, predominantly along the north and eastern margins of the Peel Inlet and the southern fringes of the Harvey Estuary (Figure 20). Salt marshes occur in the intertidal zone where they are inundated by high tide and exposed during low tide. As such, the distribution of salt marshes in the estuary was predominantly determined by shoreline topography and tidal regime (Murray *et al.* 1995a). The majority of salt marsh occurred in areas that were inundated 0–30% of the year (Murray *et al.* 1995b). Tidal driven water regime was responsible not only for broad distribution of salt marshes in the system, but also for zonation of the salt marshes into distinct communities (Figure 21).

Figure 20: Extent and location of salt marsh (shown in red) in the Peel-Harvey Estuary 1986 (Glasson et al. 1995).

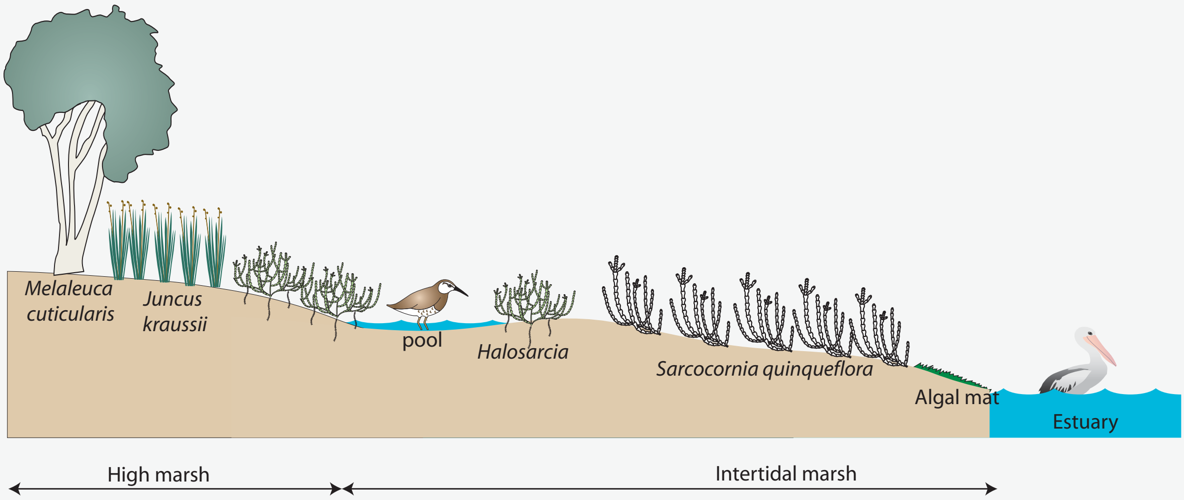


*Figure 21: Cross section of a typical salt marsh in the Peel-Harvey Estuary (adapted from Murray **et al.** 1995a).*

Samphire (dominated by *Sarcocornia quinqueflora*) was the most extensive of the salt marsh communities and occupied the lowest elevation. At the time of listing there was approximately 625 hectares of samphire associated with the estuary (Glasson *et al.* 1995) approximately 500 hectares of which was within the Ramsar site[2]. By the time of listing, there had already been substantial reductions in the extent of samphire within the Peel-Harvey Estuary, with an estimated 37 % loss between 1965 and 1986 (Table 14). The changes in tide and hydrodynamics following the permanent opening of the Mandurah Channel and the dredging of the Sticks Channel were suggested as possible contributing factors to this decline (Glasson *et al.* 1995).

Table 14: Extent of Samphire (ha) in the Peel-Harvey Estuary in 1986 (Glasson et al. 1995).

AREA	1965	1977	1986	1994
Austin Bay	30	23	32	38
Creery Wetlands	170	163	133	140
Harvey Estuary	131	88	107	145
Roberts Bay	115	88	67	81
Other	432	272	190	181
Total	**878**	**634**	**529**	**585**

A total of 45 plant species were identified from surveys of salt marsh undertaken in 1994 (Murray *et al.* 1995a) some key aspects of the ecology of dominant species are provided in Text Box 1.

In addition to salt marsh there were areas of the estuary that contained littoral vegetation dominated by trees. Behind the salt marsh areas these were dominated by the salt tolerant species *Casurina obesa* (Salt Sheoak) and *Melaleuca cuticularis* (Saltwater Paperbark). Both of these species have a relatively high salt tolerance (10 ppt) and are adapted to periodic inundation (Department of Agriculture and Food, Western Australia 2007). The Ramsar site includes some areas of riparian vegetation along the inflowing river systems (Figure 3). These areas contained a mixture of freshwater and estuarine vegetation including tree species such as *Melaleuca rhaphiophylla* (Swamp Paperbark) and sedges such as *Typha orientalis* (Cumbingi). However, there was no quantitative information on extent and distribution of this vegetation from the time of listing (Monk and Gibson 2000).

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2 Note that not all of the Creery Wetlands are currently within the designated Ramsar site; however it was not possible to distinguish the salt marsh that was within the Ramsar boundaries from that outside. This figure includes all of the Creery Wetlands and over estimates the actual extent within the Ramsar site.

Sarcocornia quinqueflora

This is a small green halophytic shrub with succulent stems and branches, which turn from green to red during autumn. This species occupied the lowest elevations and is tolerant of frequent inundation. Seeds are released in April with the onset of winter rains and it is thought that germination is more successful under low salinity conditions. Seedlings require three days free of tidal inundation to establish.

Suaeda australis

This is a small (30 cm) halophytic shrub that was found in association with organic debris. Seeds are released in June and germination is more successful under conditions of low salinity.

Bolboschoenus caldwellii

This small sedge grows from rhizomes in winter/spring when salinity is low and senesces when salinity increases in summer and autumn. Seeds are produced in spring during high tides and low salinity.

Halosarcia species

Several species of halophytic shrub from the genus Halosarcia were found in the marshes usually at higher elevation where inundation is less frequent. These species have a high salt tolerance and germination of seed is not thought to be affected by salinity. However, high temperatures are required for successful germination. At the time of listing Halosarcia species germinates under intensely saline conditions that preclude the germination of seeds of other species.

Frankenia pauciflora

This is a small, prostrate shrub found on the drier banks in the marsh. It has an inability to regenerate under conditions of severe disturbance.

Juncus kraussii

This is a species of tall (up to 1.5m rush) that was found in the drier, elevated parts of salt marshes or in brackish areas where the salinities were lower. Light is required for germination, which, under appropriate conditions takes 12 hours. The fresh seeds are highly salt tolerant but tolerance decreases with age and mature plants possess little salt tolerance.

Atriplex species

These are grey coloured herbs or shrubs that occurred in the higher marsh. Germination in Atriplex seeds is reduced by saline conditions, and the seeds are very sensitive to aeration, so rarely germinate when inundated.

Text Box 1: Ecological characteristics of dominant salt marsh species in the Peel-Harvey Estuary (summarised from Murray et al. 1995b).

3.2.8 INVERTEBRATES

Peel-Harvey Estuary

Aquatic invertebrates are an integral part of the ecology of the Peel-Harvey Estuary, although relatively little work has been undertaken on this key component of the ecosystem. Collectively, invertebrates are a diverse group of organisms and constitute approximately 95 % of the world's biodiversity, with only 2–3 % of invertebrate species occurring in aquatic environments. However being less charismatic than many of the vertebrate species, invertebrates are often ignored as being significant components of ecosystems. In aquatic environments diversity varies according to the wetland type in which they occur and include representatives of the protozoa, rotifers, nematodes, worms, leeches, crustaceans, molluscs, water mites, and insects. Invertebrate productivity can vary in different wetland ecosystems, however aquatic invertebrates are generally considered the primary link between plant primary production and higher trophic levels in wetlands systems (Batzer *et al.* 2006)

Invertebrates can be described in a number of ways, which often relate to the habitat in which they are found within a wetland, or by communities which occur associated with wetland types (e.g estuarine communities, salt marsh communities, freshwater lake communities). The two most commonly studied groups are the zooplankton, small, often microscopic, animals that float in the water column and the benthic, or bottom dwelling, invertebrates which are found on or in the wetland substrate. Zooplankton are important grazers of phytoplankton and in turn are an important food for larger invertebrates, fish, and other vertebrates. Benthic invertebrates are believed to be important in the detrital food chain; aiding the breakdown of organic matter as well as being involved in bioengineering (turn over of sediments and nutrients).

As discussed above the Peel-Harvey Estuary supports high levels of primary productivity with extensive stands of macroalgae and sea grasses and significant amounts of phytoplankton which in turn support significant invertebrate populations (Lord *et al.* 2002). In a limited number of studies more than 20 taxa of benthic invertebrates were recorded in Peel Inlet and Harvey Estuary. DAL (2002) described the benthic fauna as being dominated by a few species at the time of listing and suggested that the low species richness was a reflection of eutrophic conditions in the estuary. The benthic fauna was believed to be tolerant and well adapted to recolonise areas denuded after periods of anoxia caused by *Nodularia* blooms (DAL, 2002).

At the time of listing the natural outlet channel of Peel Inlet supported 50 foraminifera. Foraminifera or forams are single celled amoeboid protists that typically build a test or shell, which can have a single or multiple chambers, with some resembling small molluscs. Forams are typically found in marine environments, although they do occur in brackish environments as well, and are considered to be highly sensitive to environmental influences. They are important components of the fossil record in marine environments. At the time of listing the distribution pattern of forams in the Peel-Harvey Estuary broadly reflected the pattern of estuarine flushing (Hodgkin *et al.* 1981). Hodgkin *et al.* (1981) report that the forams were dominated by a single species, *Ammonia beccarii*, with this species being the only one recorded from the eastern sections of the estuary.

The other dominant benthic fauna of the time were molluscs, polychaete worms and crustaceans. These three groups of invertebrates are typically the dominant groups in estuarine environments. The mollusc fauna of the estuary constituted 18 species in the Peel Inlet and 7 in the Harvey Estuary, with *Hydrococcus graniformis, Athritica semen, Spisula trigonella and Anticorbula amara* accounting for 90 % of the mollusc biomass (Wells *et al.* 1980; Hodgkin *et al.* 1981). Distribution patterns of the molluscs reflect habitat and salinity preferences. *Hydrococcus* and *Athritica* are estuarine species (Wells *et al.* 1980) occurring on sandy substrates and were considered important food items for some bottom feeding fish and wading birds (Hodgkin *et al.* 1981). *Spisula trigonella* are small white cockles with a marine affinity (Wells *et al.* 180) reaching about 25mm in size. They are common molluscs in estuarine environments around Australia and were abundant in the “black sticky mud” of the Harvey Estuary (Hodgkin *et al.* 1981). *Anticorbula* is an estuarine species which was found attached to rocks and logs in the tidal rivers and occasionally on sandy substrates. *Anticorbula amara* has been recorded as a food item for black bream in other estuaries in the southwest (Norriss *et al.* 2002) as has *Gladioferens imparipes,* an estuarine copepod which was recorded as being the dominant species of the zooplankton during winter in the estuary (Hodgkin *et al.* 1981).

Six species of polychaete worms were found in the estuary with *Capitella capitata* considered abundant (Hodgkin *et al.* 1981). This species grows to around 10 cm in length and has an earthworm like appearance. Polychaete worms burrow in the sediment and also occur in masses of decaying weed, with most being detrital feeders, although some are predatory (Hodgkin *et al.* 1981).

Crustaceans are a diverse group of invertebrates with most species being aquatic. They can be found in both the zooplankton and the benthic fauna, and several species constitute significant fisheries. Crustaceans include copepods, ostracods, barnacles, amphipods, isopods, shrimps, prawns, crabs, yabbies and crayfish. The zooplankton of the estuary was dominated by crustaceans at the time of listing with the estuarine copepod *Gladioferens imparipes* occurring in large numbers in winter, whilst other copepods dominated the zooplankton at other times of the year. Benthic crustaceans included amphipods (three widespread species), a single species of mysid, and harpacticoid copepods. In summer these benthic species were known to enter into the night plankton (Hodgkin, *et al.* 1981). Zooplankton populations were reported as being greater in the Harvey Estuary than the Peel Inlet and this was attributed to flushing patterns and differences in suspended detrital material between the two sections of the estuary (Hodgkin *et al.* 1981).

Several of the lager species, such as the Western School or River Prawns (*Metapenaeus dalli)*, Western ‘King Prawn’ (*Penaeus latisulcatus*) and Blue Manna Crabs or Blue Swimmer Crabs (*Portunus pelagicus*), are important fisheries in the Peel-Harvey Estuary (Hodgkin, 1981; de Lestang *et al.* 2000; Malseed and Sumner 2001; DAL 2002). The Blue Manner Crab and the Western King Prawn being the more significant of the invertebrates in the commercial catch and recreational fisheries at the time of listing (DAL 2002). The Western King Prawn was shown to be adversely affected by excessive growth of *Cladophora* and *Ulva*, and was attributed to impacts on habitat of the juvenile stages (DAL 2002). Blue swimmer crabs spawn in mid spring to early summer with recruitment occurring in the estuary in late summer and the following spring, with maturity reached after one year (de Lestang *et al.* 2000). Deaths of Blue Swimmer Crabs in the summer of 1981 were attributed by recreational fishermen to *Nodularia* blooms (Potter *et al.* 1983).

Fringing salt marshes

Invertebrate species richness is typically lower in salt marsh and other estuarine wetlands than that found in marine or freshwater systems. The environmental conditions in estuaries are harsher, requiring greater adaptability for species to be able to survive in such habitats. Even so salt marshes, including those of the Peel-Harvey Estuary, contain significant invertebrate biomass as whilst there may be few species they typically are highly productive (Keally *et al.* 1995). Salt marsh invertebrate communities have both aquatic and also a significant terrestrial component associated with the salt marsh vegetation, both components playing critical roles in food webs and other ecological processes such as decomposition and export of carbon and nutrients into adjacent waters of the estuary (Keally *et al.* 1995).

Relatively little is known about the invertebrate fauna of the salt marshes of the Peel-Harvey Estuary. Surveys in 1993 and 1994 showed zonation and seasonal patterns in the invertebrate communities (Keally *et al.* 1995). Species richness and abundance was greatest in winter during periods of peak inundation and associated with increased mobilisation of nutrients. Conversely richness and abundance were lower in summer during when the marshes experienced greater periods of dryness and lower nutrient availability (Keally *et al.* 1995).

Overall, sixty invertebrate taxa were collected from the salt marshes in 1993/1994. The crustaceans were the most species rich with 17 taxa being recognised, then the diptera (true flies) with 11 taxa. Coleoptera (beetles) and arachnids (spiders and water mites) were the next most species rich group with eight and 11 taxa respectively, then the molluscs, worms (polychaete, flatworms and annelids) and other insects (hemipterans and collembolans) (Keally *et al.* 1995). In the Peel-Harvey Estuary, the isopods *Syncassidina aestuaria* and *Haloniscus* sp. were dominant.

Patterns of species richness and abundance varied according to zonation within the marshes. The dominant taxa also varied at different sites around the estuary, being attributed to local site characteristics (i.e. presence of drains) and position within the estuary. Oligochaetes, the bivalve *Arthritica semen*, *Syncassidina aestuaria* and *Haloniscus* (isopods), and amphipods including Ceinidae amphipods, *Corphium minor* and *Erichthonius* were all abundant. A Harpacticoid copepod was abundant at two sites and believed to be a new species. An ostracod *Bennelongia* and the polychaete *Ceratonereis aquisetis* were not abundant but were considered interesting as they were only found towards the bottom of the Harvey Estuary (Keally *et al.* 1995).

3.2.9 FISH

Estuarine fish can be broken into several distinct categories based on the use of different environments at different life history stages and the relative importance of the alternative habitats. Categories of estuarine fish include the following (Able, 2005):

- estuarine species that breed only in estuaries;
- estuarine species that breed in estuaries and the marine environment;
- euryhaline marine species that usually breed in the ocean but the juveniles are dependent on estuaries as nursery areas;
- euryhaline marine species that usually breed in the ocean, with the juveniles occurring in estuaries but also being found in the ocean;
- euryhaline marine species that usually breed in the ocean, with the juveniles occurring in estuaries but being more abundant in the ocean;
- marine stragglers not dependent on estuaries; and
- diadromous species.

In general most fish found in estuaries are euryhaline marine species that enter estuaries in large numbers at various intervals of their life cycles (Potter *et al.*1990). Immigration of marine species into estuaries is most often done by the 0+ age class therefore estuaries are often considered nursery habitat for many marine species. Marine stragglers are species that will occasionally enter the higher salinity areas of estuaries, usually in low numbers (Potter *et al.* 1990) Euryhaline refers to species which are able to tolerate a wide range of salinities, as opposed to most marine and freshwater fish which are typically stenohaline, or able to tolerate a small range of salinities. Many species of fish undertake migrations which can range on time scales of daily to annual with distances ranging from a couple of meters to hundreds of kilometers. Most migrations are for feeding or breeding with fish being classified in the following groups:

- **diadromous** fish migrate between salt and fresh water
- **anadromous** fish live in the sea mostly, but migrate to breed in fresh water
- **catadromous** fish live in fresh water, migrate to breed in the sea
- **amphidromous** fish migrate between fresh and salt water during some part of life cycle, but not for breeding
- **potamodromous** fish migrate within fresh water only
- **oceanodromous** fish migrate within salt water only

For ease of comparison with historic data the life cycles groupings used in Potter et al. (1990) have been adopted (see Appendix A and Figure 22), which groups species into those which breed in estuaries, are marine-estuarine opportunists, and migratory groupings as above.

Over 50 species of fish have been recorded from the Peel-Harvey Estuary in the period 1979-1981 (see Appendix A), the majority being marine species that entered the estuary as juveniles or are considered marine–estuarine opportunists (Potter et al. 1990). Several species are important commercial and recreational fisheries, in particular Sea Mullet (Mugil cephalus), Yellow-eye Mullet (Aldrichetta forsteri) and Cobbler (Cnidoglanis macrocephalus). Recreationally important fisheries include the Cobbler, whiting (Sillaginodes punctatus), Black Bream (Acanthopagrus butcheri) and Tailor or Bluefish (Pomatomus saltatrix).

Species respond to their immediate surroundings in a number of ways leading to variation in the frequency of use of estuary habitat (Abel 2005). For example several marine species spend considerable time in the Peel-Harvey Estuary, which has been attributed to the unusual conditions in the estuary where tidal influence is reduced (referred to as microtidal), the geomorphology of the two main basins, and the high salinities (Loneragan et al. 1986; Potter and Hyndes 1999). Microtidal estuary systems typically have a narrow and usually shallow entrance channel, which opens into a large, wide central basin or basins (Potter and Hyndes 1990; Young and Potter 2003a). The Peel-Harvey Estuary at the time of listing was considered to be microtidal, and along with the geomorphology of the system could account for the relatively high number of "estuarine opportunists" (Lenanton and Potter 1987 cited in Able 2005).

The catadromous fish the Pouched Lamprey (*Geotria australis*) inhabits the rivers feeding into the Peel Inlet and Harvey Estuary (D. Morgan, pers comm.). This species lives its juvenile life-cycle (3–4 years) in freshwater, in the sediments at the bottom of rivers. It migrates to the sea where it spends the majority of its adult life, parasitically feeding on other fish. It returns to freshwater river environments to breed where it dies once spent. Although not recorded from the Peel Inlet or Harvey Estuary, logic dictates that to reach the Indian Ocean from the Murray, Serpentine or Harvey Rivers, it must pass through this estuarine system.

The eutrophic conditions in the Peel-Harvey Estuary in the 1970s and 1980s influenced the pattern of distribution and abundances of fish. The increases in macroalgae led to an increase in catch per unit effort (CPUE) reflecting an increase in abundance of fish (Lenanton *et al.* 1985; DAL 2002). This increase in CPUE was not uniform across the estuary with the occurrence of *Nodularia* blooms in the Harvey Estuary leading to reduced water clarity and fish abundance. During blooms fish tended to avoid affected areas and this was reflected in the fishing effort as it moved more into the Peel Inlet where fish were less affected by the blooms and altered water quality. Despite the eutrophic conditions, including incidences of fish deaths, the overall catch figures for the whole system actually increased (Lenanton *et al.* 1985; DAL 2002). The increased macroalgae growth provided additional shelter from predators and food supply (invertebrates associated with the algae), which benefited some fish such as the Sea Mullet, Cobbler and Yellow-Eye Mullet (Lenanton *et al.* 1985; DAL 2002).

Although there are no data on introduced fish species from within the estuary, there has been investigations into introduced species in the catchment. Within the Peel-Harvey catchment six introduced fishes are known to exist (Morgan et al. 2004). These include the eastern Mosquitofish (*Gambusia holbrooki*), which is widespread thoughout, including the upper sections of the estuary; Goldfish (*Carassius auratus*) have been found within the lower Harvey River, Serpentine River and Murray River; Redfin Perch (*Perca fluviatilis*) are common in the Murray and Harvey rivers Rainbow Trout (*Oncorhynchus mykiss*) are known from the Harvey, Serpentine and Murray Rivers; Brown Trout (*Salmo trutta*) are found in the Harvey catchment, at least (Morgan et al. 2004). Silver Perch (*Bidyanus bidyanus*) have recently been reported from the Harvey Dam (M. de Graaf, pers. Comm.)

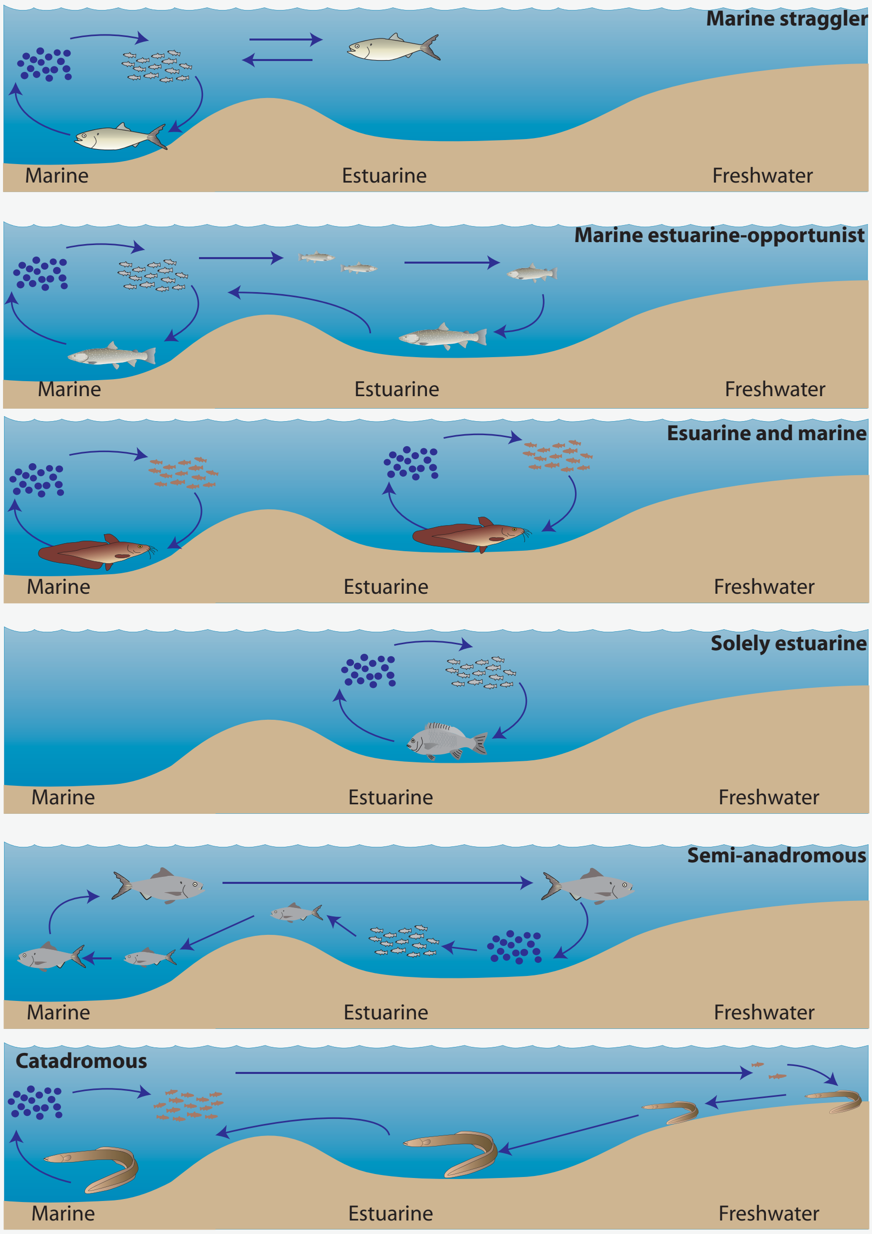

Figure 22: Fish use of estuaries (adapted from Potter and Hyndes 1999).

3.2.10 MARINE MAMMALS

Although not well studied, there is anecdotal evidence that the Peel-Harvey Estuary supported a small population of bottlenose dolphins (*Tursiops truncates*). Animals were observed feeding in the estuary and travelling up the Serpentine River as far as Goegrup Lake. It is suspected that they were not residents in the estuary, but using the estuary for feeding travelling between the estuary and the ocean via the Mandurah Channel.

3.2.11 BIRDS

General

Habitat resources, which are determined largely by climate, geomorphology and hydrological regimes, drive waterbird abundances, with movements of waterbirds in Australia considered to be largely unpredictable and complex. For example, in the drought years of 1969-1970 the Peel-Preston waters showed a marked increase in the annual summer influx of waterfowl that were considered to have immigrated from drier inland areas (National Trust of Western Australia 1973). Shorebirds have the most regular movements, with many species migrating between Australia and the Northern Hemisphere. Within estuarine wetlands, such as the Peel-Yalgorup site, resident shorebird species may be present all year round with migratory species contributing to an influx of species and numbers mainly in spring and summer.

Waterbirds collectively display a number of feeding strategies relating to morphological, behavioural and physiological factors as well as food availability. This affects how waterbirds use wetlands, with different species being able to use the same areas by feeding on different resources (Kingsford and Norman 2002). Bill shape and size is often related to diet, and closely related species can use different habitats but eat the same or different prey. Diet requirements affect the behaviour and patterns of habitat use, thus it is typical to see herbivorous species feeding for extended periods, as their food is harder to digest.

Waterbirds have been placed into the following broad groups:

- Ducks and allies (Anatidae) – ducks and swans. These feed on both plant and animal material, and require freshwater for drinking
- Grebes (Podicipedidae) – diving waterbirds that feed mainly on animals including fish and are associated with both saline and freshwater wetlands
- Pelicans (Pelecanidae), cormorants (Phalacrocoracidae), darters (Anhingidae) – piscivorous waterbirds (fish eating) although they will also eat invertebrates such as crabs, prawns, crayfish. They typically feed in water >1 m.
- Herons and egrets (Ardeidae), ibises and spoonbills (Threskiornithidae) – these forage in the shallows feeding on fish and invertebrates.
- Hawks and eagles (Accipitridae) – raptors that eat fish and/or waterbirds and/or nest in wetlands
- Crakes, rails, coots, water-hens (Rallidae) – forage on open water by diving (coots), or in the shallows and amongst inundated vegetation, feeding on plants and/or animals
- Shorebirds (Scolopacidae, Recurvirostridae, Charadriidae) – forage in the shallows and on exposed mud flats for benthic and other invertebrates
- Gulls and terns (Laridae) – feed mainly on animals, especially fish, both in the shallows and in water > 1 m deep; some are omnivorous scavengers.

Jaensch (2002) described a series of guilds that group species that share a common set of ecological requirements or behaviour patterns. The data on waterbirds of the Peel-Yalgorup Ramsar site have been organised according to these guilds and are contained in Appendix B in the following tables:

- B1 - Species recorded from the Ramsar site
- B2 - Feeding habitats
- B3 - Dietary preferences
- B4 - Nesting sites
- B5 - Other behaviour

For the purposes of the ecological character description of the Peel-Yalgorup Ramsar site, the discussion has been limited to birds that are considered wetland dependant and so excludes terrestrial birds recorded in adjacent landscapes. Wetland dependant in this context is defined as birds that are dependant on the habitats and vegetation that are considered to require periods of inundation.

Diversity and abundance

The variety of food and habitat resources available within the Peel-Harvey Estuary supports both a diversity of species as well as a great abundance of individuals. A total of 86 species of waterbirds have been recorded in the Peel-Harvey Estuary (Table 15). This includes species

such as Black Swans and Pelicans, which are present throughout the year, as well as temporary residents such as migratory shorebirds that use the estuary seasonally. This list includes 29 species that are listed under the international migratory agreements JAMBA and CAMBA as well as an additional 32 Australian migratory species that are listed under the *Environmental Biodiversity and Conservation Act 1999* (EPBC) (Appendix B).

There are four species that have been observed in the Peel-Harvey Estuary that have not been recorded in any other part of the Peel-Yalgorup Ramsar site; Eastern Reef Egret, Artic Tern, Common Tern and Roseate Tern. However, these are considered rare in the system because they are principally marine species.

Table 15: Number of waterbird species found within the Peel-Harvey Estuary section of the Peel-Yalgorup Ramsar site (1976-2007).

WATERBIRD GROUP (NUMBER WITHIN RAMSAR SITE)	TYPICAL FEEDING AND FORAGING INFORMATION	NUMBER OF SPECIES
Ducks and allies (12)	Shallow or deeper open water foragers Vegetarian (Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	12
Grebes (3)	Deeper open waters feeding mainly on fish	3
Pelicans, Cormorants, Darters (7)	Deeper open waters feeding mainly on fish	7
Heron, Ibis, Egrets (13)	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	12
Hawks, Eagles (3)	Shallow or deeper open water on fish and occasionally waterbirds and carrion	3
Crakes, Rails, Water Hens, Coots (8)	Coots in open water; others in shallow water within cover of salt marsh. Omnivores	7
Shorebirds (43)	Shallow water mudflats and salt marsh Feeding mainly on animals (invertebrates and fish)	32
Gulls, Terns (12)	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats	10
Total		86

It should be noted that because waterbirds are highly mobile, some with continental or international range of occurrence, and because many are secretive or easily overlooked within dense aggregations, lists of species recorded at a particular site are rarely complete and tend to increase over time. However, given the high level of survey effort within this part of the Ramsar site, it is likely that the relatively few future additions to the list will be vagrants.

One of the reasons that the Peel-Yalgorup site is listed as a Wetland of International Importance is that it regularly supports greater than 20,000 waterbirds. Large total numbers of total waterbirds were recorded in the Peel-Harvey Estuary prior to and at the time of listing, the highest being 150,000 in February 1977, which was the highest reported total for wetlands in south-western Australia (Lane and Pearson 2002). This included 63,000 Banded stilt, 25,000 Grey Teal, 17,000 Eurasian Coot, 13,000 Red-necked Stint, 10,000 Hoary-headed Grebe and 8000 Black Swans. In addition, Curlew Sandpiper, Little Black Cormorant, Little Pied Cormorant, Pied Cormorant, Black-winged Stilt, Red-necked Avocet, Australian Pelican, Silver Gull, Sharp-tailed Sandpiper, Red Knot and Red- capped Plover all had counts over 1000 individuals. Of the 67 species recorded in this year only 15 had counts of less than 10 individuals (Lane and Pearson 2002).

During the period 1981-1985 surveys were undertaken in nature reserves, which included portions of the Peel Inlet (Jaensch *et al.* 1988). For two years of the 1980s study the surveyed portion of the inlet supported in excess of 20,000 waterbirds, with the numbers being just below 20,000 for the remaining years. In each year of the study the Peel Inlet supported more than 10,000 swans and ducks. Species that occurred in the highest numbers (compared to other reserves assessed) included the Australian Pelican, Pied Cormorant, Grey Teal, Blue-billed Duck, Greenshank, Red Knot, Sharp-tailed Sandpiper, Curlew Sandpiper, Silver Gull, Whiskered Tern, Caspian Tern and Crested Tern. The Eastern Curlew, Osprey, White-bellied Sea-Eagle, Little Egret, Royal Spoonbill, Large Sand Plover, Whimbrel, Grey-tailed Tattler and Ruff also had the highest counts at Peel Inlet (although this was less than 10 individuals for these species) (Jaensch *et al.* 1988). The most abundant species recorded in the 1981-1985 period were the Grey Teal, Red-necked Stint, and the Banded Stilt (Jaensch *et al.* 1988).

Different species of waterbird used different habitats within the estuary. Large numbers of ducks arrived in summer attracted to the clay flats and silt jetties at the mouths of the Harvey and Murray Rivers (National Trust of Western Australia 1973), whereas shorebirds made use of the submerged flats along the eastern shore of the Harvey Estuary and south eastern shore of the Peel Inlet (National Trust of Western Australia 1973). The Creery Wetlands in the north-west supported a large variety of waterbirds as did the samphire areas around Soldiers Cove. Specifically, the abundance of shorebirds was attributed to the lack of tidal variation and considerable area of shallow water (DAL 2002). Black Swans were most often seen grazing on the seagrass beds along the east of the Peel Inlet and birds such as cormorants were often seen utilising cays and sandbars for roosting.

Based on data from the 1970s, the Peel-Yalgorup site has supported > 1% of the known population size of eleven waterbird species (Table 16). This included the resident shorebird, the Banded Silt, which was regularly recorded in numbers > 20,000, as well as international migratory species such as the Red-necked Stint. In addition, Australian waterbirds such as Shelduck, Musk Duck, Grey Teal and Eurasian Coots were recorded in sufficient numbers to represent 1% of the population. In addition, > 10,000 Hoary-headed Grebes have been recorded in the estuary (Lane and Pearson 2002). However, population estimates for these birds, as well as cormorants are not exact and as such an assessment against population levels cannot be made. This should be re-visited if better population data becomes available.

The 4th edition of the Waterbird Population Estimates (WPE) applies the range 10,000 to 100,000 to the Australian population of the Caspian Tern and, by the WPE methodology (using the upper limit), this equates to a 1% threshold of 1000. Previously, the third edition gave the population estimate as 1000 to 5000 and 1% threshold as 30. Updates incorporate new information and so estimates and thresholds can change over time. The 4th edition took into account recently collated information about important inland sites that each supported several thousand birds, as well as aerial survey data across eastern Australia, concluding that the population most likely exceeded 10,000 and possibly exceeded 25,000. As such the Caspian Tern numbers at Peel-Yalgorup (maximum counts of approximately 300) are no longer sufficient to meet the criteria.

Table 16: Species with maximum 1976-77 Peel-Harvey Estuary counts exceeding 1% population levels (Lane and Pearson 2002).

SPECIES	DESCRIPTION	COUNT	% OF POPULATION
Banded Stilt	Nomad, breeding in the inland, but parts of the population may be sedentary and species has been recorded in the estuary year round Prefers shallow, saline waters Feeds mainly on crustaceans and insects by foraging in shallow water	63,000	30 %
Red-necked Stint	International migrant, breeds in Siberia; most likely in estuary between late August and early April Uses intertidal habitat feeding in mudflats and in saltmarsh on invertebrates and plants such as seagrass and seeds	13,259	4 %
Red-capped Plover	Australian nomad, but parts of the population may be sedentary and has been recorded in the estuary year round. May breed in coastal wetlands Prefers shallow, saline waters Feeds mainly on gastropods and insects by foraging on mudflats and shores	1,250	1.3 %
Red-necked Avocet	Australian nomad, breeding in the inland Occurs in the Peel Inlet predominantly in summer and autumn Often uses saline to hypersaline shallow waters Feeds in shallow waters and mudflats on crustaceans and insects	2,180	2 %
Fairy Tern	Resident of the Australian coastline Feeds in shallow waters by plunge diving for small fish	84	1.4 %
Curlew Sandpiper	International migratory species that breeds in Siberia Feeds on invertebrates in mudflats	6,260	3.5 %
Sharp-tailed Sandpiper	International migrant that breeds in Siberia. Feeds in shallows and mudflats on small aquatic invertebrates	1,972	1.2 %
Musk Duck	Australian nomad, but parts of the population are sedentary Occurs in permanent waters fresh and saline and prefers open water habitat Omnivorous	491	2 %
Grey Teal	Mainly nomadic wandering large distances across the continent Occur in most wetland types commonly n intertidal areas in estuaries Seeds of aquatic plants are an important food source as are invertebrates	25,077	1.2 %

SPECIES	DESCRIPTION	COUNT	% OF POPULATION
Australasian Shoveller	Mainly sedentary occurring on a wide range of wetland types Feed mainly on aquatic animals	358	3 %
Eurasian Coot	Some parts of the population are nomadic Occurs in many wetland types but favours large areas of deep water and is reliant on littoral vegetation Feeds mainly on plants and seeds also molluscs and other invertebrates	17,039	1.7 %

Breeding

The Peel-Harvey Estuary is considered a locally important breeding site for a number of waterbird species. In total, twelve species have been recorded breeding within the estuary using various habitats (Table 17). Breeding was recorded for four species during the 1976-77 waterbird surveys: the Black Swan, Australian Shelduck, Grey Teal and Australian Pelican (Lane and Pearson 2002). Whilst there have been relatively few nesting sites recorded for Australian Pelicans in Western Australia (Serventy and Whittell 1976) it would appear that several small colonies have started in the Peel Inlet since 1962 with varying success. Disturbance by humans and also tidal changes have led to abandonment of some nests (D. Rule pers. comm.). In 1976 Boodalan Island and Nirimba Cay supported Australian Pelican nesting activity (Lane and Pearson 2002).

During the 1980s, breeding within the Peel Inlet was observed for the Australian Shelduck, Pacific Black Duck, Black Swan and Grey Teal in the Peel Inlet Nature Reserve and Little Pied and Little Black Cormorants from areas of paperbark from Carraburmup Nature Reserve (Jaensch *et al.* 1988). In addition breeding of Pied Oystercatcher, Black-winged Stilt, Pacific Black Duck, White-faced Heron and Buff-banded Rail has been recorded at Soldiers Cove in the estuary (Rule, 2007). Within the Harvey Estuary only two species had breeding events recorded in the 1981-1985 studies, they being the Pacific Black Duck and Darter. Harvey Estuary was considered an important site for the Darter in terms of number of individuals counted throughout the study.

Table 17: Requirements of waterbirds recorded breeding in the Peel-Harvey Estuary (adapted from Jaensch 2002).

SPECIES	BREEDING BEHAVIOUR/NESTING SITES
Australian Shelduck	Typically nests in dead trees in hollows. Ducklings leave the nest after 2 days by dropping to the ground. First flight at approximately 8 weeks.
Black Swan	Nest mound built in open water, on an island, or in swamp vegetation. Requires minimum water depth of 30–50 cm until cygnets are independent. First flight 20–25 weeks.
Grey Teal	Commonly nest in a tree hollow or on the ground or in swamp vegetation. Ducklings leave the nest soon after hatching by dropping to the ground/water. First flight at approximately 8 weeks.
Pacific Black Duck	Commonly nest in a tree hollow or on the ground or in swamp vegetation. Ducklings leave the nest soon after hatching by dropping to the ground. First flight at approximately 8 weeks.
Australian Pelican	Colonial breeder with nests usually on islands with little or no vegetation Adults can obtain food for their dependent young locally or from distant wetlands. Young leave nests to form crèche at about 3–4 weeks. First flight at 3 months.
Darter	Nests in horizontal branches and forks of trees (Eucalyptus or Melaleuca) in or over water. Requires water to remain until nestlings are independent. Hatchlings leave nest after 4 weeks, first flight at approximately 8 weeks.
Pied Oyster Catcher	Nesting takes place on sand, shell grit or shingle just above high water mark on beaches, sandbars. Young remain with parents for 2–3 months.
Black-winged Stilt	Nest made in a small mound in salt marsh or swamp, or in a scrape in the substrate of an island or spit. Young leave nest within 1 day and self-feed close to parents.
White-faced Heron	Nests in tree forks and horizontal branches, not necessarily in a wetland. Little information on nesting period or fledging.

SPECIES	BREEDING BEHAVIOUR/NESTING SITES
Bluff-banded Rail	Nests rarely observed but are built within shallowly inundated vegetation, sometimes within dense cover on dry ground. Hatchlings leave nest within 24 hours but remain with parents for 2 months.
Little Black Cormorant	Nests in forks and branches of Melaleuca trees in or over water. Colonial breeder with up to tens of nests within a tree. Young remain in nests until mature.
Little Pied Cormorant	Nests in forks and branches of Melaleuca trees in or over water. Colonial breeder with up to 100 nests in a tree (but typically in the tens). Young remain in nests until mature.

Variability

There is a high variability in the records of waterbirds within the Peel-Harvey Estuary both in terms of numbers and distribution. Spatial and temporal variability in waterbird species is common in wetland environments and waterbirds in Australia respond to environmental conditions beyond the local or site scale (Chambers and Loyn 2006). Although it is difficult to determine variability based on annual surveys (Underhill and Prys-Jones 1994), Bamford and Bamford (2003) collated summary statistics for waterbirds at Creery wetlands, within the Peel Inlet (but outside the surveyed eastern reserves, Jaensch *et al.* 1988) from 1982 to 1988. The results illustrate the high degree of variability of numbers recorded between years. The most abundant species (Figure 23) often had means less than standard deviations and maximum counts were an order of magnitude higher than counts for some years. In addition, many of the rare species were absent in one or more years and a small number of species were recorded on single occasions only.

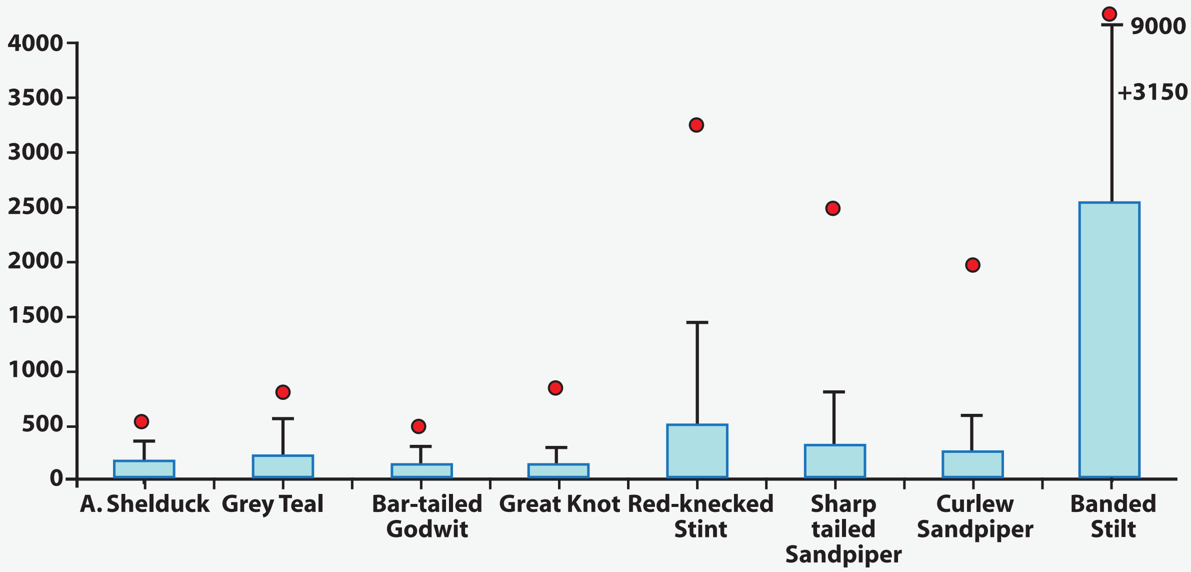

Figure 23: Variability in abundance of waterbird species 1982–1988 at Creery Wetlands (data from Bamford and Bamford 2003). Blue bars represent mean, error bars, standard deviation and red dots maximum numbers.

3.3 YALGORUP LAKES

This component of the Peel-Yalgorup Ramsar site comprises the saline lakes of the Yalgorup National Park. The key components and processes for the Yalgorup Lakes are summarised in Table 18 and described in sections 3.3.1 to 3.3.7 below.

Table 18: Critical ecosystem components and processes of the Yalgorup Lakes.

COMPONENT	SUMMARY DESCRIPTION
Geomorphology	Shallow depressional wetlands No defined surface water inflow or outflow channels
Hydrology	Highly seasonal freshwater inflows predominantly from groundwater No surface water outflows
Water Quality	Brackish to hypersaline conditions Seasonal salinity cycles Low nutrient concentrations Some lakes exhibit stratification Highly alkaline (calcium and bicarbonate)
Benthic Microbial Community	Thrombolites in Lake Clifton Cyanobacterial algal mats across the sediment surface in some lakes
Flora	Small buffer zones Some areas of paperbark communities
Fauna	Significant site for waterbirds Large numbers of Shelduck and Black Swans annually 1% of population of Banded Stilt, Red-necked Stint, Hooded Plover, Shelduck and Musk Duck Breeding of eight species

3.3.1 GEOMORPHOLOGY

Yalgorup Lakes comprise ten wetlands in the Yalgorup National Park, situated in the depression between a series of linear coastal dunes (Figure 24). They are separated from the Indian Ocean by the recently formed Quindalup Dune System, which is comprised of sand that is subject to movement. The older, more stable Spearwood Dune System flanks the eastern shore of Lake Preston and surrounds the other lakes in the system (Figure 24).

The lakes are all shallow (< 3 m deep) and have no defined inlet or outlet channels. Lake Preston is the largest of the wetlands and is closest to the sea. It is a long, narrow water body approximately 30 km long and 0.5–1.5 km wide, running parallel to the coastline. An artificial causeway separates the northern section of Lake Preston from the remainder of the waterbody. Lake Clifton is the second largest and is the furthest inland. It is approximately 20 km long, and 0.2 to 1.5 km wide. The remaining wetlands are small by comparison and form a disconnected chain between Lake Preston and Lake Clifton.

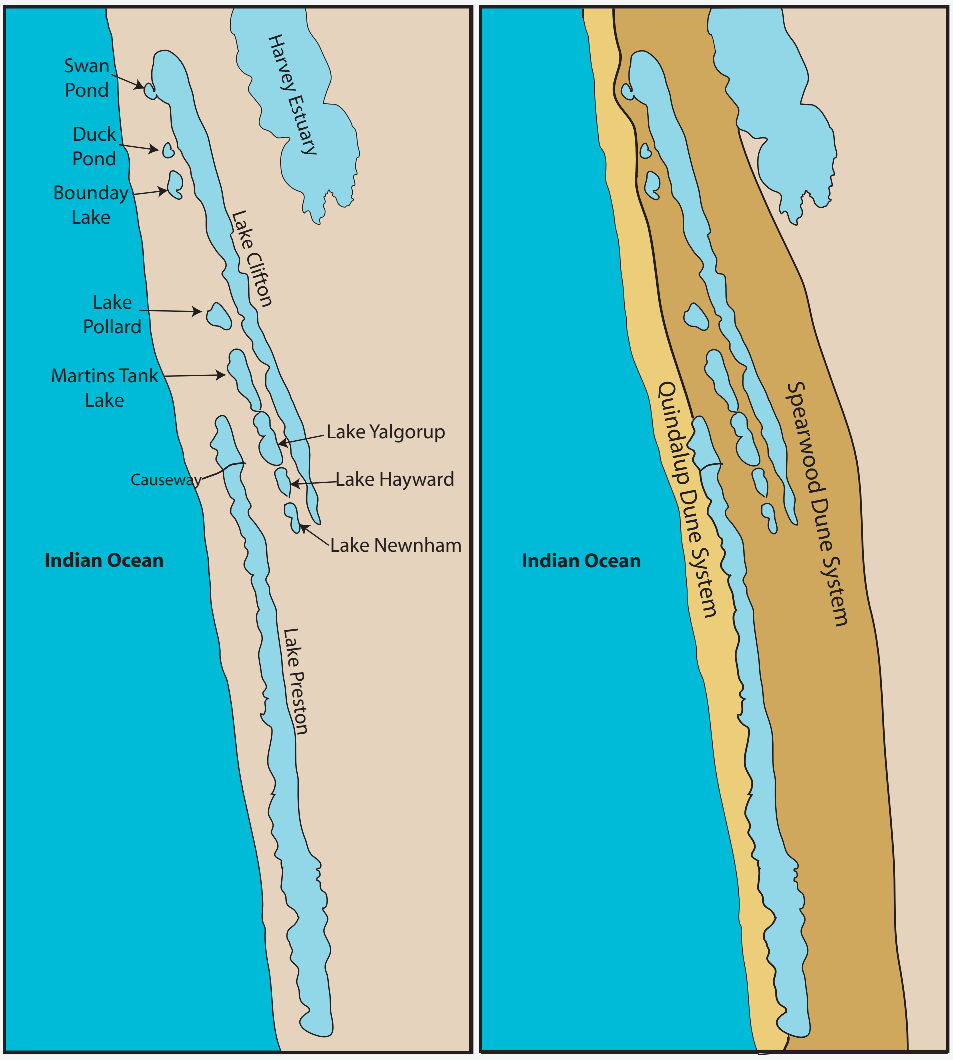

Figure 24: Location of wetlands in the Yalgorup Lakes system (left) and simplified geology of the system (right).

3.3.2 HYDROLOGY

The lakes have no inflow or outflow channels and as such water sources comprise of direct precipitation, localised run off and groundwater. Groundwater is the primary water source for the lakes and localised run off is thought to be insignificant contributing < 0.005 % of total lake volume (Davies and Lane 1996). The lakes intersect the freshwater surficial unconfined aquifer that flows from the east towards the sea. Hypersaline water of lake origin lies under the lakes with the fresh groundwater forming a lens above it (Burke and Knott 1989).

Rainfall and evaporation are similar to that of the estuarine system described above, the majority of precipitation falling in winter and spring and evaporation exceeding rainfall for six months of the year. Despite this the lakes are near permanent due to the groundwater inflows. However, groundwater inflow from the unconfined aquifer is also seasonal and water levels fluctuate seasonally.

The hydrology of Lake Clifton was investigated over a one year period in 1984 (Moore 1987). Rainfall over this period was 762 mm and evaporation 1369 mm. Eighty percent of the rain fell between March and October and over this time rainfall exceeded evaporation by 112 mm. Water levels rose over the same period by > 800 mm indicating the strong groundwater contribution (Figure 25). Groundwater discharge to Lake Clifton over the year was estimated at between 0.3 and 1.8 l/m^2/hour (Moore, 1987).

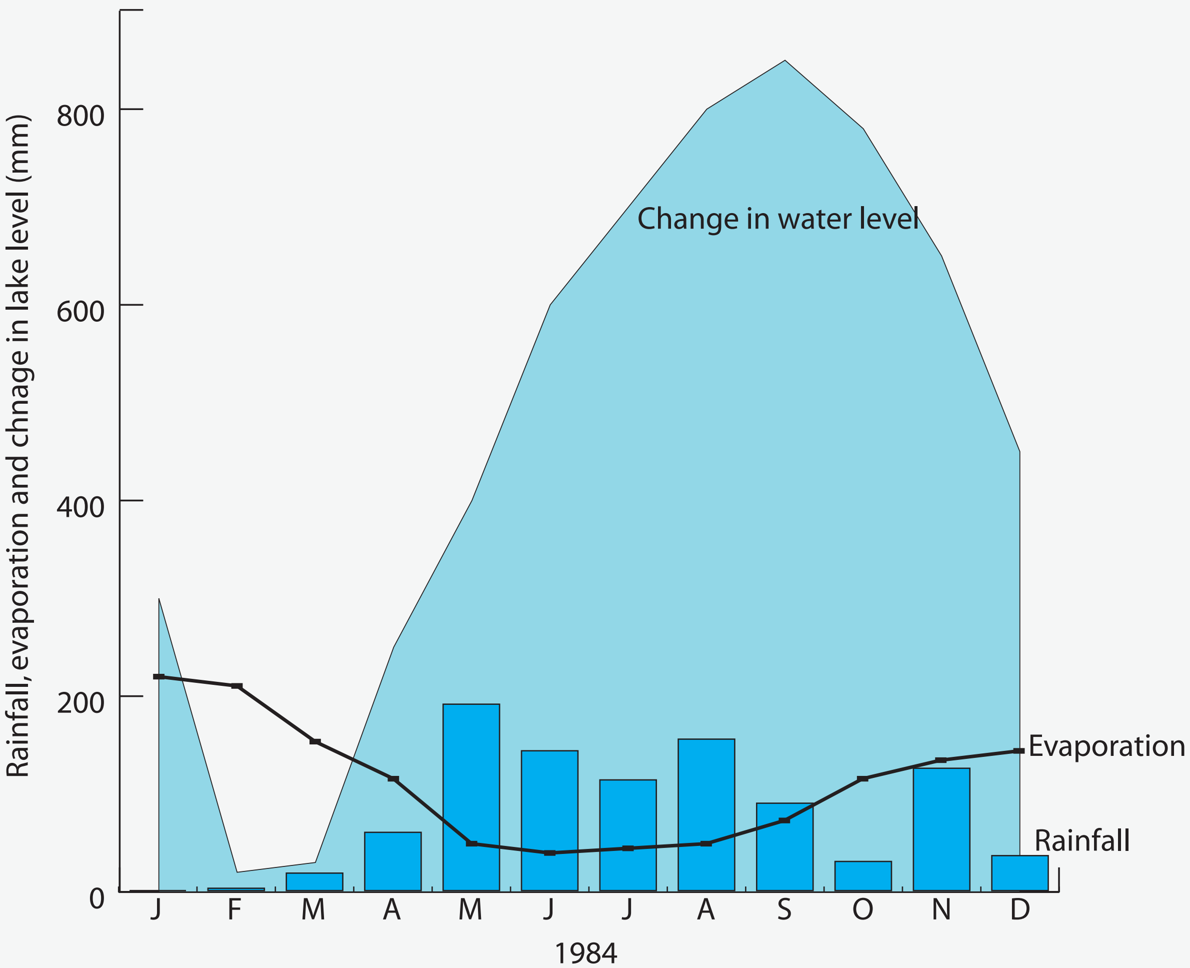

Figure 25: Hydrology of Lake Clifton, 1984 (adapted from Moore, 1987).

3.3.3 WATER QUALITY

The geomorphology and hydrology of the Yalgorup Lakes are the dominant influencing factors in the water quality. The lack of surface water outflow channels results in particulate and dissolved constituents in groundwater and rainfall being retained in the wetlands and becoming concentrated over time. Although there are no surface water outflows it is likely that groundwater flows through the systems and out towards the sea.

The lakes vary between brackish and hypersaline and with strong seasonal patterns (Figure 26). The groundwater is fresh and low in nutrients, however movement through the limestone results in alkaline conditions and high concentrations of calcium and bicarbonate are characteristic of all of the lakes (CALM 1995). The water quality information available for the Yalgorup lakes is presented below. However, there have been few investigations of water quality in this system with the exception of salinity.

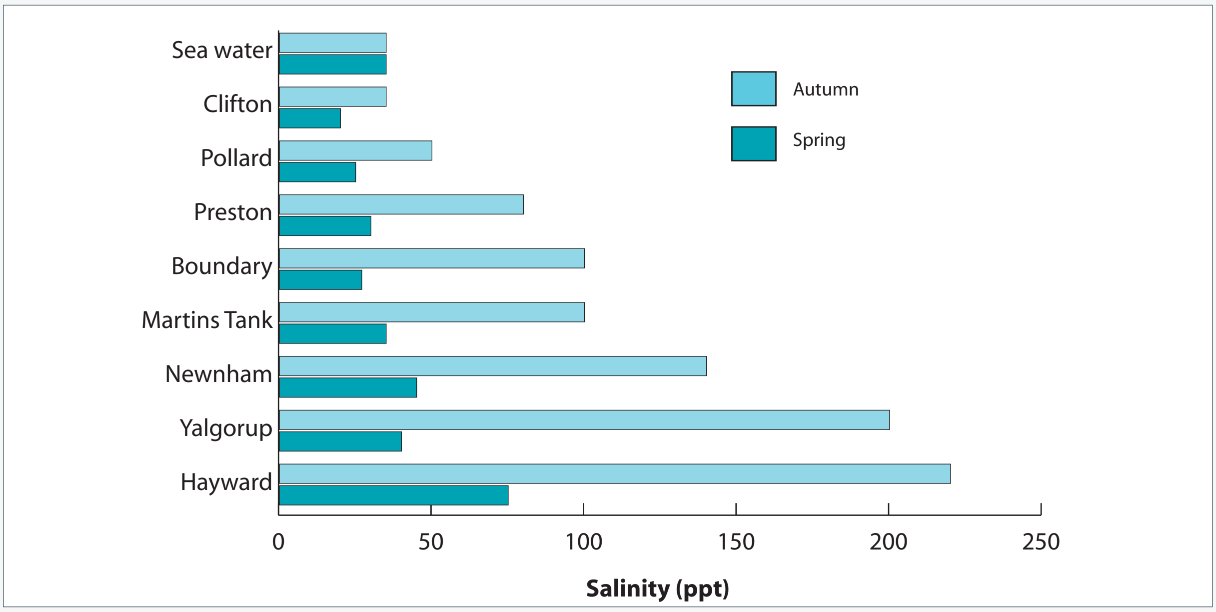

Figure 26: Average salinity of the Yalgorup Lakes in spring and autumn (adapted from Calm 1995).

Lake Clifton

Lake Clifton is the first of the Lakes to intercept the groundwater aquifer, which enters along the eastern shoreline. The Lake is situated below sea level and so acts as a sink for groundwater inflows (Moore 1987). Groundwater is fresh (< 1 ppt) and high in calcium and bicarbonate. As a consequence, Lake Clifton remains brackish throughout the year despite the high evaporation and reduction in lake levels during summer. In 1984 salinity ranged from 15–20 ppt during winter and summer to 26–35 ppt during summer and autumn (Moore 1987). The calcium and bicarbonate concentrations make the wetland highly alkaline and the ions precipitate as calcium carbonate and settle to the sediment floor. It is thought that this process also binds phosphorus at the same time (CALM 1995).

Although surface water flows do not contribute substantial volumes of water, they may contribute nutrients to the system. Davies and Lane (1996) reported concentrations of total nitrogen up to 31,000 µg /L and total phosphorus of 520 µg /L in surface water run off into Lake Clifton, with the greatest concentrations and volumes of water flowing from areas where there was minimal vegetated buffer zone. They also recorded a seasonal trend in nutrient concentrations within the lake with highest concentrations in autumn and lowest in winter (Table 19), which probably reflects dilution effects due to seasonal increasing and decreasing water volumes. Based on this limited information; Lake Clifton would be classified on the basis of tropic status as mesotrophic (Davies and Lane 1996).

Table 19: Dissolved inorganic nutrient concentrations in Lake Clifton 1993 (Davies and Lane 1996). Note concentrations are the result of single samples collected monthly.

MONTH	NITRATE-NITRITE	AMMONIUM	PHOSPHATE
May	100	180	< 10
June	20	100	< 10
July	20	20	< 10
August	40	50	< 10
September	70	20	< 10
October	40	30	< 10

Preston, Martins Tank, Pollard and Boundary Lakes

The salinity is similar in all of these lakes ranging from brackish in winter spring to hypersaline in summer (Figure 26). Salinity stratification does not generally occur and given their shallow nature it is likely that the water column remains oxygenated all year round.

Sampling in Lake Pollard 1985–1987 indicated that the water is alkaline varying between pH 8 and 10, with highest pH values recorded during summer. The high pH over summer leads to the precipitation of calcium carbonate and results in turbid conditions, with secchi depths as low as 15 cm recorded in summer 1986/87 (Burke and Knott 1989).

Hayward Lake

Lake Hayward is hypersaline but varies between approximately 60 ppt and 200 ppt over the year (CALM 1995). Sampling from 1985–1987 indicated that between January and April the water column was well mixed with salinity around 200 ppt. However, between May and December a halocline develops and the water column becomes stratified with surface water salinities between 60 ppt and 80 ppt and bottom water salinity close to 200 ppt (Burke and Knott 1989). There are significant differences in temperature and dissolved oxygen between surface and bottom waters. Bottom waters are hotter and super saturated with oxygen. The latter of these can be attributed to photosyntheses by benthic algae. As such dissolved oxygen near the sediment is lowest a night, but anoxic conditions have not been recorded.

Newnham Lake

Newnham Lake is hypersaline with salinity varying between 40 ppt and > 200 ppt (CALM 1995). Similar to Lake Hayward it is subject to seasonal stratification with bottom waters during summer being higher in salinity, temperature and dissolved oxygen (Burke and Knott 1989).

Yalgorup Lake

Yalgorup is hypersaline varying from 50 ppt in winter and spring to approximately 200 ppt in summer (CALM 1995). It is not known to undergo stratification and as such is well oxygenated year round.

3.3.4 BENTHIC FLORA

Benthic microalgae are an important ecological component of all of the Yalgorup Lakes. They form the basis of the food chain and support a wide variety of other organisms. In some of the lakes (Hayward, Yalgorup and Newnham) these microbial communities form a thick, mucilaginous layer across the sediment surface (CALM 1995).

The thrombolites are arguably the most significant ecological component of this lake system. Lakes Pollard, Newnham, Preston and Martins Tank all contain “fossil” stromatolite formations, but Lake Clifton is the only lake that contains living thrombolites (Moore 1991). The thrombolites at Lake Clifton are considered to be 2,000 years old and are one of only two examples of living thrombolites in Western Australia and a handful in the world (Moore 1991). They cover an area of approximately 400 ha and are predominantly located along the eastern shore (Moore 1987).

Thrombolites are rock-like structures that are formed by the activities of benthic microbial communities (Figure 27). Theses communities are diverse and typically comprise of cyanobacteria, diatoms and "true" bacteria. The cyanobacterium most commonly associated with the thrombolites at Lake Clifton is the filamentous *Scytonema*. Other genera include *Oscillatoria, Dichothrix, Chroococcus, Gloeocapsa, Johannesbaptista, Gomphosphaeria* and *Spirulina* (Moore 1991). Thrombolites are similar to stromatolites in outward appearance, but contain a clotted internal structure (compared to the layered strata of stromatolites). This difference in internal structure reflects the difference in formation processes. Stromatolites are formed by the mechanical trapping of sediments while thrombolites are formed by the precipitation of calcium carbonate by the benthic microbial community as they photosynthesise and grow (Moore 1991).

Figure 27: Thrombolites at Lake Clifton (photo by Janusz Kobryn).

The thrombolites at Lake Clifton are actively growing and rely on the inflow of fresh groundwater rich in calcium and bicarbonate. This water source maintains lake levels that in turn prevents desiccation of the thrombolites, and keeps salinity in the system hyposaline (1–10 ppt) through out the year. Unlike other cyanobacterial communities (such as phytoplankton) the thrombolites do not require significant nutrient inputs and it has been suggested that increased nutrients could be detrimental (Moore 1991). In 1988, *Cladophora* was noted to be growing over the thrombolites in late spring and summer, but was removed by wave and wind action during winter (CALM 1995). It was hypothesised that if nutrients in the groundwater source increased the growth of this and other macroalgae (or phytoplankton) could affect the thrombolites.

In addition to the thrombolites, there is a benthic plant community that consists of macroalgae (*Cladophora*), seagrass (*Ruppia megacarpa*) and charophytes (*Lamprothamnium papulosum*). The charophyte (stonewort) *L. papulosum* is also a dominant feature at Lake Pollard where it covers most of the benthos (CALM 1995). This stonewort is adapted to the high alkalinity and calcium carbonate concentrations. It can tolerate a wide range of salinities (up to 70 ppt) but requires fresh to brackish water to reproduce (Burke and Knott 1989).

3.3.5 LITTORAL VEGETATION

Paperbark Swamp vegetation complex dominated by *Melaleuca cuticularis* and *Melaleuca rhaphiophylla,* occurs around the edges of the lakes, with smaller patches of *Melauleca preissiana* in areas subject to flooding from freshwater sources (CALM 1995). The fringing vegetation is typically narrow, with rural and urban development within 20 metres of the eastern shore of Lake Clifton and western shore of Lake Preston (Figure 28).

The majority of the shorelines are devoid of littoral vegetation due mostly to the hypersaline conditions. Although salt marsh vegetation is adapted to conditions of high salt and alkalinity, most can tolerate salt loads of between 50 ppt and 100 ppt (Datson 2005), which is lower than many of the lakes during summer (Figure 26). The fresher water bodies, such as Lake Clifton, however, can support littoral vegetation and there are areas of the sedges such as *Gahnia trifida*, *Leptocarpus aristatus* and patches of *Typha domingensis*.

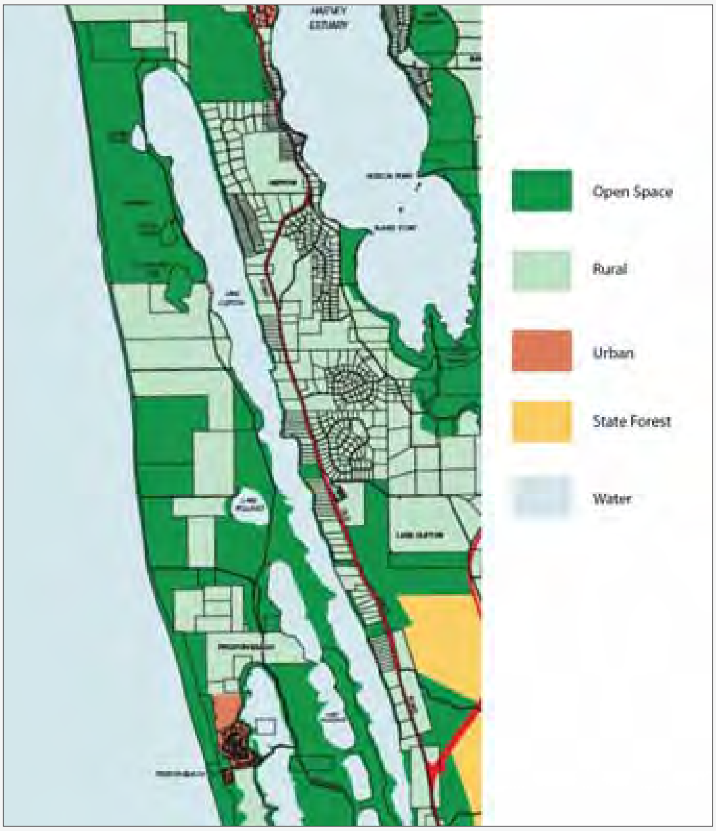

Figure 28: Example of the vegetated areas surrounding the Yalgorup Lakes and the proximity to rural and urban developments (Peel Regional Scheme, 2000).

3.3.6 AQUATIC INVERTEBRATES

Aquatic invertebrates of the Yalgorup system are poorly studied (National Trust of Australia 1973) with most survey work focusing on vertebrate species or important fishery species. The exception is the fauna associated with the thrombolites. Konishi et al. (2001) published the only study of aquatic invertebrates associated with the fabric of living thrombolites of Lake Clifton. They identified 20 invertebrate taxa associated with the thrombolites: predominantly, by crustaceans (amphipods, isopods) and polychaetes. Other invertebrates collected included species of foraminifera, ostracods, nematodes, midge larvae, water mites, beetles and harpacticoid copepods (Konishi et al. 2001).

Thrombolites in Lake Clifton support a diverse invertebrate community, which includes several grazing species which use the stromatolites as both food and refuge. Invertebrates found associated with the thrombolites include isopods, amphipods, gastropods and bivalves (McNamara 1990). Other invertebrates recorded associated with the microbilaties in Lake Clifton are shrimp, sea anemone and bryozoans (CALM 1995). Two species of snails are reported from the shallow lake edges (CALM 1995).

3.3.7 FISH

There is little information on the fish communities in the Yalgorup Lakes. Lake Clifton is known to support Black Bream (*Acanthopagrus butcheri*), Western Hardyheads (*Leptatherina wallacei*) and Long-headed Goby (*Favonogobius lateralis*) (Sarre & Potter 2000, Hoddell 2003). While the Hardyhead and Goby may be endemic to the system and remnants from times of greater connectivity between the lakes and other surrounding waterways, the Black Bream have been introduced. Sarre and Potter (2002) suggested that they were genetically similar to the population in the Collie River and this may have been the original source. Studies of feeding behaviour suggest that the Black Bream in Lake Clifton are feeding predominantly on polychaete worms (Sarre and Potter 2000) however; cladophora was a large component of the diet at other sites investigated. The feeding behaviour of Black Bream, which includes grazing from hard surfaces, may pose a threat to the thrombolite communities (D. Morgan, pers. comm.).

While the salinity in many of the lakes (Boundary, Martins Tank, Yalgorup, Newnham and Hayward) would appear to be too high to support the majority of fish species, the brackish to saline waters of Lakes Pollard and Preston would also be suitable for estuarine and marine fish species.

3.3.8 WATERBIRDS

Diversity and Abundance

The Yalgorup lakes are important habitat for a number of waterbird species and are considered a summer sanctuary for waterfowl (CALM 1995). Lake Clifton and Lake Preston, in particular, supported large numbers of waterbirds in the period up to Ramsar listing. The cumulative number of species recorded for the Yalgorup lakes during 1976-2007 is 73 and represents records spanning three decades (Table 20). This includes 24 species listed under the international migratory bird agreements JAMBA and CAMBA as well as an additional, 15 Australian migratory species protected under the EPBC Act (Appendix B). There are two species for which the Lakes represent the only observations within the Ramsar site. These are the Bridled Tern and Pacific Gull, both of which are principally marine species. In addition, the Little Stint and Pacific Golden Plover, which are regularly recorded at the Yalgorup Lakes, have only been rarely seen at other locations within the Ramsar site.

Table 20: Number of waterbirds found within the Yalgorup section of the Peel-Yalgorup Ramsar site 1976-2007.

WATERBIRD GROUP (NUMBER WITHIN RAMSAR SITE)	TYPICAL FEEDING AND FORAGING INFORMATION	NUMBER OF SPECIES
Ducks and allies (12)	Shallow or deeper open water foragers Vegetarian (Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	8
Grebes (3)	Deeper open waters feeding mainly on fish	3
Pelicans, Cormorants, Darters (7)	Deeper open waters feeding mainly on fish	7
Heron, Ibis, Egrets (13)	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	7
Hawks, Eagles (3)	Shallow or deeper open water on fish and occasionally waterbirds, and carrion	3

WATERBIRD GROUP (NUMBER WITHIN RAMSAR SITE)	TYPICAL FEEDING AND FORAGING INFORMATION	NUMBER OF SPECIES
Crakes, Rails, Water Hens, Coots (8)	Coots in open water; others in shallow water within cover of salt marsh. Omnivores	5
Shorebirds (43)	Shallow water, mudflats and salt marsh Feeding mainly on animals (invertebrates)	33
Gulls, Terns (12)	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats	7
Total		73

The Yalgorup Lakes regularly support large numbers of waterbirds, and although there have been instances where total waterbird numbers across the lakes exceeded 20,000 (e.g. January 2005; Russell, unpublished), the system would not meet this Ramsar criterion in isolation from the other components of the Peel-Yalgorup site. However, maximum bird counts from the lakes (Figure 29) indicate that Lakes Clifton and Preston support > 15,000 birds on occasion.

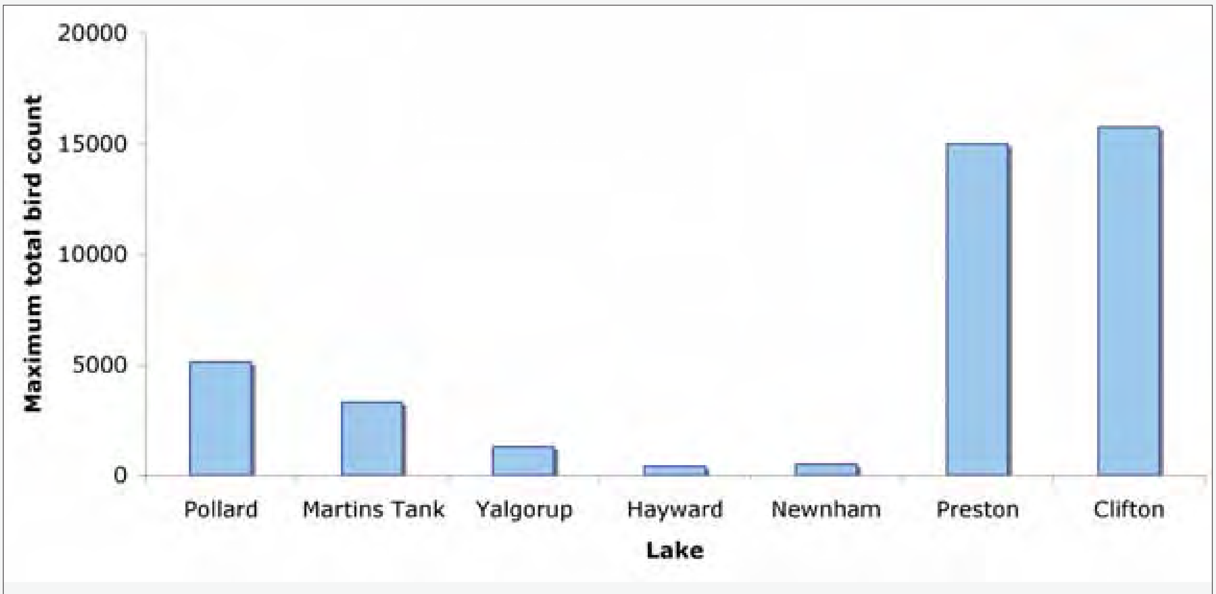

Figure 29: Maximum bird counts for each of the Lakes in the Yalgorup system 1994–2006 (Russell unpublished).

Large flocks of salt tolerant Musk Ducks and Australian Shelduck have been reported on the lakes as well as Black Swans, with 9,000 Australian Shelduck recorded on Lake Preston in 1988 (National Trust of Western Australian 1973; Halse *et al.* 1990; Halse *et al.* 1992; CALM 1995). Counts of up to 3200 Musk Duck at Lake Clifton (Jaensch *et al.* 1993) have been the highest for the western population of this species, well above the 1% threshold (250 birds: Wetlands International 2006); these represent aggregations outside the breeding season, and birds presumably dispersing in winter-spring to breed in freshwater wetlands of surrounding catchments. Numbers of Australian Shelduck also exceed the 1% threshold for the western population of that species.

Lake Preston was considered an important site for ducks during their moulting phase, particularly the Australian Shelduck (National Trust of Western Australian 1973, CALM 1995).

Large numbers of Black Swans use Lake Pollard and graze on the brackish water charaphyte *Lamprothamnium papulosum* during October to January (CALM 1995). These, together with the Shelducks follow a distinct seasonal pattern arriving in large numbers in spring and departing in late summer (Figure 30).

Relatively large numbers of Great Crested Grebe (up to 190, Clifton Lake: Jaensch *et al.* 1993) occur in the Yalgorup Lakes, which are the highest counts from south-western Australia. Though below the 1% threshold (250 birds: Wetlands International 2006), a systematic comprehensive survey across the lakes and estuary may yet prove that the Ramsar site is internationally important for the Australian population of Great Crested Grebe.

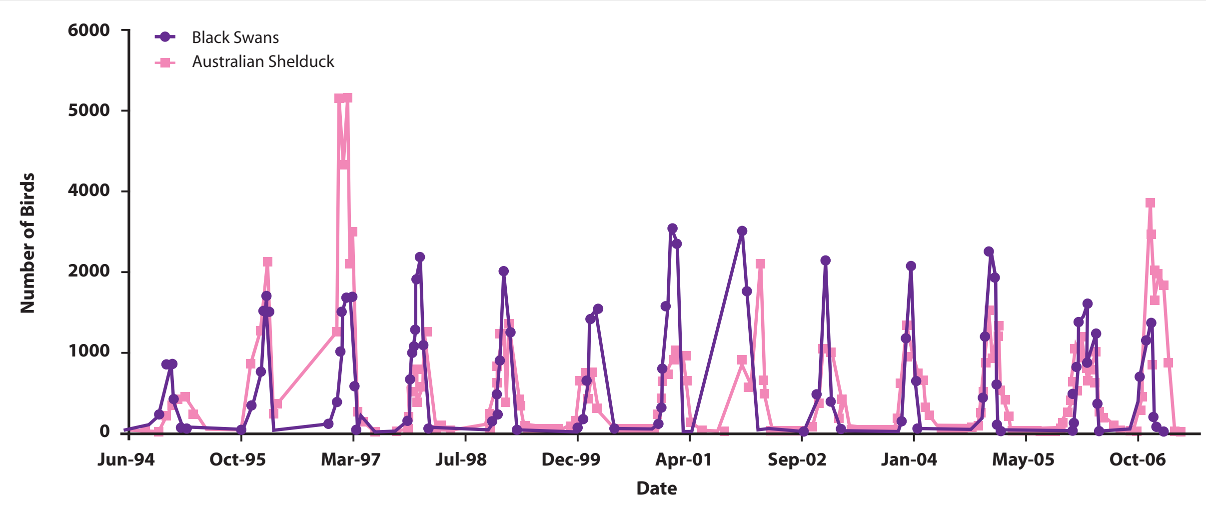

Figure 30: Numbers of Shelduck and Black Swans at Lake Pollard 1994–2006 (Russell unpublished).

The Yalgorup Lakes support at least 1% of the known population size of five waterbird populations; the Banded Stilt, Red-necked Stint , western Hooded Plover, Musk Duck and Australian Shelduck (Table 21). The majority of these birds have been recorded at Lake Preston, although there are significant observations of Banded Stilt from Lake Clifton and Martins Tank (Russell unpublished).

Table 21: Species with maximum Yalgorup Lake counts exceeding 1% population levels (Russell unpublished; Jaensch et al. 1993).

SPECIES	DESCRIPTION	COUNT	% OF POPULATION
Banded Stilt	Australian nomad, breeding in the inland, but parts of the population may be sedentary and species has been recorded at the lakes year round. Prefers shallow, saline waters Feeds mainly on crustaceans and insects by foraging in shallow water	5,000	2.5 %
Red-necked Stint	International migrant, breeds in Siberia; most likely at the lakes between late August and early April Feeds in shallow lake water and damp mudflats on invertebrates	15,000	3 %
Hooded Plover	Resident, breeding locally Forages at the waterline, feeding on invertebrates	170	2–3%
Musk Duck	Australian nomad, but parts of the population are sedentary Occurs in permanent waters fresh and saline and prefers open water habitat Omnivorous	3500	14 %
Australian Shelduck	Generally sedentary, but post breeding migration over short distances for moulting At Yalgorup Lakes most commonly observed at Lake s Pollard, Clifton and Preston (the less saline wetlands within the system)	5000	2 %

Breeding

Eight species have been recorded breeding at the lakes (CALM 1995; Birds Australia 2005b; Rule 2007; Russell unpublished) (Table 22). Of particular significance is the Hooded Plover (*Thinornis rubricollis*). The Yalgorup Lakes contains the largest known aggregation of documented breeding efforts for Hooded Plovers in Western Australia (Birds Australia 2005). Hooded Plovers use a number of the lakes within the National Park with breeding recorded from Preston Lake, Boundary Lake, Duck Pond and Swan Pond (Birds Australia 2005a; Rule 2007).

Table 22: Requirements of waterbirds recorded breeding at the Yalgorup Lakes (adapted from Jaensch 2002; Birds Australia 2005a).

SPECIES	BREEDING BEHAVIOUR/NESTING SITES
Australian Shelduck	Typically nests in dead trees in hollows Ducklings leave the nest after 2 days by dropping to the ground First flight at approximately 8 weeks
Black Swan	Nest mound built in open water or in aquatic vegetation Requires minimum water depth of 30–50 cm until cygnets are independent First flight 20–25 weeks
Grey Teal	Commonly nest in a tree hollow or on the ground or in aquatic vegetation Ducklings leave the nest soon after hatching by dropping to the ground/water First flight at approximately 8 weeks
Pacific Black Duck	Commonly nest in a tree hollow or on the ground or in aquatic vegetation Ducklings leave the nest soon after hatching by dropping to the ground First flight at approximately 8 weeks
Banded Lapwing	Commonly nest on bare ground not necessarily in a wetland. Observed nesting in samphire at Lake Preston
Red-capped Plover	Nests in scrape made in sand or mud Young leave nest within one day and self fed, require vegetation for cover
Hooded Plover	Nest at Lake Preston between December and February on hard limestone near the waterline. Nesting success is thought to be low (< 30%)
Great Crested Grebe	Nest on floating mound of aquatic vegetation Young leave the nest soon after hatching and can dive after approximately 1 week

3.4 LAKES MCLARTY AND MEALUP

This component of the Peel-Yalgorup Ramsar site comprises two freshwater depressional wetlands on the eastern shore of the Harvey Estuary. The key components and processes for Lakes McLarty and Mealup are summarised in Table 23 and described in sections 3.4.1 to 3.4.7 below.

Table 23: Critical ecosystem components and processes of Lakes McLarty and Mealup.

COMPONENT	SUMMARY DESCRIPTION
Geomorphology	Shallow depressional wetlands No defined surface water inflow or outflow channels
Hydrology	Highly seasonal freshwater inflows predominantly from groundwater No natural surface water outflows (although there are drains present)
Water Quality	Fresh to brackish conditions Alkaline
Flora	Typha across parts of each lake Sedges on the margins Paperbark community at higher elevations
Fauna	Important habitat for freshwater invertebrates Provides habitat for a large diversity and number of waterbirds Breeding recorded for 12 species of waterbird

3.4.1 GEOMORPHOLOGY

Lakes McLarty and Mealup are shallow; moderate sized depressional wetlands on the plain to the east of the Harvey Estuary (Figure 31). The lakes are part of the “Bibra” suite, a linear wetland system that are located near the interface of the Bassendean and Spearwood dune systems. The lakes are approximately 600 m from the Harvey Estuary separated from the estuary by a fossil dune ridge (CALM 2005). They are both on the Spearwood dune system, which is characterised by shallows sandy soils over limestone.

Lake McLarty is approximately 2.1 km long and 1.25 km wide and covers approximately 200 ha. The lake is, oval in shape with shallow gradient shorelines and a fine layer of silt across the bottom (CALM 2005). Lake Mealup is situated 500 m to the north, has a similar morphology, but is approximately one third the size at 70 ha.

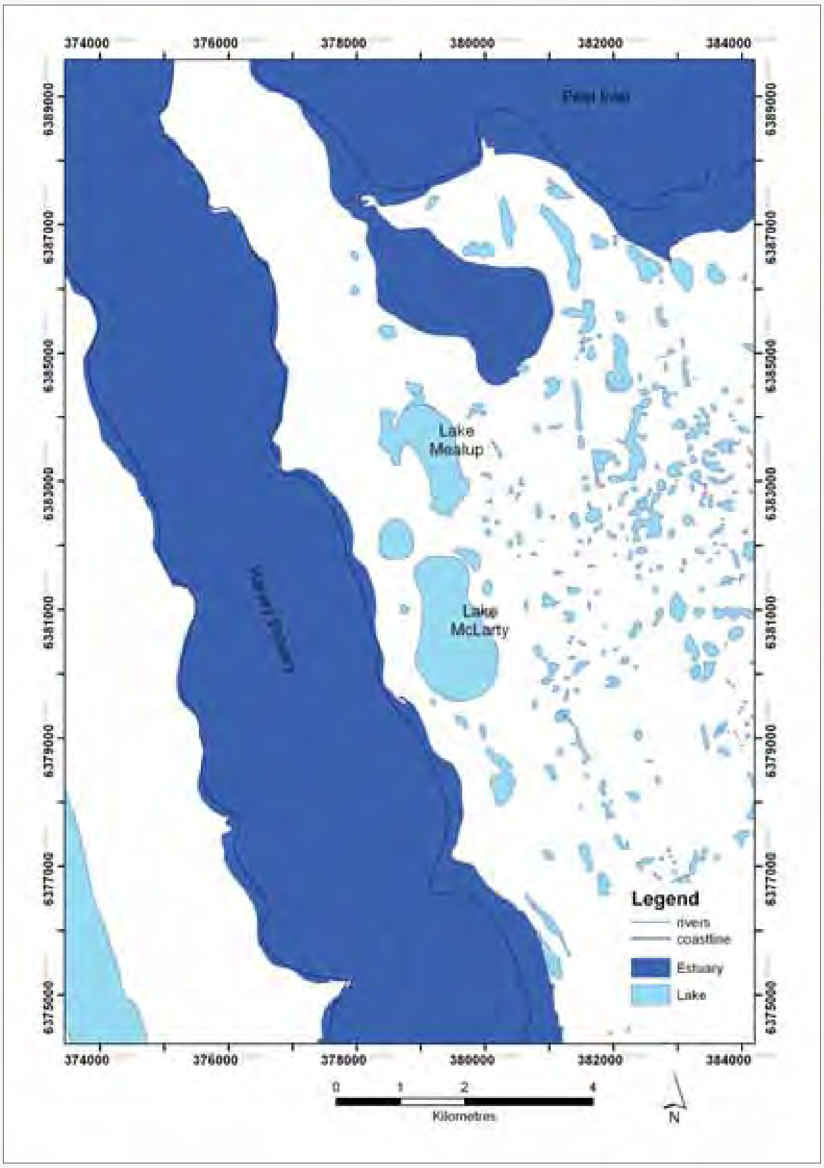

Figure 31: Location of Lakes McLarty and Mealup.

3.4.2 HYDROLOGY

Lakes McLarty has no natural surface water drainage channels (although there is a drainage channel to the south that has the potential to overbank into the wetland). The dominant water source is groundwater and the lake intersects the shallow, surficial freshwater groundwater aquifer, which flows seasonally in response to rainfall. As a consequence, water levels are highest in spring after winter rains and groundwater seepage reach their maximum. The wetland is seasonally dry, with evaporation and loss of water back into the groundwater as aquifer levels fall. Lake McLarty is typically dry for 1–4 months over late summer and autumn, but not in all years (Craig *et al.* 2006). This wetland is shallow with maximum water depths typically less than 1.5 m, however, this is greatly variable depending on annual variability in rainfall and temperature.

The hydrology of Lake Mealup is more complex. At the time of listing there was a surface drainage connection to the lake from the Mealup Main Drain and this contributed significantly to the inflowing water. In addition, it is thought that Lake Mealup not only is connected to the shallow, surficial groundwater aquifer, but also to the deeper artesian groundwater (Peter Wilmot, pers. comm.) Lake Mealup has water depths of < 1.5 m and could be classified as seasonal or intermittent with a dry phase in early/late autumn to the first rains in winter. Over the period 1987–1994, Lake Mealup dried in approximately half of the years (Lake Mealup Preservation Society, unpublished).

3.4.3 WATER QUALITY

Water quality in the lakes is a product of groundwater quality and surface water run-off from the surrounding local catchment. Lake McLarty is a freshwater system and salinity is less than 1 ppt though out the year (CALM 2005). However, salinity varies seasonally with water level and with maximum readings in summer/autumn when water levels are lowest and concentration effects are apparent. Salinity typically ranges from 0.1 ppt in winter to 0.9 ppt during summer, although a survey during December 2006 in a few mm of water recorded salinity of 20 ppt (Syrinx 2007).

The water at Lake McLarty is neutral to slightly alkaline (pH 7–8.5) reflecting the limestone influence on groundwater. There is a small amount of data for nutrient concentrations in Lake McLarty, which suggest potentially high levels of available nitrogen (up to 3000 µg/L nitrate-nitrite) and phosphorus (up to 3000 µg/L of phosphate). However, as seasonal wetlands naturally experience peaks of nutrients during wetting and drying cycles, and the available data is from a small number of spot samples, it is unknown if this is representative of the system.

Water quality collected by the Lake Mealup Preservation Society (unpublished) over the period 1987–1994 indicated that the water in Lake Mealup was fresh (< 0.1 ppt) and typically tannin stained. Nutrient concentrations indicated moderate levels of total nitrogen and phosphorus and low concentrations of ammonium. Lake Mealup was generally slightly acidic to neutral (pH typically 6.7–7.5). However, in the periods following drying, pH levels were very low (pH approximately 3–4) and correspondingly this led to a release of ammonium from the sediment and high concentrations of ammonium were recorded (up to 14,000 µg/L). It is thought that this may be due to exposure of acid sulfate soils to the air during prolonged drying and the formation of sulphuric acid (Peter Wilmot, pers comm.).

3.4.4 FLORA

At the time of listing Lake McLarty was dominated by sedges with extensive stands of *Typha orientalis* across the bed and *Baumea articulara* around the margins (Craig *et al.* 2006). There was very little open water area and no submerged plants were recorded. The fringing vegetation was dominated by paperbark vegetation communities adapted to seasonal inundation for a few months of the year over winter (Figure 32). Species included *Melaleuca rhaphiophylla* and *Eucalyptus rudis* (CALM 2005).

The fringing vegetation at Lake Mealup was also closed paperbark (*Mealueca raphiophylla* and *M. preissiana*) with the centre of the wetland dominated by sedges and rushes (Figure 32).

3.4.5 FAUNA

Invertebrates

As with other parts of the Peel-Yalgorup Ramsar site the understanding of aquatic invertebrate communities at Lake McLarty and Mealup is limited. Lake McLarty was surveyed in the summer of 2000, the first survey of aquatic invertebrates at the wetland. Forty six species were recorded, with species of ostracods, damselflies and diptera being dominant, and considered important food items for water birds (CALM 2005).

Whilst the information on the invertebrate fauna is limited for Lake McLarty and lacking for Lake Mealup, these wetlands would support different invertebrate communities to those found in other areas of the Ramsar site. Seasonal freshwater wetlands can be highly productive systems with considerable invertebrate diversity.

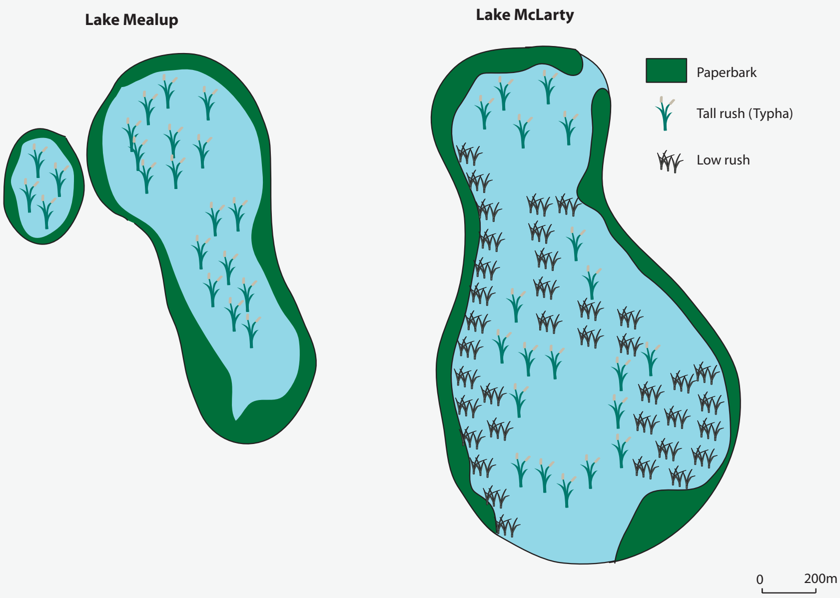

Figure 32: Vegetation at Lakes Mealup and McLarty (adapted from Jaensch et al. 1988). Note that the two waterbodies are shown side by side for convenience only, this is not representative of their locations.

Fish

No information was sourced on fish in either Lake McLarty or Mealup, however as seasonal wetlands they may not support fish populations.

Birds

<u>Diversity and Abundance</u>

Lakes McLarty and Mealup are important waterbird habitats, with a total of 85 water bird species recorded (Table 24), the highest number within the Peel-Yalgorup site. This includes 32 species listed under international migratory bird agreements (JAMBA, CAMBA) and an additional 19 Australian migratory species protected under the EPBC Act (Appendix B). Nine species (Asian Dowitcher, Double-banded Plover, Little Ringed Plover, Oriental Plover, Oriental Pratincole, Pin-tailed Snipe, Long-toed Stint and Wood Sandpiper) have not been recorded elsewhere within the Ramsar site, although several of these species have only been observed on one occasion. In addition, the Australasian Bittern was recorded at Lake McLarty in the 1980s, but is thought to now be regionally extinct.

Table 24: Number of waterbird species recorded within Lakes McLarty and Mealup.

WATERBIRD GROUP (NUMBER WITHIN RAMSAR SITE)	TYPICAL FEEDING AND FORAGING INFORMATION	NUMBER OF SPECIES
Ducks and allies (12)	Shallow or deeper open water foragers Vegetarian (Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	12
Grebes (3)	Deeper open waters feeding mainly on fish	3
Pelicans, Cormorants, Darters (7)	Deeper open waters feeding mainly on fish	6
Heron, Ibis, Egrets (13)	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	11
Hawks, Eagles (3)	Shallow or deeper open water on fish and occasionally waterbirds, and carrion	2
Crakes, Rails, Water Hens, Coots (8)	Coots in open water; others in shallow water within cover of salt marsh. Omnivores	8
Shorebirds (43)	Shallow water, mudflats and salt marsh Feeding mainly on animals (invertebrates)	38
Gulls, Terns (12)	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats	5
Total		**85**

Jaensch *et al.* (1988) surveyed Lake McLarty and found it to be an important site for Great Crested Grebe, Great Egret, White-faced Heron, Wood Sandpiper, Greenshank, Marsh Sandpiper, Sharp-tailed Sandpiper, Pectoral Sandpiper, Long-toed Stint, and Ruff. The numbers of Long-toed Stints at Lake McLarty at that time was the greatest of the 197 reserves surveyed, with only two other records of higher counts in Australia (Jaensch *et al.* 1988). The Long-toed Stints were observed in all parts of the lake except the far northern end. Counts of Wood Sandpipers, Marsh Sandpipers and Ruffs were also the highest for the study. The most abundant species were the Grey Teal, Black-winged Stilt, and Sharp-tailed Sandpiper (Jaensch *et al.* 1988). The most commonly encountered species were the Pacific Black Duck, White-faced Herons, and Great Egrets.

Waterbird surveys at Lakes McLarty and Mealup are seasonally biased, with the majority of records from spring and summer (Craig *et al.* 2004). During this time, wading species are dominant and utilise the mudflats around the drying wetland. However, during winter, the species composition shifts with a higher proportion of ducks and allies, water-hens and coots. At this time of the year over 70 % of the waterbirds were observed in the paperbark woodland (Kirkby 1996). At the time of listing, there were few records from Lakes McLarty and Mealup and it was not possible to say if they supported > 20,000 waterbirds or > 1% of the population of any one species.

<u>Breeding</u>

A total of twelve species have been recorded breeding at Lakes McLarty and/or Mealup (Table 25) (Kirkby 1996; Jaensch *et al.* 1988). Of note, is the provision of habitat for breeding of freshwater birds such as the Spotless Crake, Eurasian Coot and Purple Swamphen; as these lakes represent the only large freshwater wetlands within the Peel-Yalgorup Ramsar site. Jaensch *et al.* (1988) also noted that the lake was potentially suitable for breeding by the Australasian Bittern, herons and other ducks.

Table 25: Requirements of waterbirds recorded breeding at Lake McLarty (adapted from Jaensch 2002; Birds Australia 2005).

SPECIES	BREEDING BEHAVIOUR/NESTING SITES
Australian Shelduck	Typically nests in dead trees in hollows Ducklings leave the nest after 2 days by dropping to the ground First flight at approximately 8 weeks
Black Swan	Nest mound built in open water or in swamp vegetation Requires minimum water depth of 30–50 cm until cygnets are independent First flight 20–25 weeks
Grey Teal	Typically nest in a tree hollow Ducklings leave the nest soon after hatching by dropping to the ground. First flight at approximately 8 weeks
Pacific Black Duck	Typically nest in a tree hollow Ducklings leave the nest soon after hatching by dropping to the ground. First flight at approximately 8 weeks
Musk Duck	Nest in dense reeds over water
Red-capped Plover	Nests in scrape made in sand or mud Young leave nest within one day and self fed, require vegetation for cover
Great Crested Grebe	Nest on floating mound of aquatic vegetation Young leave the nest soon after hatching and can dive after approximately 1 week
Eurasian Coot	Nests in or over water in vegetation (shrubs, trees, sedges) or in a partly floating mound Young leave nest soon after hatching, but are dependant on adults for approximately 5 weeks
Purple Swamphen	Nest in clumps or beds of reeds, sedge or *Typha*, over water Young leave the nest after a few days, but are fed by adults for 2 months
Dusky Moorhen	Nests in clumps of reeds, sedge or *Typha* over water, or in floating aquatic plants Young leave the nest after 3–4 days, use nursery nests and are dependant on adults for 4 weeks
Spotless Crake	Nests in swamps over water in dense to open beds of tall sedge, rush or *Typha*, or in inundated shrub thickets infused with sedge Hatchlings leave the nest in 1–2 days and are able to swim
Little Pied Cormorant	Nest in vegetation (shrubs, trees, dead trees) over water Require inundation to continue for length of breeding Young remain in nest until maturity (approximately 10 weeks)
Darter	Nests in horizontal branches and forks of trees (Eucalyptus or Melaleuca) in or over water Requires water to remain until nestlings fledge Hatchlings leave nest after 4 weeks, first flight at approximately 8 weeks
Black-fronted Plover	Nests in a scrape on the ground close to water Young leave nest within a few days and first flight at 3 to 4 weeks

3.5 LAKES GOEGRUP AND BLACK

These wetlands are not yet a part of the Peel-Yalgorup Ramsar site, but are the major component of a planned extension. As such a description of their ecological character has been included. However, unlike the other systems detailed above, the description for these wetlands "at the time of listing" is synonymous with current condition. The key components and processes for Lakes Goegrup and Black are summarised in Table 26 and described in sections 3.5.1 to 3.5.5 below.

Table 26: Critical ecosystem components and processes of Lakes Goegrup and Black.

COMPONENT	SUMMARY DESCRIPTION
Geomorphology	Riverine wetlands on the Serpentine River Goegrup within the river Black connected to Goegrup by a narrow channel
Hydrology	Highly seasonal freshwater inflows predominantly from river flows Tidal influence from the Indian Ocean via the Peel Inlet
Water Quality	Seasonal cycle of salinity High concentrations of nutrients Low dissolved oxygen concentrations
Flora	High phytoplankton biomass Samphire at low elevations in the littoral zone Paperbark communities at high elevations
Fauna	Data deficient Supports waterbirds

3.5.1 GEOMORPHOLOGY

Lakes Goegrup and Black are riverine wetlands on the Serpentine River approximately 5 km upstream of the discharge to the Peel Inlet. Goegrup Lake spans the main channel of the Serpentine River and is connected to the adjacent Black Lake, by a narrow secondary channel (Figure 33). Black Lake is actually the local name given to a series of lakes comprising of Black Lake (proper), Wolyanup, Bulbiba and Road Lakes.

3.5.2 HYDROLOGY

The Serpentine River is the main source of surface water for the Lake Goegrup. This river flows through predominantly agricultural catchments before entering the Peel Inlet. The flow is highly seasonal with peaks in winter and spring (see section 3.2.2 above). With the opening of the Dawesville Channel, the tidal range of the estuary has increased and Goegrup and Black Lakes are under tidal influence. As a consequence the lakes are permanent with tidal fluctuations in water level.

Black Lake also receives water from Nambeelup Brook, which flows into the wetland from the north east. The narrow channel connecting Black Lake to Goegrup restricts tidal movement and although there is still some tidal exchange, Black Lake water levels fluctuate seasonally.

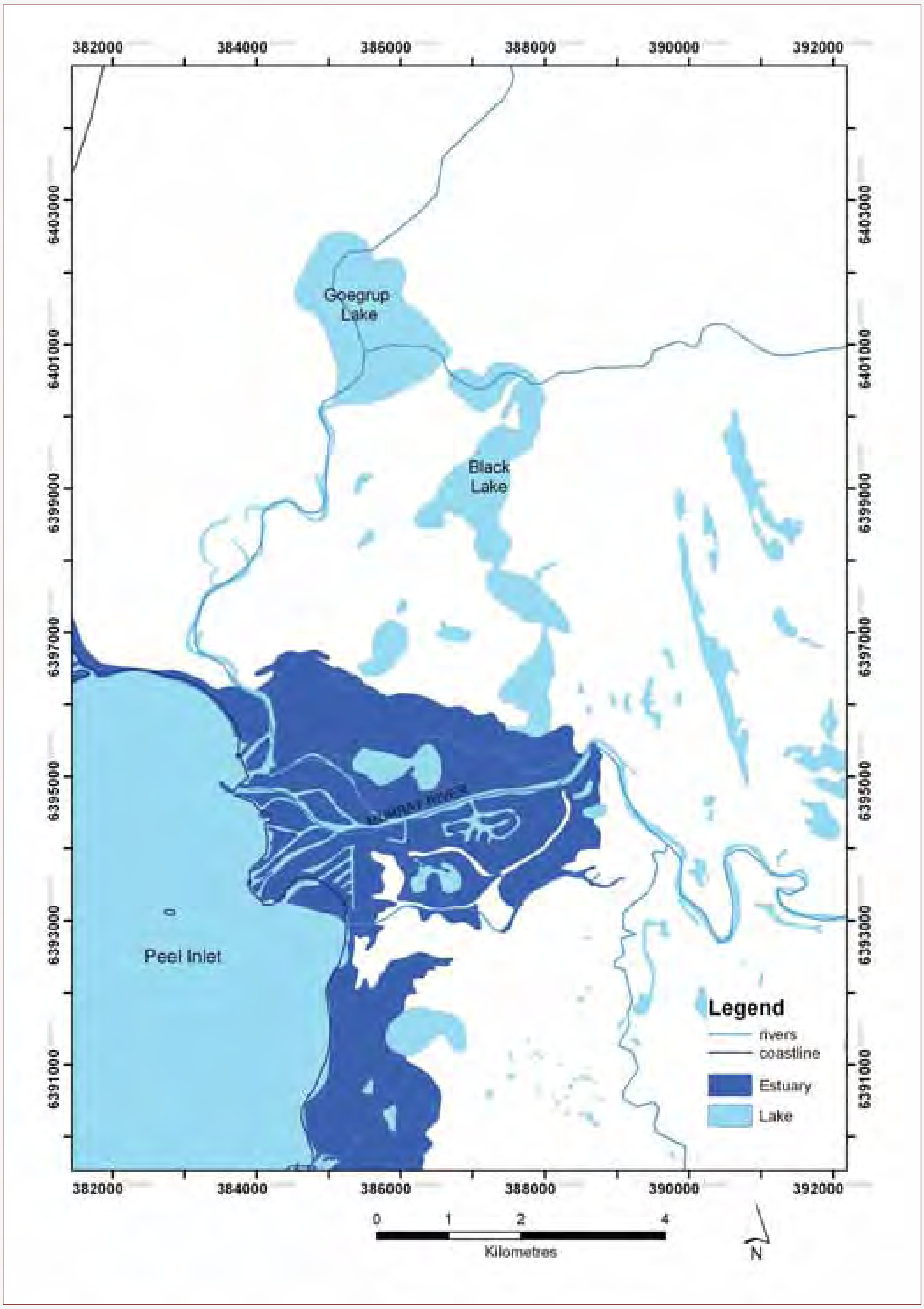

Figure 33: Location of Lakes Goegrup and Black.

3.5.3 WATER QUALITY

Water quality in the lakes has not been monitored, however, the water quality monitoring program from the Serpentine River includes a site located at the upstream edge of Lake Goegrup (DoW 2007). Results from this program indicate that salinity varies considerably throughout the year in response to the variability in river flow. During winter when freshwater flows from the river dominate, salinity is fresh (< 0.5 ppt). However, the influence of the tide and the decreased river flow during summer leads to hypersaline conditions with salinity > 50 ppt. The water column is generally neutral to alkaline (pH 7–8.5) with no obvious seasonal pattern. Dissolved oxygen concentrations are typically low (< 65 % saturation) throughout the year. The exception to this is during conditions of high phytoplankton biomass (see below).

Nutrient concentrations also vary seasonally in response to river flows. During summer when tidal influence is the dominating hydrological factor, nutrient concentrations are low; peak concentrations are reached during winter and spring. Results form monitoring in 2005–2006 indicated nitrate-nitrite concentrations ranging from < 10 µg /L in summer to 300 µg /L in August 2006. Ammonium concentrations ranged from 10 µg /L to 530 µg /L and phosphate from < 5 µg /L to 230 µg /L. Concentrations of total nitrogen and phosphorus were linked to both phytoplankton biomass as well as river flow and ranged from 900 µg /L to 2500 µg /L for total nitrogen and 20 µg /L to 430 µg /L for total phosphorus.

3.5.4 FLORA

Phytoplankton

Phytoplankton blooms are common in the lower Serpentine River and patterns of winter blooms of diatoms followed by summer blooms of *Nodularia* have been recorded (WRC 2004). The monitoring from the site the upstream end of Lake Goegrup (2005–2006) indicated relatively high cell counts of phytoplankton (> 10,000 cells per ml) for much of the year. Blooms (> 20,000 cells per ml) are recorded during winter/spring and summer autumn. For example, an autumn bloom (> 600,000 cells per ml) dominated by green algae was recorded in April 2005 and a winter bloom of diatoms (170,000 cells per ml) was recorded in June 2006 (DoW 2007). In addition the toxic cyanobacterium Lyngbya has been recorded in bloom proportions at both Goegrup and Black Lakes.

In December 2006 Lyngbya covered approximately 75% of the surface area of Lake Goegrup. This was present as floating mats in January and February and then sunk to the bottom of the lake where it decomposed, resulting in deoxygenation of the water column. The triggers for bloom formation have yet to be determined but there are high levels of nutrients within the lake and temperature and salinity changes may also be contributing factors (DoW, in prep.).

Littoral vegetation

There are three wetland vegetation complexes present at Lakes Goegrup and Black, with zonation in response to water regime (Figure 34, Table 27). The Samphire community is similar to that described above for the Peel-Harvey Estuary and occupies the lowest elevation, being regularly inundated by the tidal regime. The saltwater paperbark community sits higher in the landscape and is inundated less frequently. Finally, the freshwater paperbark is located at the highest elevations of the inundation tolerant vegetation. It is likely that this community is inundated only during winter when river flow is high and salinity is low.

Table 27: Wetland vegetation of Goegrup and Black Lakes, September 2006 (Ecoscape 2006).

DESCRIPTION	AREA (HA)
Samphire flats of *Sarcocornia quinqueflora, Halosarcia syncarpa* and *Suaeda australis*	82.8
Scattered *Eucalytpus rudis* over Low Open Forest of *Melaleuca cuticularis, Melaleuca rhaphiophylla, Casuarina obesa, Acacia saligna* over Sedgeland of *Baumea Juncea, Juncus krausii*	144.6
Low Closed Forest of *Melaleuca rhaphiophylla* over Open Herbland of *Conostylis aculeata, Dasypogon bromeliifolius*	47.2

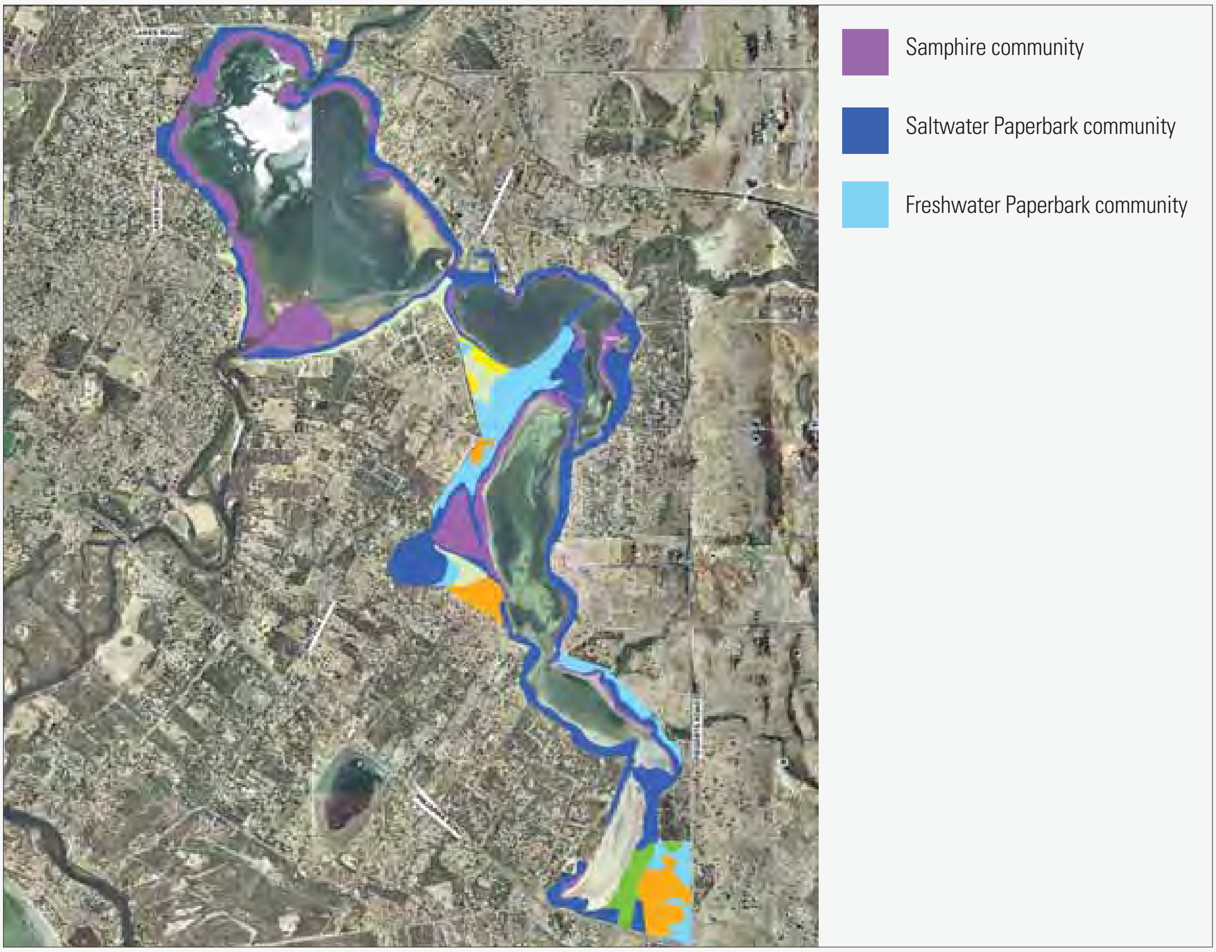

Figure 34: Littoral vegetation at Goegrup and Black Lakes (adapted from Ecoscape 2006). Note additional colours represent terrestrial vegetation communities.

3.5.5 FAUNA

Invertebrates

Data on aquatic invertebrates at Lake Goegrup samphire is reported in Keally *et al.* (1995) and is the only invertebrate data sourced for Goegrup and Black Lakes. Of the salt marshes surveyed in the study, the site at Lake Goegrup showed very low abundances across all zones of the salt marsh and also relatively low species richness. Species recorded at Lake Goegrup included *Hydracarina*, oligochaetes, *Corixidae* water boatmen and a beetle. Oligochaetes were the most abundant taxa encountered in summer 1993/94 (Keally *et al.* 1995).

Fish

The fish fauna of Lake Goegrup between 1979 and 1981 is documented in Loneragan *et al.* (1986). They recorded 17 species of teleosts, including *Pelates sexlineatus, Apogon rueppellii, Gerres subfasciatus, Hyperlophus vittatus, Aldrichetta forsteri, Favonigobius lateralis, Atherinosoma elongate, Atherinomorus ogilbyi, Sillago schomburgkii, Atherinosoma wallacei, Nematalosa vlaminghi, Amniataba caudavittatus, Mugil cephalus, Pseudogobius olorum, Hyporhamphus regularis, Allanetta mugiloides, Atherinosoma presbyteroides* and *Acanthopagrus butcheri.* Both mean density and biomass of species was higher in the dry season compared to the wet. They found several other species approximately 4 km downstream of the lake in the Serpentine

River. Loneragan *et al*. (1987) recorded a further four species from Lake Goegrup utilising different capture methods, these included *Cnidoglanis macrocephalus, Argyrosomus hololepidotus, Engraulis australis* and *Rhabdosargus sarba.*

Loneragan *et al*. (1981) also report on the salinities in Lake Goegrup and note that during the wet season salinities are significantly lower than sites in the estuaries proper. Loneragan *et al.* (1987) noted that halocline formation in Lake Goegrup tended to be restricted to between May and November and that salinity has a pronounced influence on the diversity of species, with fewer species occurring when salinities become reduced.

Birds

Goegrup and Black Lakes support moderate numbers of waterbirds, with 52 species recorded from two sampling periods (Bamford and Wilcox 2003) (Table 28). This includes 13 species that are listed under international migratory agreements (JAMBA and CAMBA) and an additional 15 Australian migratory species protected under the EPBC Act (Appendix B).

Anecdotal evidence suggests that the Lakes act as a refuge for waterbirds during high tides in the Peel-Harvey Estuary (Lo Conte and O'Connor 2006). Data from 1988/89 and 2000/2001 are the main source of information on waterbirds for the lakes (Bamford and Wilcox 2003). In the 1988/89 sampling period the most abundant species were the Eurasian Coot, Grey Teal, Red-necked Avocet and Australian Shelduck all with counts over 300 individuals (Bamford and Wilcox 2003). Total counts of waterbirds at Black Lake in November 1988 recorded 2616 birds (Halse *et al.* 1990).

Table 28: Number of waterbirds recorded within Lakes Goegrup and Black.

WATERBIRD GROUP (NUMBER WITHIN RAMSAR SITE)	TYPICAL FEEDING AND FORAGING INFORMATION	NUMBER OF SPECIES
Ducks and allies (12)	Shallow or deeper open water foragers Vegetarian (Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	11
Grebes (3)	Deeper open waters feeding mainly on fish	3
Pelicans, Cormorants, Darters (7)	Deeper open waters feeding mainly on fish	6
Heron, Ibis, Egrets (13)	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	7
Hawks, Eagles (3)	Shallow or deeper open water on fish and occasionally waterbirds, and carrion	3
Crakes, Rails, Water Hens, Coots (8)	Coots in open water; others in shallow water within cover of salt marsh. Omnivores	2
Shorebirds (43)	Shallow water, mudflats and salt marsh Feeding mainly on animals (invertebrates)	15
Gulls, Terns (12)	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats	5
Total		52

Four species were recorded breeding at Goegrup and Black Lake: Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal. Bamford and Wilcox (2003) suggested that this is not a complete list as observations were opportunistically collected. It is assumed the site is important for breeding with the fringing vegetation offering sites for nesting and foraging. Black Lake may be the more favoured of the two lakes for waterbird breeding as it is less affected by the tidal influences (Bamford and Wilcox 2003). Black Swan cygnets and juveniles were found at three sites, mainly samphire (mixed species) and marsh club-rush (*Bolboschoenus caldwellii*) and some patches of sea rush (*Juncus kraussii)* with fringing vegetation a mixture of sheoak (*Allocauarina obesa)* and melaleucas. Australian Shelduck adults with dependent young were observed at one site with dense stands of *Sarcocorina quiniqueflora* surrounded by *Bolboshoenus caldwellii*, *Juncus kraussii* and fringing sheoak and *M. cuticularis.* Black Duck young were observed at two sites and breeding at a third within similar vegetation associations as the swans and shelduck. Grey Teal juveniles were observed at one site on Black Lake.

4. CHANGES IN THE ECOLOGICAL CHARACTER OF THE PEEL-YALGORUP: CURRENT STATE OF CRITICAL COMPONENTS AND PROCESSES

4.1 SIGNIFICANT CHANGES

The Peel-Yalgorup site was first listed under the Ramsar convention as a wetland of international importance in 1990. Since that time there have been a number of changes in the surrounding catchment and to the wetlands. There has been a substantial increase in the population of Mandurah, which has nearly doubled to around 70,000 people since the time of listing and is expected to reach 150,000 by 2025. This has put increased pressure on the wetlands in the Ramsar site in terms of recreational use, nutrient and contaminant loads, groundwater extraction and urban development, including the development of canals within the estuary. All of these have the potential to impact on the ecological character of the site and are discussed in the relevant sections below.

However, the single most influential factor was the construction of the Dawesville Channel, which was opened in April 1994. The Dawesville Channel was one component in a three part strategy designed to address the problems of eutrophication in the estuary. The three actions were (Peel Inlet Management Authority 1994):

1. Reduction of nutrient run-off from the catchment;
2. Continued harvesting of macroalgae as necessary; and
3. Increased flushing to the ocean.

The third of these was achieved by the construction of the Dawesville Channel, which connects the estuary to the Indian Ocean near the junction of the Peel Inlet and Harvey Estuary. The increased flushing provided by the Channel, together with the long-term strategy of nutrient reduction in the catchment, was predicted to eliminate *Nodularia* blooms, increase dissolved oxygen concentrations, improve water clarity and stabilise salinity (Peel Inlet Management Authority 1994). The Channel is 2.5 km long, 200 m wide and between 4.5 and 6.5 m deep and has associated canal developments that have been constructed over the last 15 years (Figure 35).

The increased connection to the marine environment has resulted in fundamental and permanent changes to ecological components of the Peel-Harvey Estuary. Attributes such as hydrology and water quality have changed significantly and had effects on the biotic components of the system. While there can be no doubt that the Peel-Yalgorup remains a wetland of international importance and that it continues to meet the Ramsar criteria under which it was listed (Lane *et al*. 2002), management of the system must be consistent with this new environment. For this reason, the ecological character description based on current conditions, detailed below, is the benchmark against which future change should be measured.

Figure 35: Aerial image of the Dawesville Channel.

4.2 PEEL-HARVEY ESTUARY

The key changes to the ecological character of the estuarine component of the Peel-Yalgorup Ramsar site are summarised in Table 29 and described in sections 4.2.1 to 4.2.9 below.

Table 29: Critical ecosystem components and processes of the Peel-Harvey Estuary that have changed since 1990.

COMPONENT	SUMMARY DESCRIPTION
Geomorphology	Dawesville Channel
Hydrology	Increased exchange with the Indian Ocean Changed tidal regime
Water Quality	Nutrient concentrations in the water column decreased Salinity conditions more marine (temporally and spatially) Stratification reduced
Acid Sulfide Soils	Monosulphidic black ooze Exposed via dredging Selenium risk
Phytoplankton	Decreased phytoplankton biomass No *Nodularia* blooms recorded in the Harvey Estuary
Benthic Plants	Decreased macroalgal biomass Increased extent of seagrass
Littoral Vegetation	Changes to samphire – data deficient Deterioration of tree health in the Harvey Estuary
Fish	Increase in marine species Decrease in Cobbler Possible decrease in estuarine species
Birds	No evidence of change in abundance or diversity

4.2.1 HYDROLOGY

Hydrological aspects such as rainfall, evaporation, river inflows and groundwater influences have not changed as a result of the Dawesville Channel. As such the descriptions of these aspects contained in section 3.2.2 above also reflect current conditions. The Dawesville Channel, however, has had a significant effect on the tidal regime of the Peel Inlet and Harvey Estuary.

The movement of water through the Dawesville Channel now dominates tidal exchange in the estuary. It was predicted that the average residence time would reduce from 30 days to 10 days in the Peel Inlet and from 40–50 days to 17 days in the Harvey Estuary (Ryan, 1993). It also was predicted that tidal exchange between the Peel Inlet and the Indian Ocean through the Mandurah Channel and between the Peel Inlet and Harvey Estuary through Grey Channel would increase (Table 30). Average tidal exchange was expected to remain highest in winter with the influence of river flows, but the magnitude of this seasonal difference would be reduced (DAL, 1997). Where summer residence times were approximately 5 times longer than those in winter prior to the opening of the Channel there is now < 10 % difference between seasons.

Modelled tidal current velocities through the Dawesville Channel indicated average peak currents for flood tides of 1.13 m/s and 1.13 m/s for ebb tides and maximum flood and ebb tidal velocities of 1.90 m/s and 1.85 m/s, respectively (Ryan, 1993). Observed maximum flood and ebb tidal currents through the Dawesville Channel have been higher than those predicted at 2.17 m/s and 2.90 m/s, respectively (DAL, 2002).

Table 30: Modelled water exchange (ML) per tidal cycle through the channels of the Peel-Harvey Estuary (adapted from DAL 1997).

CHANNEL	BEFORE THE DAWESVILLE CHANNEL	AFTER THE DAWESVILLE CHANNEL
Mandurah	55,000	63,000
Grey	35,000	64,000
Dawesville		156,000

The increased tidal exchange through the Dawesville Channel has also affected the tidal levels within the estuary. Model predictions indicated that the maximum water level would increase and the minimum water level decrease, such that the tidal range is much larger (Table 31). The tidal range has changed from an average of approximately 10 cm for both the Peel Inlet and Harvey Estuary to approximately 32 cm for the Peel Inlet and 45 cm for the Harvey Estuary some 6 cm higher than predictions (DAL 2002). In addition, there has been a phase change such that the Harvey Estuary now experiences high tide approximately 45 minutes before the Peel Inlet.

Table 31: Model predictions of water levels in cm above Australian Height Datum, AHD (% change from pre-Dawesville Channel) in the Peel-Harvey after the opening of the Dawesville Channel (adapted from Ryan 1993).

DESCRIPTION	PEEL INLET	HARVEY ESTUARY
Maximum Level	64 (11%)	65 (12%)
Mean High High Water Level	14 (9%)	17 (12%)
Mean Water Level	-1 (-1%)	-2 (-2 %)
Mean Low Low Water Level	-14 (-9 %)	-21 (-17%)
Minimum Level	-48 (-8%)	-61 (-21%)

This increase in tidal range has resulted in changes to the intertidal areas around the estuary. The intertidal zone is now broader than it was and upper intertidal areas are submerged more frequently but for a reduced duration, while lower areas are inundated less frequently for increased periods (DAL 2002).

Prior to the opening of the Channel, extreme water levels were predominantly due to river flows and floods. It was predicted that the Channel would result in decrease flooding from catchment inflows due to the increased drainage to the ocean. However, it was also predicted that storm surges from the ocean would have a more dramatic effect on water levels within the estuary. In 2002, DAL reported that there had been no observed changes in extreme water levels in the estuary following the opening of the Channel.

4.2.2 WATER QUALITY

Salinity

Salinity in the Peel-Harvey Estuary is currently more stable and more marine than it was at the time of listing. Salinity is generally higher in surface and bottom waters with average salinity approximately 30 ppt. There are still seasonal trends in salinity with freshwater inflows from the rivers during the winter months. However, salinity rarely drops below 10 ppt in surface waters or 20 ppt near the bottom in the centre of the basins. As freshwater inflows decrease after winter, salinity rapidly returns to marine levels of 35 ppt, although hyper-saline concentrations of > 45 ppt are still regularly recorded in the summer (Figure 36 and Figure 37).

During winter months when freshwater inflows are highest, there is a gradient between in salinity from the areas of the estuary near the river mouths and the areas near the channel connections to the ocean (Figure 38). There are still instances of salinity stratification, however, they are of generally of short duration.

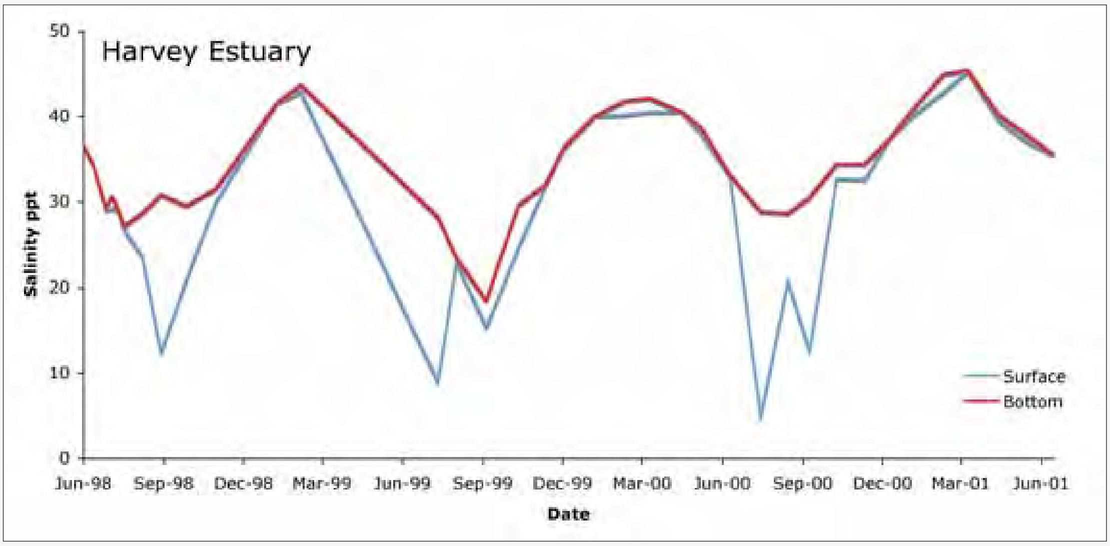

Figure 36: Typical seasonal pattern of salinity in the Harvey Estuary (centre site, June 1998 to June 2001; data from Kobryn et al. 2002).

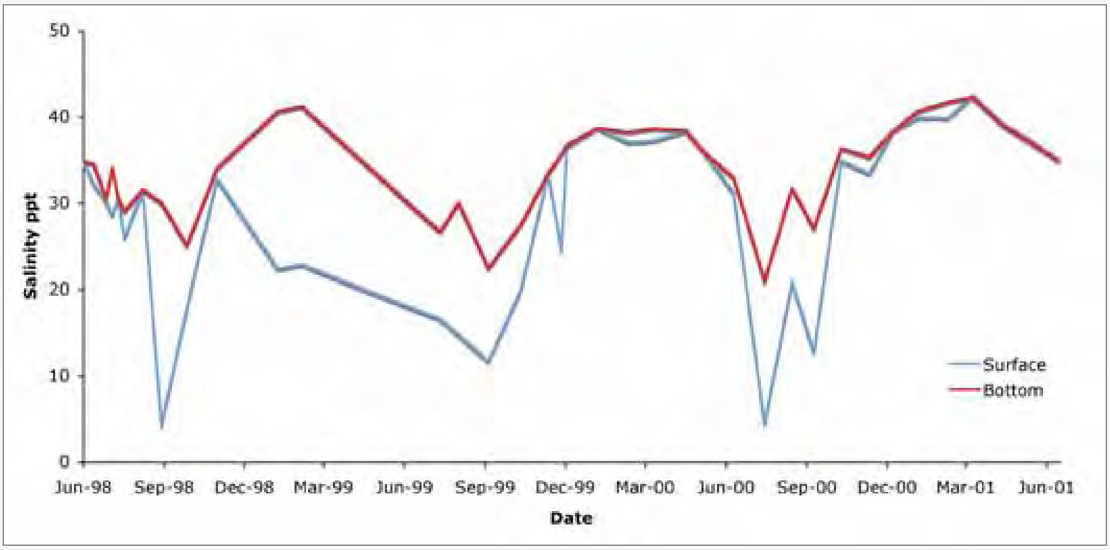

Figure 37: Typical seasonal pattern of salinity in the Peel Inlet (centre site, June 1998 to June 2001; data from Kobryn et al. 2002).

Dissolved Oxygen

The Peel-Harvey Estuary is generally well oxygenated and well mixed as a result of the shallow water and high winds. Typically dissolved oxygen concentrations are > 8 mg/L and > 90% saturation (PH CD ROM and DoW 2007). The extended periods of oxygen stratification that were a characteristic of the system at the time of listing have greatly reduced, particularly during summer (Hale and Paling 1999). The increased flushing and corresponding decrease in eutrophic conditions and phytoplankton growth (see below) are likely contributing factors. While lower river reaches are often very low in dissolved oxygen (< 5 mg/L and < 50 % saturation) with incidences of extreme deoxygenation (< 1 mg/L; < 20 % saturation), this is not reflected in the water column of the estuarine areas (data from DoW 2007).

Salinity stratification is still common in winter months and this leads to periods of decreased oxygen in bottom waters. Data collected from 1995 to 2001 indicate that this was more common at sites closest to river inflows. However, this was only recorded on one occasion between January 2005 and December 2006 in the centre of the Peel Inlet (DoW 2007).

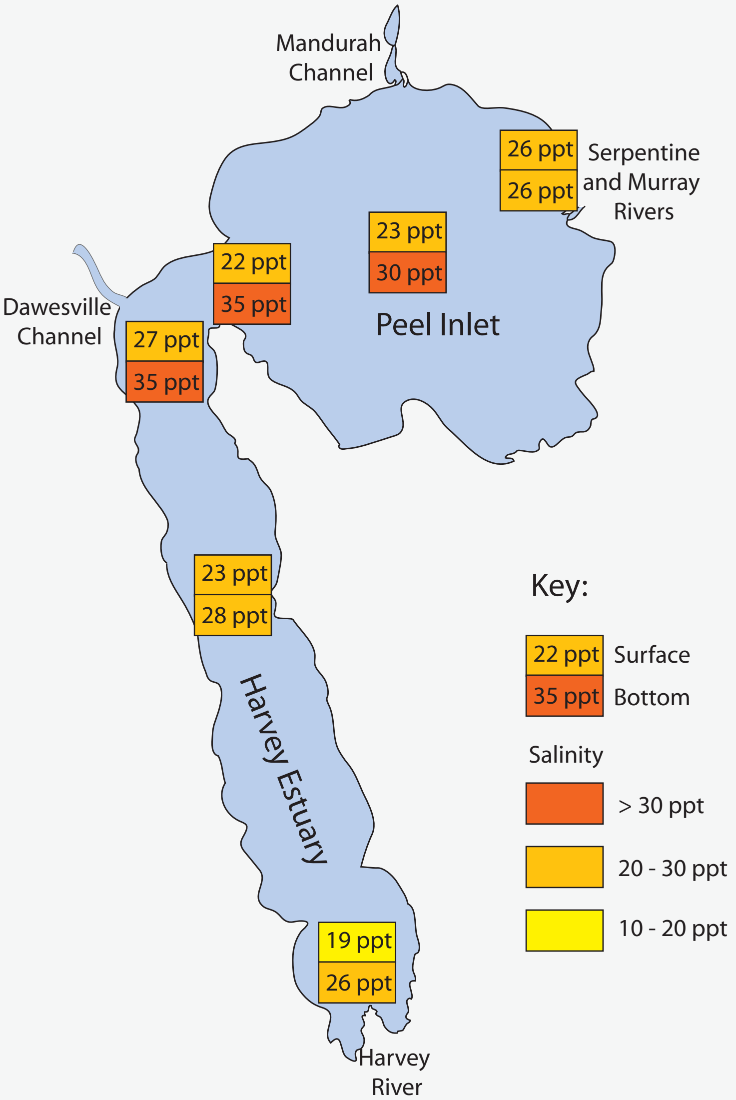

Figure 38: Spatial variability in salinity across the Peel-Harvey during winter (August 2006, data from DoW 2007)

Water Clarity

Water clarity has improved since the opening of the Dawesville Channel and light penetration is typically to the bottom, especially in areas adjacent to the Channel. In addition, increased flushing and decreased phytoplankton biomass in the Harvey Estuary has resulted in similar conditions in both basins. However, the effects of turbid freshwater inflows are still evident during winter in areas adjacent to river discharge.

Water clarity is difficult to quantify in the Peel-Harvey Estuary as routine measurements have been made for secchi depth and light attenuation. However, the shallow water depth (< 2m) prevents a true indication of water clarity from secchi depth, as the disc can be visible on the sediment surface in conditions of moderate turbidity. In addition, light attenuation measurements over short distances (< 2 m) are also subject to substantial errors (DoW 2007). Recent monitoring has also included measurements of turbidity, however at reduced frequency (9–15 samples per year). These results indicate clear water (< 5 NTU) during most of the year across both basins. The exception to this in the Harvey Estuary near to river inflows where winter turbidities were generally 15–20 NTU as a result of turbid water inflows and a summer phytoplankton bloom in January 2005 resulted in extreme turbidity of > 400 NTU (DoW 2007).

Nutrients

The strategy to reduce nutrients in the Peel-Harvey Estuary included actions to increase dilution (the Dawesville Channel) and reduce nutrient inputs (catchment management actions). However, while the first of these has certainly occurred, there is no evidence that there have been significant reductions in nutrient inputs to the system. Phosphorus was identified as the nutrient limiting algal growth and total loads from the catchment of phosphorus remain high and are in fact greater than those at the time of listing (Table 32). While load data for nitrogen is not available there is evidence from measurements of water column concentrations that there has been no trend in nitrogen reduction from the catchment (URS 2007). As such it can be expected that total nitrogen loads remain in the order of 1,200 tonnes per annum.

Table 32: Current total phosphorus loads to the Peel-Harvey Estuary (DEH 2006).

SOURCE	TOTAL PHOSPHORUS (TONNES/YEAR)
Serpentine River	69
Murray River	15
Harvey River	61
Total	**145**

Peak concentrations in nutrients in the estuary are a result of river inflows during winter and spring months and these remain similar to those recorded at the time of listing. Inorganic phosphorus (PO_4) concentrations are highest in winter and in areas adjacent to river inflows. Mean (± standard deviation) PO_4 concentrations in the Peel Inlet and Harvey Estuary during winter range from 55 (± 70) µg/L in areas closest to the rivers to 17 (± 25) µg/L adjacent to the Channel (1995–1999, Hale and Paling 1999). Peak concentrations of > 250 µg/L have been recorded during winter in both basins in the last decade. Summer concentrations of PO_4 remain low and are typically < 10 µg/L.

Concentrations of nitrate-nitrite follow a similar pattern with highest mean concentrations recorded during winter and adjacent to river inflows. Mean (± standard deviation) winter nitrate-nitrite concentrations are approximately 140 (± 150) µg/L in the Harvey Estuary and 230 (± 350) µg/L in the Peel Inlet (1995–1999, Hale and Paling 1999). Peak concentrations > 2000 µg/L have been recorded in the Peel Inlet during winter. Summer concentrations of nitrate-nitrate are typically low and < 10 µg/L.

Ammonium concentrations are also higher in winter than summer and mean winter concentrations are approximately 115 (± 130) µg/L in the Harvey Estuary and 75 (± 80) µg/L in the Peel Inlet (1995–1999, Hale and Paling 1999). Peak winter concentration > 400 µg/L have been recorded in both basins. Summer ammonium concentrations are significantly lower than at the time of listing and are typically < 10 µg/L. This is due to the reduced incidence of oxygen stratification and a corresponding reduction in sediment nutrient release.

Recent investigations of sediment-water nutrient relations in the Peel-Harvey Estuary indicated that aerobic oxidation processes dominate (Longmore and Nicholson 2007). This results in efficient denitrification and conversion of inorganic, bioavailable forms of nitrogen into nitrogen gas, which is lost from the system. In addition, phosphorus release from the sediment is also low as a result of well oxygenated sediment-water interfaces.

Concentrations of organic forms of nitrogen and phosphorus are significantly lower than at the time of listing. This is most likely due to the reduction in phytoplankton biomass in the system. Mean concentrations of organic phosphorus remain similar year round and are between 40 and 50 µg/L. Average concentrations of organic nitrogen are higher in winter (500–600 µg/L) than in summer (300–400 µg/L). Peaks of organic nutrients still occur, most often during spring and summer algal blooms with concentration of organic phosphorus > 300 µg/L and organic nitrogen > 2000 µg/L recorded in the last decade.

4.2.3 ACID SULFATE SOILS

Acid sulfate soils (ASS) form in coastal and estuarine environments where water-logged soil provides ideal conditions for the build up of mineral iron pyrite (FeS_2). Left undisturbed, ASS are benign, but disturbance exposes sulphidic compounds in the soil to air and results in the formation of sulphuric acid. Further effects are caused by the action of the acid on other elements in the soil, which includes the production of high concentrations of toxic metals (Hicks *et al*. 1999).

Regional mapping by the Department of Environment and Conservation has identified more than 11,500 ha in the Peel Region that is likely to contain ASS (Sullivan *et al*. 2006), which is predominantly in and around the Peel Inlet. Sampling conducted in canals around the Peel Inlet in 2006 indicated that concentrations of iron pyrite were high in the black organic mud (monosulphidic black ooze, MBO) found around the canal developments (Sullivan 2006). These sediments have a high potential for the production of sulphuric acid if disturbed and potentially for the release of bound contaminants.

Concentrations of most metals and toxicants in the sediments sampled were low. However, sediments with high concentrations of iron pyrite also contained very high levels of selenium. Concentrations as high as 5.4 mg/kg recorded in the sediment and 200 µg/L in pore waters (Sullivan *et al*. 2006). Although selenium is a naturally occurring element and an essential trace mineral for biota, it has the potential to bioaccumulate and in high concentrations can cause reproductive and immune dysfunction in fauna (US Department of the Interior 1998). Concentrations recorded in the Peel Inlet sediments are within the ranges known to cause such effects (Table 33).

Table 33: Selenium concentrations of environmental concern in water and sediment

MEDIUM	"NO EFFECT" LEVEL	LEVEL OF CONCERN	TOXICITY THRESHOLD
Water (total recoverable Se)	<1 µg/L	1–2 µg/L	>2 µg/L
Sediment	<1 mg/kg	1–4 mg/kg	>4 mg/kg

While it is certain that there is increased awareness of acid sulfate soils and metals in the sediments of the Peel Inlet, it is unknown if this is a change since the time of listing.

4.2.4 PHYTOPLANKTON

The reduction in nutrient concentrations within the water column has had a dramatic effect on phytoplankton in the system. Large prolonged algal blooms are no longer a common feature within the estuary and cyanobacteria comprise a minor part of the phytoplankton community. Data collected in 2005 and 2006 (DoW 2007) indicate that the phytoplankton populations are generally diverse. Diatoms are still a major component, but cryptophytes are more often dominant, particularly species of the marine genus *Plagioselmis*.

In February 2006, the raphidophyte *Heterosigma akahiwo* was the dominant phytoplankton taxa near the river inflows in the Peel Inlet. This is a marine species that is known to be directly toxic to fish, but not to humans. However, at 700 cells/ ml it was unlikely to be in sufficient density to cause ecological harm.

Algal blooms still occur on occasion in the estuary, but there have been no incidences of *Nodularia* blooms since the opening of the Dawesville Channel in 1994. It is suspected that the increased salinity is sufficient to prevent germination of akinetes. Winter blooms of the non-toxic marine dinoflagellate *Heterocapsa triquetra* occurred in the Harvey Estuary in 1997, 1998, 1999, 2000 and 2001 (DAL 2002) but not in more recent years.

Although no *Nodularia* blooms have occurred in Peel Inlet or Harvey Estuary, they have occurred in the Serpentine River as well as other cyanobacteria such as *Anabaena* and *Microcystis*. There have also been blooms of the potentially toxic dinoflagellate *Alexandrium minutim* recorded in the Murray River (DAL 2002).

Phytoplankton biomass in the Peel-Harvey Estuary is typically < 10 µg/L year round. Mean chlorophyll *a* is higher in winter than summer (the reverse of the situation at the time of listing) and generally slightly higher in the Harvey Estuary than the Peel Inlet. Chlorophyll *a* concentrations of > 100 µg/L have been recorded in both the Peel Inlet and the Harvey Estuary in the last decade mostly during winter months. However, they were typically short lived, lasting for less than a week or so.

4.2.5 BENTHIC PLANTS

The distribution and composition of benthic plants in the Peel-Harvey Estuary was last surveyed in summer of 2000. At this time, the benthic plant community was dominated by seagrass, which comprised 50% of the total biomass (Wilson *et al.* 2000). *Halophila ovalis* was the most common species although both *Ruppia megacarpa* and *Heterozostera* were also recorded. Biomass estimates were 2,568 tonnes (dry weight) in the Peel Inlet and 62 tonnes in the Harvey Inlet.

Prior to the opening of the Channel seagrass biomass senesced in autumn and was dormant over winter when temperature light and salinity restricted growth. Plants would then germinate from seed or rhizomes in spring and reach a peak biomass in summer. The light and salinity in the estuary may be sufficient for seagrass to sustain vegetative forms during winter, although temperature would still inhibit growth. However, there is insufficient information to determine if this happens. Anecdotal evidence suggests that peak biomass is still achieved in summer and that winter inflows of freshwater and nutrients result in increased epiphytic algae (such as *Hinksia*), which smothers seagrass and leads to a decline in their distribution and biomass.

Macroalgal biomass in the Peel Inlet is significantly lower now than at the time of listing. There has been a change in growth and distribution with peak biomass now occurring in spring (as opposed to autumn). In spring 1998 total Macroalgal biomass in the Peel Inlet was nearly 6,000 tonnes (dry weight) and by summer this had decreased to 2,560 tonnes. However, mean biomass over the five year period following the opening of the Dawesville Channel (1994–1999) was approximately 8,000 tonnes in spring and summer and 5,000 tonnes in autumn (Wilson *et al.* 1999).

Macroalgal distribution remains similar to 1990 with the highest biomass around the shallow margins of the Peel Inlet (Figure 39). Green algae (Chlorophyta) are the dominant taxonomic group and *Chaetomorpha* dominates the macroalgal community in the Peel Inlet, comprising 50–70% of the total biomass (Figure 40). Other genera recorded include members of the Rhondophyta (red algae) such as *Gracilaria*, *Spyridia, Ceramium*, *Polysiphonia*, *Laurencia;* Phaeophyta (brown alga) *Hinksia*, *Dictyota* and *Cladosiphon vermicularis* and the Cyanophyta (blue-green algale) *Schizothrix mexicana* and *Microcoleus lyngbyaceus* (Wilson *et al.* 1999). An average of 10–12 species were recorded in each survey.

In November of 2000 a survey conducted by the Aquatic Science Branch, Water and Rivers Commission, found the Cyanophyta *Lyngbya spp.* along the Coodanup foreshore, and in Robert Bay in the Peel Inlet (EPA 2007). However no biomass estimates were made and there is no survey data subsequent to this time.

Although the benthic plant flora is more diverse and lower in biomass than in 1990, mechanical harvesting from the channels in the Peel Inlet still occurs and front end loaders are used on the beaches of the Peel Inlet to remove wrack that washes on shore (J. Pszczola, pers. comm.).

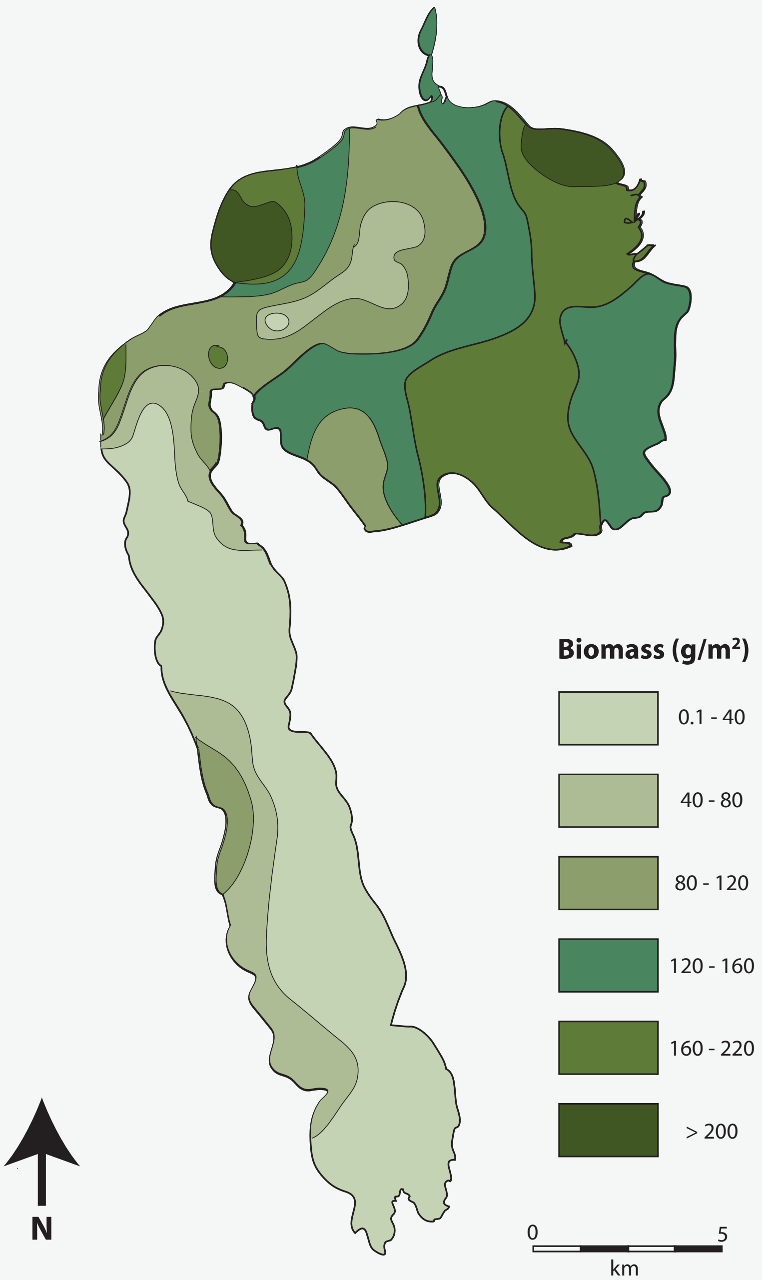

Figure 39: Distribution of macroalgae in the Peel-Harvey Estuary, spring 1998 (adapted from Wilson et al. 1999).

Macroalgal biomass is lower in the Harvey Estuary than the Peel Inlet and follows a different seasonal pattern with peak biomass in summer (approximately 1,500 tonnes). Species composition is also different with *Cladophora* comprising the major proportion of macroalgal biomass during spring and summer (47% and 69%), followed by *Caulerpa* and the combined species of Rhodophyta (Wilson et al. 2000). The brown algae (Phaeophyta) and blue green algae (Cyanophyta) are also components of the macroalgal community in the Harvey Estuary (Figure 41).

The macroalgal biomass recorded in the Harvey Estuary in summer of 2000 was higher than mean macroalgal biomass in this basin at the time of listing. It is possible that the increased salinity and water clarity which has ceased *Nodularia* blooms has provided an ideal habitat for macroalgae, particularly as there has not been a reduction in nutrient loads entering into the system. However, in the absence of more recent data it is not possible to determine if the summer of 2000 was an anomaly or if there is a continuing trend for increased macroalgae in the Harvey Estuary.

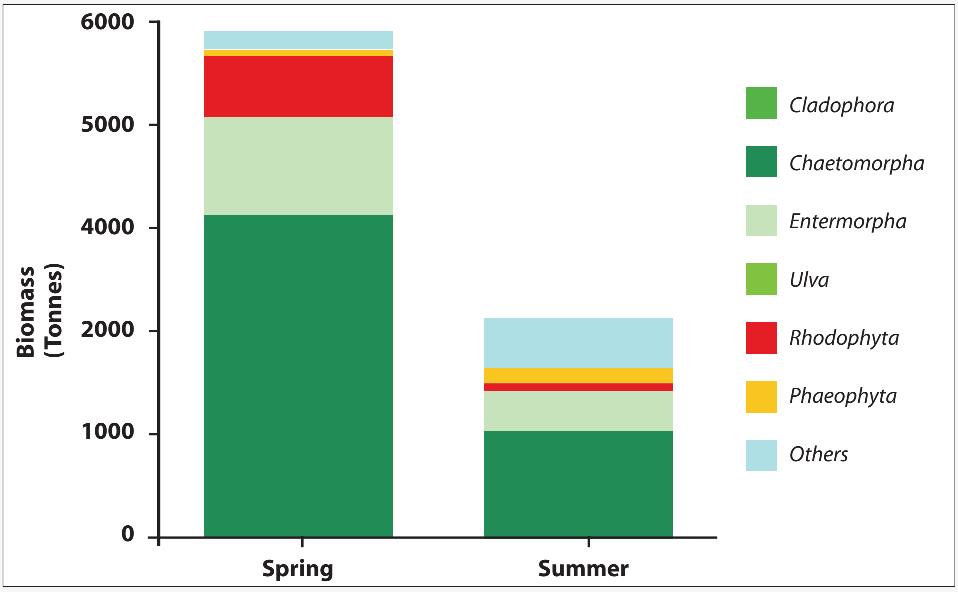

Figure 40: Composition of macroalgae in the Peel Inlet in spring 1998 and summer 1999 (adapted from Wilson et al. 1999).

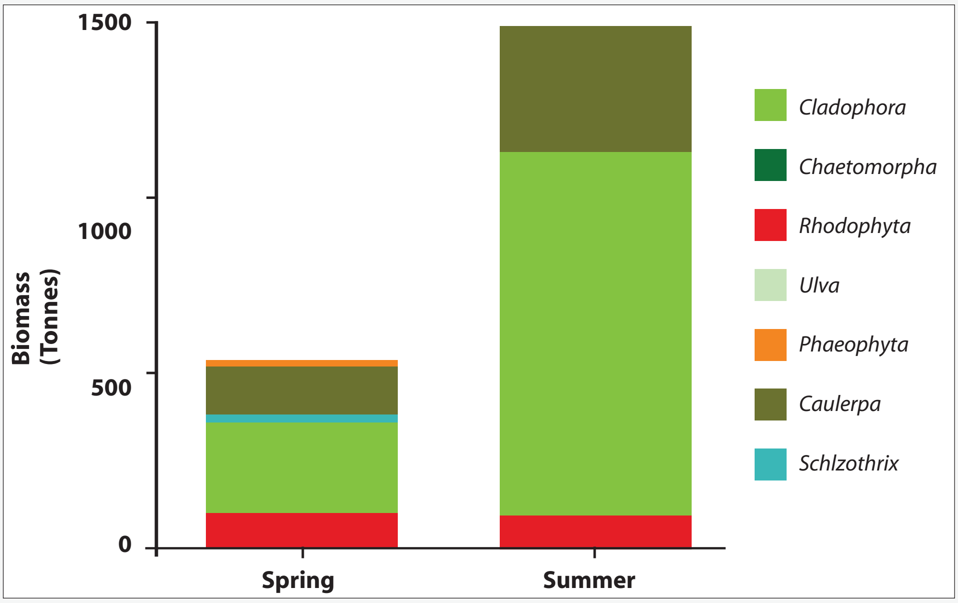

Figure 41: Composition of macroalgae in the Harvey Estuary in spring 1998 and summer 1999 (adapted from Wilson et al. 1999).

4.2.6 LITTORAL VEGETATION

There has been no wide scale mapping of salt marsh extent since 1994 so it is not possible to determine if there have been significant changes in distribution and composition since the time of listing. Surveys of Samphire in the Peel inlet and Harvey Estuary undertaken annually from 1994 to 1998 did not indicate any clear patterns of change with the opening of the Dawesville Channel (Monks and Gibson 2000). It was suggested that 5 years might be insufficient to determine changes in perennial vegetation, especially for communities with a high level of natural variability.

Changes to other littoral vegetation in the estuary have been more marked. Over the period 1994 to 1998 there was a significant decline in the canopy condition of *Melaleuca rhaphiophylla* along the lower Harvey River and a general decline of *Casuarina obesa* at the river mouth (Monks and Gibson 2000). This was attributed to the increasing intrusion of marine water and the corresponding increased salinity.

In addition, Monks and Gisbon (2000) reported widespread decline in the littoral shrubs and trees along the western shoreline of the Harvey Estuary (Figure 42). This has also been attributed to the increased tidal regime and salinity. However, anecdotal evidence suggests that the large changes in littoral vegetation that occurred after the opening of the Dawesville Channel have settled to a new equilibrium in response with current environmental conditions (B. Pond, pers. comm.).

Figure 42: Tree death along the shore of the Harvey Estuary November 2007 (K. Wilson).

4.2.7 INVERTEBRATES

In general benthic invertebrate species richness was predicted to increase as a result of the Dawesville Channel. Invertebrates are sensitive organisms with many species capable of responding to subtle changes in water quality and habitat types. The changes in salinity regime, the absence of *Nodularia* and the decreased frequency and duration of anoxic periods were all predicted to affect the invertebrate fauna. One of the main expectations was that there would be a shift in species among the polychaete worms and molluscs to longer-lived species to those typically found in other less eutrophic estuaries such as Leschenault Inlet and the lower reaches of the Swan-Canning Estuary (DAL 2002). More marine species were expected to dominate the estuarine areas and brackish and freshwater species distribution was expected to contract. Increased tidal range was predicted to create a less extreme environment, particularly in summer, with greater or more frequent inundation of the intertidal zone (DAL 2002).

To date however there has been little investigation of the impacts of the Dawesville Channel on invertebrates within the Peel-Harvey Estuary. The exception is work done on the blue swimmer crab which constitutes a large commercial and recreational fishery. The Peel-Harvey Estuary is the largest fishery for this species in Western Australia with catches in the late 1990s exceeding 200 tonnes in the Peel Inlet and 60 tonnes in the Harvey Estuary (Malseed and Sumner 2001; de Lestang et al. 2003a-c). Studies on the blue swimmer crab, Portunus pelagicus, pre and post the channel show distinct changes that have been attributed to the impacts of the Channel. Density patterns post the Channel being opened were more even from the Mandurah Entrance Channel to the Serpentine River than previously, with densities significantly greater in the Harvey Estuary and Serpentine River than in the 1980s (de Lestang et al. 2003a). Increased fishing pressure was also noted in the months February to May post the Dawesville Channel in the late 1990s with overall low densities recorded throughout the estuary. Overall the hydrological changes caused by the opening of the Dawesville Channel led to changes in density, size composition and early growth of the crab as well as stimulating an earlier emigration of ovigerous females (de Lestang et al. 2003a).

Annual summer studies indicate that the predictions regarding changes in the polychaete fauna appear to have been borne out, with *Capitella capitata* decreasing in abundance, and *Ceratonereis aequisetis, Australonereis ehlrsi* and *Leitoscoloplos normalis* which are longer lived polychaetes occurring in greater numbers. Changes in the abundance of the mollusc *Arthritica semen* were also observed in northern Peel Inlet (Rose, *pers. comm.* cited in DAL 2002). Shifts in spatial and temporal patterns in the benthic invertebrate community have been attributed to increased prevalence of marine conditions in the proximity of the Channel and increased diversity and abundance in the Harvey Estuary have also been reported (Whisson 2000 cited in DAL 2002).

Recruitment of juvenile Western King Prawns and crabs into the Harvey Estuary occurs earlier than it did, due to the decreased duration of freshwater influences on salinity. However, it also seems that these crustaceans are leaving the estuary earlier and at smaller sizes. There is no evidence that this has resulted in a change in the population, as indicated by recreational and commercial fishing catches (Fisheries WA 2005).

Results from the survey work undertaken in the salt marshes in 1993 and 1994 (discussed in section 3.2.7) are not believed to reflect any effects of the Dawesville Channel as the sampling was undertaken before and soon after the Channel was opened. Changes in tidal regimes are expected to affect the vegetation and also inundation patterns in the marshes, however as indicated in section 4.2.6 such changes have not been documented. Changes to invertebrate communities are expected to be greater in the estuary than in the salt marsh areas (Keally *et al.* 1995) but will occur in response to changes in vegetation, inundation pattern, and water quality. This in turn will have implications for the food web structure of the estuary, in particular fish and wading birds, which rely on invertebrates as a major food source. Biotic feedback loops may also come into play, with changes in invertebrate community structure having a feedback on ecological processes such as decomposition, sediment mixing (bioengineering) and nutrient cycles (Keally *et al.* 1995).

The salt marshes of the Peel-Harvey Estuary are breeding ground for two species of mosquito of human health concern *Aedes camptorhynchus* and *Aedes vigila*, These two species are vectors of Ross River Virus and Barmah Forest Virus in the region. Mosquitos are found in large numbers (> 1000 larvae per m^2) and mosquito breeding is strongly linked to climatic and tidal regimes (City of Mandurah, 2007). As such, the change in tidal inundation of saltmarshes following the opening of the Dawesville Channel may have impacted on mosquito populations by providing greater areas of inundated land in which to breed.

However, it is difficult to determine if there has been a change since listing due to the effects of mosquito management which includes multiple aerial sprays of the target specific hormone based Prosand®.

4.2.8 FISH

It was predicted that the increase in salinity as well as the provision of an additional route for passage of fish between the ocean and the estuary (through the Dawesville Channel) would lead to an increase in recruitment of fish which mature or only occur at marine salinities (DAL 2002). In addition, it was expected that although there should be little effect on estuarine fish, species such as sea-mullet, which utilise low salinity water in juvenile stages, were expected to be disadvantaged. Finally, the absence of *Nodularia* blooms was expected to be beneficial to benthic fish, crabs and prawns.

Movement of larvae into and out of the Peel-Harvey Estuary was investigated in 1997 to establish if the Dawesville Channel affected the characteristics of ichthyoplankton on flood and ebb tides. In both the Dawesville and Mandurah channels flood tides carried significantly more species in higher concentrations than on ebb tides. Peaks in concentration occurred in spring and early autumn. Species that spawned in the ocean such as sandy sprat (Hyperlophus vittatus), small toothed flounder (Pseudorhombus jenynsii) and goldlined seabream (Rhabdosargus sarba) were more abundant on the flood tide, and species which breed in the estuary were more abundant on the ebb tide including elongate hardyhead (Atherinosoma elongate), and gobbleguts (Apogon rueppellii) (Young and Potter 2003b). Species composition of the larvae was different in each channel and underwent cyclical changes in both tides and both channels (Young and Potter 2003b).

Young and Potter (2003b) concluded that the fish fauna in shallow waters of the Peel-Harvey Estuary is now dominated by marine species, with 65 % of the species and 70 % of the total number of fishes caught representing marine stragglers and marine estuarine-opportunists (Appendix A). Marine species such as the banded blowfish (*Torquigener pleurogramma*) and sandy sprat (*Hyperlophus vittatus*) increased in abundance and penetrated further south into Harvey Estuary, the latter of these comprising 60% of total fish caught (Table 34). Species that showed declines were those that were associated with the increased algal growths of the 1970s and 1980s such as the six-lined trumpeter (*Pelates sexlineatus)* and gobbleguts (*Apogon rueppellii*) (DAL 2002).

Table 34: Fish composition and abundance in the Peel-Harvey Estuary 1996–97 for species that comprised > 1% of total catch (Young and Potter 2003b).

SPECIES	COMMON NAME	LIFECYCLE	NUMBER	% OF TOTAL
Hyperlophus vittatus	Sandy sprat	Opportunist	42,275	58
Atherinosoma elongata	Elongate hardyhead	Estuarine	8,784	12
Leptatherina presbyteroides		Estuarine & Marine	7,892	11
Torquigener pleurogramma	Weeping toado/banded blowfish	Opportunist	3,931	5.4
Aldrichetta forsteri	Yellow-eye mullet	Opportunist	3,210	4.4
Favonigobius lateralis	Long-headed goby	Estuarine & Marine	2,242	3.1
Apogon rueppellii	Gobbleguts	Estuarine & Marine	1,240	1.7
Atherinomorus ogilbyi	Ogilby's hardyhead	Opportunist	833	1.2
Leptatherina wallacei	Western hardyhead	Estuarine	822	1.1

Total commercial catch has decreased since the time of listing, however, catch per unit effort has remained relatively stable (Figure 43). There has been a significant change in some commercial species. Cobbler (*Cnidoglanis macrocephalus*) catch has decreased significantly from an average catch of 57 tonnes (1976–1999) to 2.3 tonnes (2000–2005) (Fisheries WA 2005). However, there has also been a corresponding decline in the Swan-Canning Estuary for this species, suggesting that the influencing factors may not be site specific. There was a substantial increase in King George Whiting (*Sillaginodes punctata*) during 1996, possibly due to high rainfall and increased breeding opportunities. However, the recruitment cohort matured after 3–4 years and moved off shore, returning numbers to 1990 levels (Fisheries WA 2005).

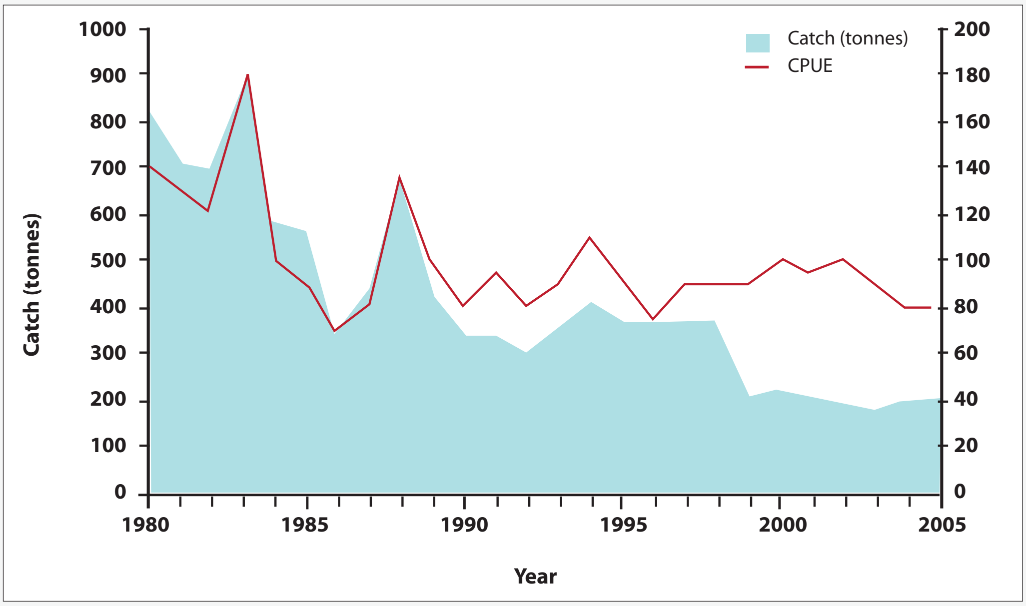

Figure 43: Total Commercial catch and catch per unit effort (CPUE) for the Peel-Harvey Estuary (Fisheries WA 2005).

4.2.9 BIRDS

The Dawesville Channel and associated changes in the abiotic environment were predicted to have effects on waterbirds both directly and through the food chain. To address this a monitoring program was established by the then Department of Conservation and Land Management (CALM). However, to date the results of this have not been published and there is no wide-scale quantitative data for bird abundance, distribution and breeding since the late 1990s, although there are records from Creery wetlands until 2003 as well as surveys conducted specifically for select development proposals.

Abundance and Diversity

The increased tidal amplitude has resulted in more frequent inundation of roosting sites across the estuary and a corresponding increase in access to shallow parts of the estuary by boats. This, together with changes through the food chain and possible reduction in fresh drinking water supplies in the Harvey River Delta were predicted to impact on both abundance and distribution of a number of bird species (Lane *et al.* 1997). In addition, the intertidal mudflats that once occurred around Boundary Island and the estuary near the Creery Marshes may also have been affected by changing tidal ampitude. These relatively small areas were the focus of occurrence by a suite of migratory shorebirds (eg. plovers, knots, godwits) that were not regularly recorded elsewhere in the estuary.

There is, however little evidence of changed species distribution, composition or abundance. Bamford and Bamford (2003) undertook a statistical comparison of abundance from 1982-1988 and 1998–2003 for five wading species in the Creery Wetlands (Table 35). However, due to the high level of natural variability in the numbers of these birds, no statistical differences were found in mean summer counts. Similarly, Lane *et al.* (1997) compared pelican numbers from 1975–1977 and 1995-1997. Once again the variability between years in the 1975-1977 counts (< 500 to > 2000) was greater than the differences between the decades. As such, there was insufficient data to determine if there has been a decline in pelican numbers.

However, it must always be remembered that 1974-76 was the wettest period in Australia for more than 100 years, with consequent explosions in waterbird numbers manifest in dispersal from temporary inland wetlands to coastal areas over the following years. Accordingly, 1975-1977 is not a very good benchmark period against which to determine what are the characteristic or typical aspects of waterbird usage at any wetland in Australia (R. Jaensch, pers. comm.).

Table 35: Waterbird abundance comparison 1982-88 and 2002-03 for the Creery Wetlands (Bamford and Bamford 2003).

SPECIES	1982–1988 MEAN (STD. DEV.)	2002-2003 MEAN (STD. DEV.)	SIGNIFICANCE (T-TEST)
Curlew Sandpiper	205 (490)	49 (88)	Not significant
Sharp-tailed Sandpiper	280 (610)	459 (451)	Not significant
Grey Plover	95 (149)	7 (9)	Not significant
Pacific Golden Plover	15 (25)	14 (18)	Not significant
Banded Stilt	2488 (3148)	1786 (1331)	Not significant

Breeding

The increased tidal range has resulted in more frequent inundation of Nirima Cay, which was formerly a nesting site for Australian Pelicans. As a result, Boundary Island is the major nesting site for these birds. This site is subject to frequent disturbance by people (boating, camping, dogs) and this has the potential to disrupt breeding birds. However, Lane *et al*. (1997) indicated that the breeding success of pelicans has not changed since the 1970s and is sufficient to maintain local populations.

The decline in trees in the Harvey River delta due to increased salinity also has the potential to affect waterbird breeding for species that nest in trees (Darter, ducks). However there is no information on changes in breeding for these or other species in this area of the Ramsar site.

4.3 YALGORUP LAKES

There is little long term monitoring information available for the ecological components of the Yalgorup Lakes, with the exception of waterbirds. As such, there are few changes in ecological character from 1990 to present that can be quantified. There is evidence, however, that the salinity in the lakes and particularly in Lake Clifton may be increasing. Knott *et al*. (2003) reported that the salt load in Lake Clifton was stable throughout the 1980s, but has increased by 40% during the 1990s. Given that average annual rainfall has not significantly changed it is suggested that this may be attributed to changes in the groundwater quality and an increase in salinity. No recent information exists, however, it would be expected that changes to groundwater quality would have a negative impact on the thrombolites, associated invertebrate communities and to waterbird usage of the system.

Nutrient concentrations in the lakes and the inflowing groundwater may also have increased. Shams (1999) reported concentrations of ammonium, nitrate-nitrite and ortho-phosphate from 1995/96 in the groundwater source above the then guideline values for West Australian lakes. Concentrations of nitrate-nitrate as high as 10,000 µg/L and ammonium concentrations in excess of 5000 µg/L were recorded in bores surrounding the lakes. Although phosphorus concentrations were lower, concentrations of ortho-phosphate as high as 200 µg/L were recorded from bores adjacent to Lake Preston. Shams (1999) concluded that the sources of nutrients were from surrounding horticultural activities and potentially sewage pollution. She estimated that the total nitrogen load from groundwater was 15 tonnes/year for Lake Clifton and 54 tonnes/year for Lake Preston. The total phosphorus load for Lake Clifton was estimated to be 0.4 tonnes/year and Lake Preston, 1.6 tonnes/year. However, with no time series data it is not possible to say if this has or is increasing over time.

In February 2007 there was a large fish kill at Lake Clifton that resulted in the death of a number of Black Bream. Although the exact cause of this event is not know, it has been suggested that increased nutrients lead to deoxygenation of the water column and the death of these fish (Johns and Paton 2007).

There is an extensive record of waterbird diversity and abundance at the Yalgorup Lakes (Russell unpublished). However, with high levels of natural variability, it is not possible to determine if there are significant changes to the waterbirds of the system.

4.4 LAKES MCLARTY AND MEALUP

There is little information on the changes to the ecological components and process at Lakes McLarty and Mealup in the 17 years since listing. There have been changes is surrounding landuse with increased intensity and urban development, which can be expected to have contributed to changes in hydrology and water quality.

There is anecdotal evidence that Lake McLarty is now drier more often and for longer periods of time and that the seasonality is shifting. In 1988, the fringing vegetation was inundated in spring, the lake was shallow during summer and dry for approximately one month over autumn. In 2002–2004, the lake dried earlier (January to February) and remained dry for four to five months (Bucktin 2004). It has been suggested that increased extraction of groundwater may be contributing to this changed hydrological regime. Average rainfall in the years 2002–2004 were below average (620 mm, 760 mm and 522 mm, respectively; Bureau of Meteorology), which could have contributed to the increased duration of the dry phase.

Lake Mealup is also drier more often and for longer periods of time than at the time of listing. Where once the lake dried on average every two years, it has been dry during late summer to autumn since 1994. There are two major contributing factors to this: the drain connecting the lake to the Harvey Estuary was closed in 1994 as it was thought that the increased tides from the opening of the Dawesville Channel may lead to saline water inflows to the lake; and there has been increased development around the lake and corresponding increases in ground water extraction.

There is insufficient data to confirm water quality changes in Lake McLarty since the time of listing. However, the increased landuse intensity may contribute to increased nutrients entering the wetlands. Nutrient data for Lake McLarty exists from monthly samples collected at the centre of the lake from 2001 and 2003 only. Concentrations of nitrate-nitrite and phosphate ranged from 20–3000 µg/L and 50–3000 µg/L respectively (Bucktin 2004). However, this may reflect concentration effects as the lake dries down rather than elevated nutrient concentrations due to human induced changes.

Water quality at Lake Mealup has declined since the time of listing. The most dramatic changes have been in the increased acidification, with pH values since 1994 ranging from 3.1 to 4.4 (Lake Mealup Preservation Society unpublished). It is thought that this is related to the acid sulfate sediments within the lake and the increased exposure of these to the air due to declining water levels (Peter Wilmott pers. comm.). The iron pyrite within the sediments oxidises when the lake is dry and exposed to the air and produces sulphuric acid, leading to decreased pH. Nutrient concentrations recorded in Lake Maelup since 1994 may also be elevated, particularly ammonium, for which a maximum concentration of 68,000 µg/L was recorded in November 2006 (Lake Mealup Preservation Society unpublished). It is likely that the increased acidity has affected the denitrification cycle and resulted in the release of ammonium from the sediments into the water column. In addition, where once Lake Mealup was characterised by high colour (from tannins), the water is now clear.

There have been successional changes in the vegetation at Lake McLarty since 1990. A survey in 2001 indicated that the *Typha orientalis* that once covered the majority of the lakebed and the sedges that dominated the margins were no longer present (Craig *et al*. 2006). A more recent survey in 2004, reported *Typha* in the centre of the lake and in disturbed soils (CALM 2005). This survey reported that *Juncus kraussi* (sea rush) is now dominant on the lake margins.

J. kraussi is adapted to saline conditions and is a component of the samphire salt marshes that surround the Peel-Harvey Estuary. Its dominance at a freshwater lake is indicative of increasing salinity within the lake, in the groundwater, the surrounding land, or a combination of these areas. However, salinity measurements collected over the period May 2000 to April 2004 do not support this. In 2000 and 2001 salinity ranged from < 1ppt (fresh) during winter and spring to 14 ppt (brackish to saline) when the lake was at its driest in autumn. However, during 2002 to 2004, maximum salinities were lower (< 5ppt) throughout the year (Bucktin 2004).

Waterbirds

Since the listing of the Peel-Yalgorup Ramsar site, Lake McLarty has undergone significant changes in ecology. The extensive *Typha* beds and *Baumea* sedges have been replaced by mud flats and open water. This has had ramifications for the waterbird populations using the lake, especially for the many species that depend on emergent wetland vegetation for shelter and nest sites. There are records of Australasian Bittern calls from Lake McLarty in the 1980s but none in recent times and this has been attributed to the altered vegetation (Lake McLarty Management Plan 2005). A range of habitats are still utilised by the waterbirds, with the lake still being used as a non-breeding, feeding ground and refuge area for shorebirds (Lake McLarty Management Plan 2005; Craig *et al*. 2006). Active management of the lake has been suggested to maintain the diversity of habitats particularly for the shorebirds, including the use of cattle grazing (Lake McLarty Management Plan 2005).

Craig *et al*. (2006) provide a comparison of data from 1981-1985 and 1996-2000 detailing the changes in waterbird populations. Based on the more recent data Lake McLarty qualifies as a significant wetland in that it supports more than 1% of the population of ten species (Table 36). This includes four international migratory species and five Australian nomads.

Table 36: Species with maximum Lake McLarty counts exceeding 1% population levels (Craig et al. 2001; Craig et al. 2006; Standring 1996).

SPECIES	DESCRIPTION	MAX. COUNT	% OF POPULATION
Sharp-tailed Sandpiper	International migrant that breeds in Siberia Occurs at Lake McLarty when water levels drop below 370mm, typically January to April Feeds in shallows and mudflats on small aquatic invertebrates	5970	3 %
Red-necked Stint	International migrant, breeds in Siberia; arrives at Lake McLarty as the water levels drop below 325 mm Feeds in mudflats on invertebrates	11,500	2.5 %
Red-capped Plover	Australian nomad, but parts of the population may be sedentary and has been recorded at Lake McLarty year round. However, peak numbers occur in late summer Feeds mainly on gastropods and insects by foraging on drier mudflats	> 1,500	2 %
Red-necked Avocet	Australian nomad, breeding inland Occurs at Lake McLarty predominantly in summer and autumn Feeds in shallow waters and mudflats on crustaceans and insects	5,468	5 %
Curlew Sandpiper	International migratory species that breeds in Siberia Peak numbers occur during February and March as the lake dries out. Feeds on invertebrates in mudflats	3,000	1.7%
Black-winged Stilt	Australian population is mainly nomadic Occurs in freshwater and saline wetland, using shallow open areas with or without short grass, sedge or saltmarsh Mainly feeds on invertebrates.	5400	2 %
Banded Stilt	Australian nomad, breeding inland, but parts of the population may be sedentary Prefers shallow, saline waters but may use McLarty Lake when conditions in the nearby estuary are not favourable Feeds mainly on crustaceans and insects by foraging in shallow waters and mudflats.	5300	2 %
Australasian Shoveler	Mainly sedentary occurring on a wide range of wetland types Feed mainly on aquatic animals.	487	1.9 %
Australian Shelduck	Generally sedentary, but post breeding migration over short distances for moulting.	4500	1.9 %
Eurasian Coot	Occurs in many wetland types but favours large areas of deep water and is reliant on littoral vegetation Feeds mainly on plants and seeds also molluscs and other invertebrates	10,000	1 %

The lake is considered important as it supports a relatively large number of more rare species. The wetting and drying pattern of Lake McLarty is believed to offer habitat to shorebird species at the critical pre-departure times (Craig *et al.* 2006). The loss of the lake's emergent vegetation combined with the tidal changes in the Peel-Harvey Estuary as a result of the Dawesville Channel, has been proposed as one explanation for the significant increase in several species of shorebirds such as the Red-necked Stint and Sharp-tailed Sandpiper at Lake McLarty, although adverse environmental conditions at wetlands elsewhere may also be influencing the patterns (Craig *et al.* 2006).

There have been no systematic surveys of the waterbird populations at Lake Mealup in the past decade.

4.5 LAKES GOEGRUP AND BLACK

Lakes Goegrup and Black are not yet within the Peel-Yalgorup Ramsar site, but rather are a part of a proposed extension. As such, the description "at the time of listing" is synonymous with the current situation (see section 3.5 above).

5. HOW THE PEEL-YALGORUP SYSTEM WORKS: THE INTERACTION BETWEEN DRIVERS, COMPONENTS, PROCESSES AND SERVICES

Harris (1999) argued that it is not possible to understand complex systems such as wetlands, simply by looking at their component parts, because we have to understand not only the parts themselves, but also the interactions between them. The interactions between ecological components and processes within any wetland system are too complex to unravel by looking at the micro-level. It is not possible, or in fact desirable, to identify and characterise every organism and all the associated abiotic attributes that are affected by, or cause effect to, that organism to describe the ecological character of a system. This would result in volumes of data and theory but bring us no closer to understanding the system and how to best manage it. What is required is to identify the key components, the initial state of the systems, and the basic rules that link the key components and cause changes in state (Holland 1998).

This section attempts to illustrate the fundamental interactions between the key ecosystem components and processes via the following:

1. Describing the associations between the ecosystem services/benefits and components/processes;
2. Identification and characterisation of the primary determinants of ecological character for the Peel-Yalgorup Ramsar site (including the use of conceptual models).

To identify the key components and processes for which interactions can be explored, guidance was taken from the *Ecological Character Framework* (DEW, 2007), which states:

"*The components, processes and benefits/services that should be selected for detailed analysis and description are those:*

- *that are key determinants of the sites' unique character;*
- *for which baseline data is available to specify the component or process;*
- *for which change is reasonably likely to occur over short or medium time scales (<100 years);*
- *which will cause significant negative consequences if change occurs; and*
- *which are practical to monitor.*"

This resulted in a subset of key components and processes being identified for the Peel-Yalgorup site for which interactions are described below. These guidelines also led to the exclusion of an important process in the Peel-Harvey Estuary, the increased tidal exchange from the opening of the Dawesville Channel. While this has a strong effect on the ecology of the system and has led to significant changes since the time of listing, it is not something that can be managed, nor is it likely to change substantially in the next 100 years. The Peel-Harvey Estuary is now more marine that it once was (see Section 3.2 and 4.2). However, the current conditions form the new baseline for the system. It is neither possible, nor desirable given the past problems with eutrophication, to return to the "pre-Dawesville" condition and it is not possible to manage the tidal regime in the estuary. As such, the following sections focus on the components and processes that can be managed to maintain the ecological character of the site.

5.1 LINKAGES BETWEEN SERVICES AND COMPONENTS

The relationships between the services and benefits for the Peel-Yalgorup site and the key components and processes have been explored to aid in the identification of the primary determinants of ecological character for the site. For each service, the following associations have been identified (Table 37):

- The location within the Peel-Yalgorup for which the service/ benefit applies;
- The components/processes that are directly responsible for the provision of the service/benefit;
- The influencing biotic components and processes that are indirectly related to the service and benefit by supporting or impacting on direct components and processes;
- The influencing abiotic components and processes that affect the service/benefit; and
- The threatening activities that are or have potential to affect to the components /processes that provide the benefit/services.

BENEFIT/SERVICE	LOCATION	DIRECT COMPONENTS	INFLUENCING BIOTIC COMPONENTS	ABIOTIC COMPONENTS	THREATS AND THREATENING ACTIVITIES
Commercial fishing	Peel-Harvey Estuary	Population of edible fish species, crabs and prawns	Seagrass distribution and extent (habitat for juvenile fish) Invertebrate populations (food source) Phytoplankton populations (food source) Piscivorus birds (predators)	Nutrient concentrations: Primary production (food sources) Eutrophication (loss of seagrass, anoxic conditions) Salinity (tolerance of species affects community composition) pH (acid conditions decrease immunity and increase disease) Toxicants (selenium uptake and biomagnification through the food chain)	Nutrient loads from the catchment Disturbance of Acid sulfate Soils
Pollution Control	Peel-Harvey Estuary	Nutrient concentrations in the water and sediment	Phytoplankton biomass and contribution to the detrital food web Benthic plant biomass	Nutrient concentrations Denitrification Dissolved oxygen concentrations Nutrient storage and release from sediments	Nutrient loads from the catchment Any actions that would reduce tidal exchange and flushing
Flood Control	Peel-Harvey Estuary				Any actions that would reduce tidal exchange and flushing
Cultural Services Recreation and tourism Spiritual and inspirational Scientific and educational	Entire Peel-Yalgorup Ramsar site	Waterbird populations Thrombolites Fish communities	Habitat extent and distribution (seagrass, samphire, mudflats) Primary production (balance between maintaining productivity and eutrophication)	Water Quality: Nutrients Dissolved oxygen Water clarity Salinity Hydrology (water levels in lakes)	Nutrient loads from the catchment Disturbance of Acid sulfate Soils Erosion of shoreline (e.g. powerboat activities) Groundwater extraction
Ecological Services: *Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region*	Entire Peel-Yalgorup Ramsar site	Extent and diversity of wetland types within the Peel-Yalgorup Ramsar site	Vegetation communities (samphire, paperbark woodland, benthic plants) Waterbird communities Fish and invertebrate communities	Water Quality: Salinity Hydrology (water levels in lakes)	Erosion of shoreline (e.g. powerboat activities) Groundwater extraction
Ecological Services: *Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region*	Yalgorup Lakes	Thrombolites	Phytoplankton Macroalgae Invertebrate populations Vegetated buffer zone	Water Quality: Nutrients Water Clarity Salinity Hydrology (water levels in Lake Clifton)	Nutrient loads from the catchment Groundwater extraction Inadequate buffer along eastern shore

BENEFIT/SERVICE	LOCATION	DIRECT COMPONENTS	INFLUENCING BIOTIC COMPONENTS	ABIOTIC COMPONENTS	THREATS AND THREATENING ACTIVITIES
Ecological Services: *Regularly supports 20,000 or more waterbirds*	All	Fish (Breeding crabs, prawns and fish, migration of Pouched Lamprey) Waterbirds (moulting of shelduck; migratory shorebirds, breeding of 12 species)	Seagrass Invertebrates Phytoplankton Habitat extent and distribution (seagrass, samphire, mudflats, reeds, paperbark)	Water Quality: Nutrients Dissolved Oxygen Water clarity Salinity Hydrology	Nutrient loads from the catchment Disturbance of Acid sulfate Soils Groundwater extraction Artificial changes to hydrological regime (surface water increase or decrease) of freshwater Erosion of shoreline (e.g. powerboat activities) Disturbance of birds and nests by vehicles, people, boating and lights Commercial and recreational fishing Introduced predators (foxes, cats)
Ecological Services: *supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*	All	Waterbirds	Habitat extent and distribution (seagrass, samphire, mudflats, reeds, paperbark) Phytoplankton Fish Invertebrate populations	Water Quality: Nutrients Dissolved Oxygen Water clarity Salinity Hydrology	Nutrient loads from the catchment Disturbance of Acid sulfate Soils Groundwater extraction Artificial changes to hydrological regime (surface water increase or decrease) of freshwater Erosion of shoreline (e.g. powerboat activities) Disturbance of birds and nests by vehicles, people, boating and lights Commercial and recreational fishing Introduced predators (foxes, cats)
Ecological Services: *Regularly supports 1% of the individuals in a population of one species or subspecies of waterbird*	All	Red-necked Avocet, Red-necked Stint, Red-capped Plover, Hooded Plover Black-winged Stilt, Banded Stilt Curlew Sandpiper Sharp-tailed Sandpiper Fairy Tern Musk Duck Grey Teal Australasian Shoveler Australian Shelduck and Eurasian Coot.	Habitat extent and distribution (seagrass, samphire, mudflats, sedges, paperbark) Invertebrates	Water Quality: Salinity Hydrology	Disturbance of Acid sulfate Soils Erosion of shoreline (e.g. powerboat activities) Disturbance of birds and nests by vehicles, people and boating Introduced predators (foxes, cats)
Ecological Services: *an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend*	Peel-Harvey Estuary	Fish (Breeding crabs, prawns and fish, migration of Pouched Lamprey)	Seagrass Invertebrates Phytoplankton	Water Quality: Nutrients Dissolved Oxygen Water clarity Salinity Hydrology	Nutrient loads from the catchment Disturbance of Acid sulfate Soils Artificial changes to hydrological regime (surface water increase or decrease) of freshwater Commercial and recreational fishing

Table 37: Linkages between services/benefits and components/processes for the Peel-Yalgorup site.

5.2 PRIMARY DETERMINANTS OF ECOLOGICAL CHARACTER

Phillips and Muller (2006) introduced the concept of "primary determinants" in the context of ecological character descriptions of Ramsar sites. Primary determinants are the components and processes that are central to maintaining the ecological character of a site. Phillips and Muller (2006) contested that if the primary determinants are maintained within certain limits, then it can be expected that the system as a whole, and its individual components will also be maintained. This concept has been adapted to the Peel-Yalgorup system and linked to the attributes that contribute to the site being recognised as a wetland of international importance. The Peel-Yalgorup Ramsar site is listed under six of the Ramsar criteria as a wetland of international importance. It is logical, therefore, that the ecological character of the site must be maintained, at a minimum, to continue to meet these criteria. To this end "primary determinants" are those components and processes that are crucial to the maintenance of the components and processes for which the site has been listed (Figure 44).

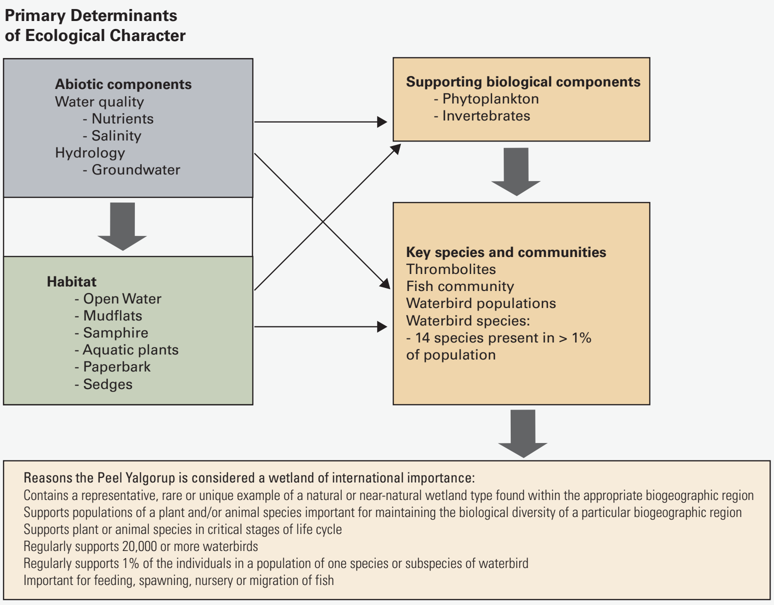

Figure 44: Primary determinants of ecological character at the Peel-Yalgorup Ramsar site.

The key species and communities that are directly responsible for the Peel-Yalgorup site being recognised as a wetland of international importance are:

- The thrombolites at Lake Clifton;
- Fish populations (including the migratory route for the Pouched Lamprey)
- The waterbird population which regularly exceeds 20,000 individuals; and
- The fourteen species for which the site maintains > 1% of the flyway population (Red-necked Avocet, Red-necked Stint, Red-capped Plover, Hooded Plover, Black-winged Stilt, Banded Stilt, Curlew Sandpiper, Sharp-tailed Sandpiper, Fairy Tern, Musk Duck, Grey Teal, Australasian Shoveler, Australian Shelduck and Eurasian Coot).

These key species and communities are dependent on a range of biotic and abiotic components and processes within the Peel-Yalgorup Ramsar site. This includes habitat and food requirements as well as tolerances to abiotic factors such as salinity. Although the interactions between components and processes are complex, the conceptual models provided in the following sections together with the relationships shown in Table 37, highlight the primary determinants of ecological character for the Peel-Yalgorup site. These are:

- Abiotic components
    - Nutrients
    - Salinity
    - Hydrology (groundwater)
- Habitat
    - Open water
    - Mudflats
    - Aquatic plants
    - Samphire
    - Paperbark communities
    - Sedges/rushes

In general the abiotic components and processes of wetland ecosystems determine the ecological signature of wetlands. A series of conceptual models for the Peel-Yalgorup Ramsar site have been developed to illustrate the abiotic determinants and how they influence the key components and processes for each section of the Ramsar site. These take the form of stressor models (Goss 2003), which highlight the links between abiotic primary determinants and ecosystem responses should the determinant be significantly altered resulting in changes to the ecological character. These models do not attempt to show every interaction that occurs within the systems, but rather highlight those important in driving ecological responses and feedback loops which in turn determine the sites' ecological character.

5.2.1 NUTRIENTS

Macronutrients nitrogen and phosphorus are essential for plant growth and reproduction. However, excessive amounts of nutrients, particularly in waterways can lead to eutrophication. Eutrophication, in the strictest sense is defined as an increase in the organic loading of a waterbody (Nixon 1983). However, more broadly it encompasses the physical, chemical and biological responses to increased nutrient loading (Cloern 2001). The responses of the systems in the Peel-Yalgorup Ramsar site to increased nutrient loads include increased phytoplankton, epiphytic and macroalgal growth, decreased dissolved oxygen, release of nutrients from the sediment and smothering of the littoral zone by decaying wrack.

Although plants require both nitrogen and phosphorus, they are not required in equal amounts. The Redfield ratio dictates that in phytoplankton the ratio of N : P is approximately 16 to 1 (atoms to atoms). Similar ratios were described for *Cladophora* in the Peel Inlet, which indicated that 100–200 µg/L of inorganic nitrogen and 20–30 µg/L of inorganic phosphorus were required for maximum growth (Hodgkin *et al*. 1981). Average inorganic nitrogen to phosphorus ratios in the Peel-Harvey Estuary during winter are between 20 and 30 to 1 (N : P). As such, it has been concluded that phosphorus is most often the nutrient limiting macroalgal growth in the estuary (McComb and Lukatelich 1995).

Filamentous Cyanobactria such as *Nodularia* and *Lyngbya* are capable of fixing di-nitrogen (N_2) dissolved in the water column and utilising this as a nitrogen source. During the blooms of *Nodularia* in the Harvey Estuary it was estimated that large amounts of nitrogen were fixed by the cyanobacteria and this added significantly to the nutrient load within the system (Huber 1986). As a consequence, these blooms were also limited by the phosphorus in the system, both from river flow and from sediment release.

Peel-Harvey Estuary

The interactions related to nutrient inflows into the Peel-Harvey Estuary are illustrated in Figure 45. The current conditions within the estuary result in dilution of nutrients in much of the water column due to the tidal flushing through the Dawesville Channel. However, with high loads of nutrients still entering from the catchment and potentially from waterside urban development, there are localised areas affected by eutrophication, predominantly adjacent to the river inflows. In these areas, and the lower reaches of the rivers, algal blooms are common, in response to high concentrations of nutrients. The high biomass of phytoplankton results in large loads of organic matter to the sediments and the decomposition processes lead to deoxygenation of bottom waters. This has two flow-on effects, the first is a direct effect on fish and other obligate aquatic fauna, which cannot tolerate the anoxic conditions, and fish kills have been reported in the lower river reaches (Water and Rivers Commission 2004). The second effect is that of the anoxic conditions on the nutrient stores in the sediment. The low dissolved oxygen concentrations disrupts the denitrification cycle and results in the release of ammonium into the water column and affects phosphorus adsorption to sediment particles, resulting in the release of phosphate into the water. These inorganic nutrients are then available for uptake by plants, including phytoplankton and a cycle of eutrophication is set in train.

The concentration of nutrients in the water column also stimulates the growth of epiphytes on seagrass (Tomasko and Lapointe 1991) causing shading of seagrass leaves. This can lead to a decline in seagrass health and an increase in wrack produced. Seagrass is important nursery habitat for juvenile fish (e.g. yellowfin silago *Sillago schomburgkii* and black bream *Acanthopagrus butcheri*), and a decline is seagrass extent can lead to a decline in survival of fish to adult stages. The decline in fish numbers then has effects through the food chain on predator species such as piscivorus birds (e.g. pelicans, cormorants).

Increased concentrations of nutrients also affect the growth of benthic plants including seagrass and macroalgae. An increase in biomass results in increased debris (wrack) washed onto beaches and intertidal zones. In large quantities this can smother intertidal mudflats and Samphire marshes (Hodgkin *et al.* 1981). This in turn can have effects on wading species of birds and shoreline stability.

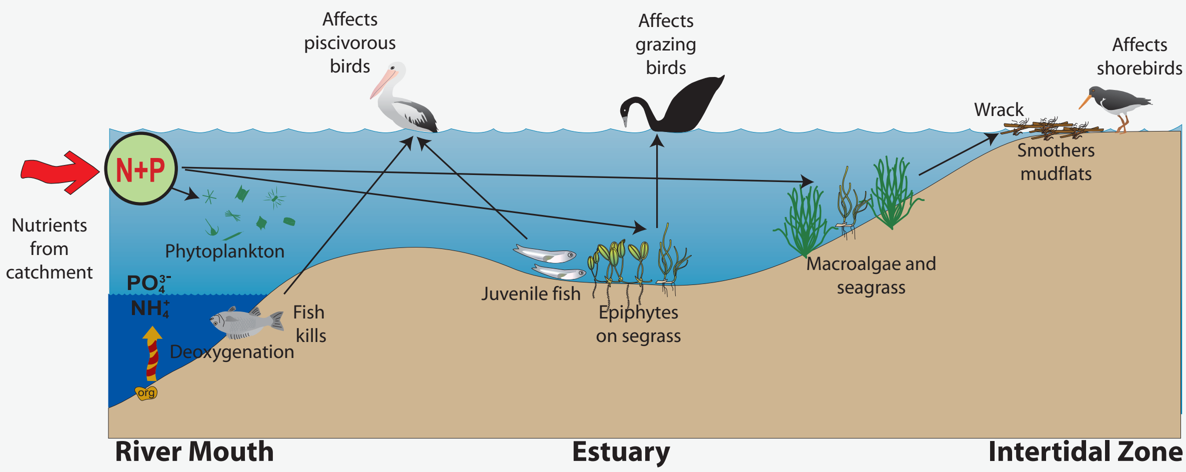

Figure 45: Conceptual model of the effects of nutrient inflows on the Peel-Harvey Estuary.

Yalgorup Lakes

Although there is little direct evidence that increased nutrient concentrations are affecting the ecological character of the Yalgorup Lakes, some investigators have listed this as a potential threat to the wetlands (Knott *et al.* 2003; Moore 1991; Davies and Lane 1996). In the absence of current information it is not possible to be sure if the ecological character of these systems has changed or is threatened. However, following the guidelines of Holland (1998) we can use our understanding of general wetland ecology to predict the effects that abiotic components may be having or will have into the future.

Increasing nutrient concentrations (Figure 46) may be a product of increasing nutrients in groundwater or surface water inflows. The narrow strip of vegetation around the eastern margins of the lakes (the direction of water inflow) does not adequately buffer the system from nutrients arriving from the surrounding catchment (Davies and Lane 1996). An increase in nutrients could have a significant effect on the thrombolites, which are adapted to low nutrient conditions (Moore 1991). In addition an increase in water column nutrient concentrations could result in increased macroalgal growth on the thrombolites surfaces and phytoplankton concentrations in the water column, both of which serve to decrease the light reaching the thrombolites and limiting the photosynthetic potential of the embedded cyanobacteria. Eutrophic conditions could result in the death of the thrombolites communities in Lake Clifton.

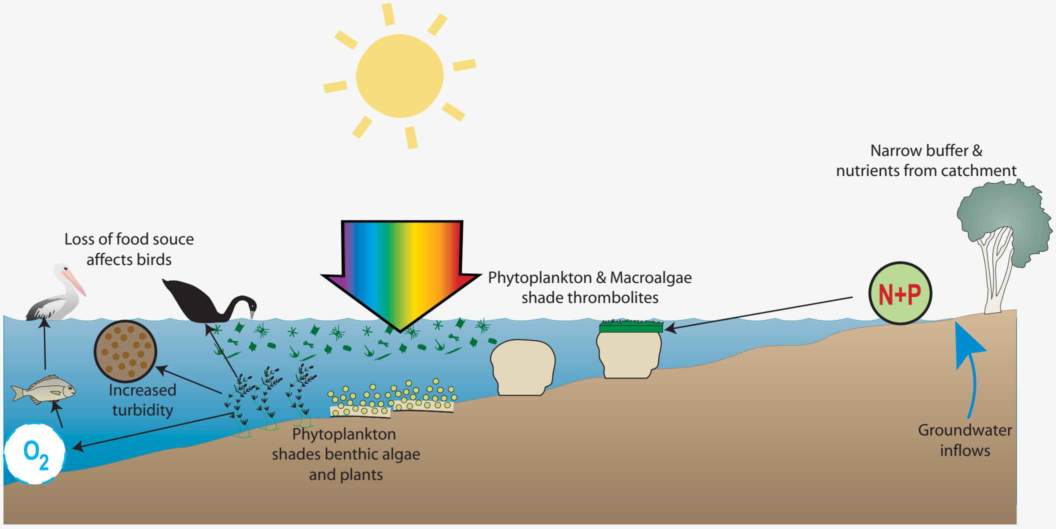

Figure 46: Conceptual model of the effects of increased nutrients on the Yalgorup Lakes.

Increased phytoplankton growth could also shade the benthic algae and aquatic plants that currently dominate some of the lakes. This would result in impacts through the food chain on dependant invertebrates and birds. In particular the Black Swans of Lake Pollard which are reliant on the submerged charophytes. The benthic plants within the system serve to bind the sediments and prevent resuspension of particles into the water column. If these plants were substantially removed, then the shallow nature of the basins, together with the prevailing high wind conditions would be likely to result in increased turbidity in the water column and further reduction in light penetration to the benthos.

If eutrophication continued such that decomposing plant biomass in the sediments result in decreased dissolved oxygen concentrations near the sediment-water interface, oxygen stratification could occur. The resulting anoxic conditions could result in fish kills and subsequent effects through the food chain to piscivorus birds such as pelicans.

Lakes McLarty and Mealup

The ecology of Lakes McLarty and Mealup are another case where there is only a small body of direct evidence of changes or threats to the ecological character. However, as demonstrated above, the fundamental principles of wetland ecology can be used to make some predictions on the interactions and responses to changing conditions. In these systems, there is some evidence of increased nutrient concentrations, which could be impacting on the ecological character of the wetlands (CALM 2005; Lake Mealup Preservation Society unpublished).

The interactions are similar to those described above of the Peel-Harvey and the Yalgorup Lakes, whereby increased nutrient concentrations from groundwater and sediment sources are potentially resulting in eutrophication of the site. In addition, the cattle grazing that is permitted in Lake McLarty, would also be contributing nutrients to the system. There are no data on the phytoplankton community in these wetlands, however, it appears that the result of increased nutrients has been excessive growth of floating leaved aquatic plants (*Lemna sp.*) in Lake McLarty. These can have the same effect as algal blooms, shading plants below and reducing the dissolved oxygen concentrations in the water column either at night when respiration exceeds photosynthesis, or via the decomposition of biomass. While it is unlikely that there are significant fish populations in these temporary systems, the anoxic condition would also affect macroinvertebrates, decreasing diversity in favour of the few species that are tolerant of anoxia (e.g. chironomids).

In addition, the increased drying at Lake Mealup and the corresponding exposure of the potential acid sulfate sediments sediment to the air and acidification of the water column represents a serious threat to this wetland. The constant low (< 4) pH will impact on all biota within the system from macrophytes and phytoplankton to invertebrates, amphibians and water birds.

Lakes Goegrup and Black

Lakes Goegrup and Black are located on the lower Serpentine River and as such are subject to similar nutrient enrichment processes as the river mouths of the Peel-Harvey Estuary (Figure 47). High loads of nutrients from the catchment have contributed to blooms of phytoplankton and the blue-green alga *Lyngbya*. The increased organic loading to the sediment leads to the consumption of oxygen by decomposers faster than it can be replenished by diffusion and anoxia of bottom waters is common. This leads to a breakdown in the denitrification cycle and the release of ammonium into the water column and facilitates desorption of phosphorus from sediment particles and the release of phosphate into the water column. These nutrients are then available for uptake by plants such as phytoplankton and the processes becomes cyclic.

Deoxygenation of bottom waters can lead to the death of fish and other aquatic fauna and fish kills have been reported in the lower Serpentine River (Water and Rivers Commission 2004) if not in the lakes themselves. The effect on fish populations can result in effects up the food chain for piscivorous birds such as pelicans and cormorants.

Macroalgal growth may result in the smothering of samphire, as was observed in the Peel Inlet during the 1970s and 1980s. This could also affect the invertebrates within the mudflats and consequently impact on wading species of birds through the food chain.

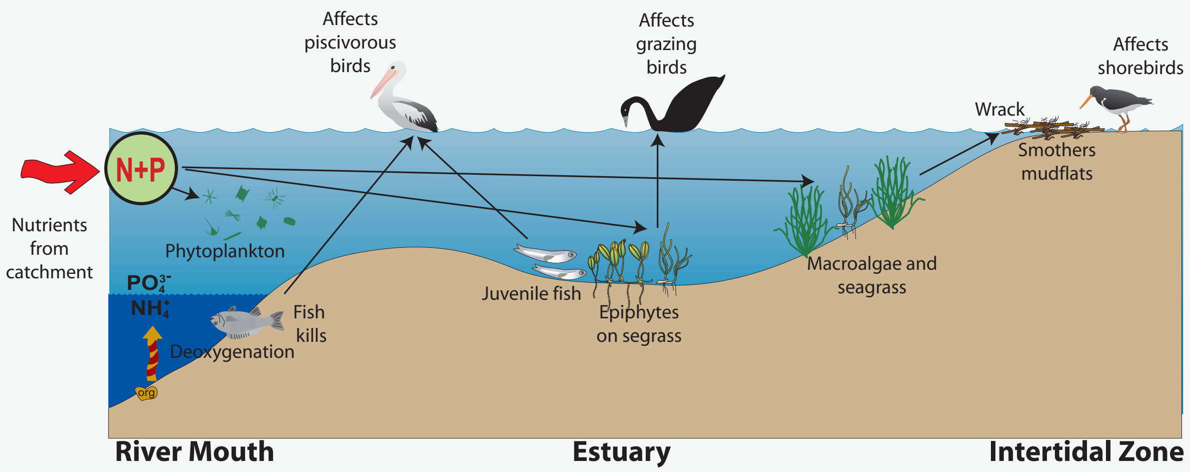

Figure 47: Conceptual model of the effects of nutrient loads on Lakes Goegrup and Black.

5.2.2 SALINITY

Salinity is the measure of the concentration of total inorganic salts within the water column. Salinity changes may affect aquatic organisms in two ways (ANZECC, 2000):

- direct toxicity through physiological changes (particularly osmoregulation) — both increases and decreases in salinity can have adverse effects;
- indirectly by modifying the species composition of the ecosystem and affecting species that provide food or refuge.

Aquatic organisms are adapted to specific salinity regimes in terms of both optimum and tolerances. In addition, changes in salinity can act as triggers for reproductive processes such as setting seed, germination, laying eggs or other breeding behaviours. The salinity tolerances for key taxa in the Peel-Yalgorup Ramsar site are provided in Table 38.

Table 38: Salinity tolerances of some key taxa in the Peel-Yalgorup Ramsar site.

ORGANISM	LOCATION	SALINITY (PPT)	REFERENCE
ALGAE			
Nodularia spumigena	Peel-Harvey Estuary	Optimum = 5–30 < 20 for akinete germination	Huber 1984
Lyngbya majuscula	Peel-Harvey Estuary Goegrup & Black	9–36	Watkinson *et al.* 2005
Cladophora	Peel-Harvey Estuary Yalgorup Lakes	Up to 40 ppt	Brock 1985
Lamprothamnium papulosum	Yalgorup Lakes (Lake Pollard)	9–125 ppt	Brock and Lane 1983
ANGIOSPERMS			
Ruppia megacarpa	Peel-Harvey Estuary Yalgorup Lakes	10–150 ppt	Brock and Lane 1983
Baumea spp	McLarty & Mealup	6 ppt	Morris 1998
Typha spp.	McLarty & Mealup	3 ppt reduced growth 6 ppt no growth	Glover and Sim 1978
Lemna sp.	McLarty & Mealup	10 ppt	Haller et al 1974
Halosarcia	Peel-Harvey Estuary Goegrup & Black Yalgorup Lakes	6–100 ppt optimum but can survive 200 ppt	Short and Colmer 1999
Casuarina obesa	Peel-Harvey Estuary Goegrup & Black Yalgorup Lakes	> 10 ppt Survived 29 ppt	Dept of Ag. & Food Carter *et al.* 2006
Melaleuca cuticularis	Peel-Harvey Estuary Goegrup & Black Yalgorup Lakes	5–10 ppt Survived 29 ppt	Dept of Ag. & Food Carter *et al.* 2006
Melaleuca rhaphiophylla	McLarty & Mealup	0.5–1 ppt	Dept of Ag. & Food
INVERTEBRATES			
Xanthagrion erythroneurum (Damsel fly)	McLarty & Mealup	0.4–5 ppt	Williams and Boulton 1990
Berosus sp. (beetle larvae)	McLarty & Mealup	0.1–2 ppt	Bailey 1998
Notospisula trigonella (mollusc)	Peel-Harvey Estuary	35–40 ppt	Geddes 2005
Arthritica semen (mollusc)	Peel-Harvey Estuary	10–45 ppt	Geddes 2005
Capitella capitata (polychaete)	Peel-Harvey Estuary	10–55 ppt	Geddes 2005
Portunus pelagicus (Blue Swimmer Crab)	Peel-Harvey Estuary	20–35 ppt	Romano and Zeng 2006
Penaeus latisulcatus (Western King Prawn)	Peel-Harvey Estuary	22–34 ppt	Sang and Ravi 2004
FISH			
Leptatherina wallacei (Western Hardyhead)	Peel-Harvey Estuary	4–85 ppt	Thompson and Whithers 1992
Leptatherina presbyteroides	Peel-Harvey Estuary	5–71 ppt	Thompson and Whithers 1992
Pseudogobius olorum (Swan River Goby)	Peel-Harvey Estuary	< 55 ppt	Halse 1981

ORGANISM	LOCATION	SALINITY (PPT)	REFERENCE
Favonigobius lateralis (Long-headed Goby)	Peel-Harvey Estuary	Spawning triggered by salinity dropping below 30 ppt	Wise 2005
Atherinosoma elongata (Elongate Hardyhead)	Peel-Harvey Estuary	Up to 122 ppt	Young and Potter 2002
WATERBIRDS			
Porzana tabuensis (Spotless Crake)	Peel-Harvey Estuary McLarty & Mealup	< 3 ppt	Halse *et al.* 1993
Porphyrio porphyrio (Purple Swamphen)	Peel-Harvey Estuary McLarty & Mealup	< 3 ppt	Halse *et al.* 1993
Fulica atra (Eurasian Coot)	Peel-Harvey Estuary McLarty & Mealup	< 10 ppt	Halse *et al.* 1993
Botaurus poiciloptilus (Australasian Bittern)	Peel-Harvey Estuary McLarty & Mealup	< 3 ppt	Halse *et al.* 1993
Most species of duck	All	< 3 ppt to < 10 ppt	Halse *et al.* 1993
Cygnus atratus (Black Swan)	All	< 10 ppt	Halse *et al.* 1993
Recurvirostra novaehollandiae (Red-necked Avocet)	All	140 ppt	Halse *et al.* 1993
Charadrius ruficapillus (Red Capped Plover)	All	10–25 ppt	Halse *et al.* 1993

Peel-Harvey Estuary

The salinity of the Peel-Harvey Estuary has changed dramatically since the time of listing. The opening of the Dawesville Channel has resulted in an increase in marine conditions and a corresponding change in the ecology and biota of the system. This cannot be altered and the tidal regime is not a component that can be managed. However, despite the increase in marine waters, the system is still functioning as an estuary with decreased salinity during the winter months as a result of freshwater inflows from rivers and drains. While it is desirable to reduce the nutrients entering the system via the river inflows, the freshwater is important for maintaining the ecological character of the estuary. This is particularly true for obligate aquatic taxa, which may take reproductive cues from salinity fluctuations (e.g. Longheaded Goby, Table 38).

Yalgorup Lakes

Knott *et al.* (2003) suggested that there might be a trend of increasing salinity at Lake Clifton due to an increase in salinity in the groundwater, which comprises the dominant water source for the lake. Although Lakes Preston and Pollard were not included in the study, they have similar salinity ranges to Lake Clifton and are fed by the same aquifer. Consequently it is likely that the salinity of these lakes would follow the same pattern as that of Lake Clifton.

The biota of Lakes Clifton, Preston and Pollard are adapted to the salinity regime where the water is brackish during winter and spring and saline during summer and autumn. All aquatic biota have optimum salinity concentrations under which they function best and a range of salinity that they can tolerate. Prolonged changes in salinity outside these ranges will result in the death of individuals and eventually the population. Although the salinity tolerances of the thrombolites at Lake Clifton are not known, the only living specimens are found at Lake Clifton where salinity does not normally exceed that of seawater (35 ppt) and is lower than this for much of the year. There are remnants of dead thrombolites at Lake Preston and it has been hypothesised that their demise could have been due to the increased salinity that has occurred over geological time scales (Knott *et al.* 2003).

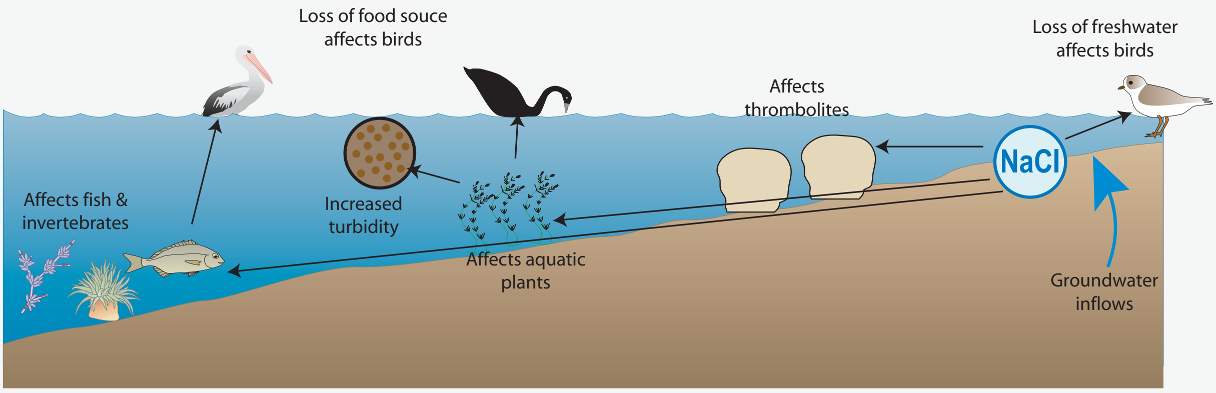

Figure 48: Conceptual model of the effects of increased salinity on the Yalgorup Lakes (Lakes Clifton, Pollard and Preston).

Increased salinity will also have a direct effect on fish, macroinvertebrate and aquatic plant populations. This in turn would have effects on waterbirds through the food chain. In addition, there is evidence that a number of birds, such as the Hooded Plover, rely on the freshwater inflows into the lakes as a source of drinking water (Birds Australia 2005). Any changes in salinity could have a direct effect on these birds, particularly those such as the Hooded Plover that breed at the lakes.

Lakes McLarty and Mealup

Increasing salinity may be the result in a change in the water quality of the inflowing groundwater. The evidence for this at the site is indirect, but the increase in saltmarsh plants in recent times (CALM 2005) is most likely a response to the increased salt in the soil and/or water column of the lakes. Lakes McLarty and Mealup are the only freshwater wetlands within the Peel-Yalgorup Ramsar site and although saline systems and salt marsh provide good habitat for many species of waterbirds, these ecological niches are filled by the other wetlands within the system. Salinisation of Lakes Mealup and McLarty would result in a decrease in waterbird species that prefer or are reliant on freshwater wetlands and associated vegetation. For example, Black Swans and some species of duck require freshwater for drinking and many waterbird species nest in freshwater habitats (Jaensch 2002). An increase in salinity in predominantly freshwater wetlands will also result in a significant shift in the invertebrate fauna, perhaps more so than for the Yalgorup lakes.

5.2.3 GROUNDWATER

Groundwater is the dominant water source for both the Yalgorup Lake system and Lakes McLarty and Mealup. Any change to the volumes or quality of this water could have significant impacts on the ecology of the systems by changing patterns and extent of inundation. This could result in the stranding of littoral vegetation (due to a decrease frequency and duration of inundation as well as affecting aquatic organisms such as the thrombolites by exposing them for longer periods. However, the only system for which there is some evidence of altered hydrology is Lakes McLarty and Mealup.

McLarty and Mealup

Decreasing water levels at Lakes McLarty and Mealup could be the result of changed climatic patterns, the result of increased groundwater extraction or a combination of both of these factors. The resulting change in hydrology would include a reduction in the maximum water level (and extent of inundation) and a reduction in the duration of inundation, with a longer dry period over summer and autumn. A decrease in extent of inundation could result in the stranding of the paperbark community and a subsequent decline in vegetation condition and ultimately extent. This could then impact on the waterbirds that are reliant on this type of vegetation for breeding such as Eurasian Coots, Purple Swamphens, Musk Duck and Spotless Crake, all of which have been previously recorded breeding at the site. A decrease in duration of inundation could result in the lakes being dry over summer, when migratory bird species are most likely to use this area as a feeding ground (Figure 49).

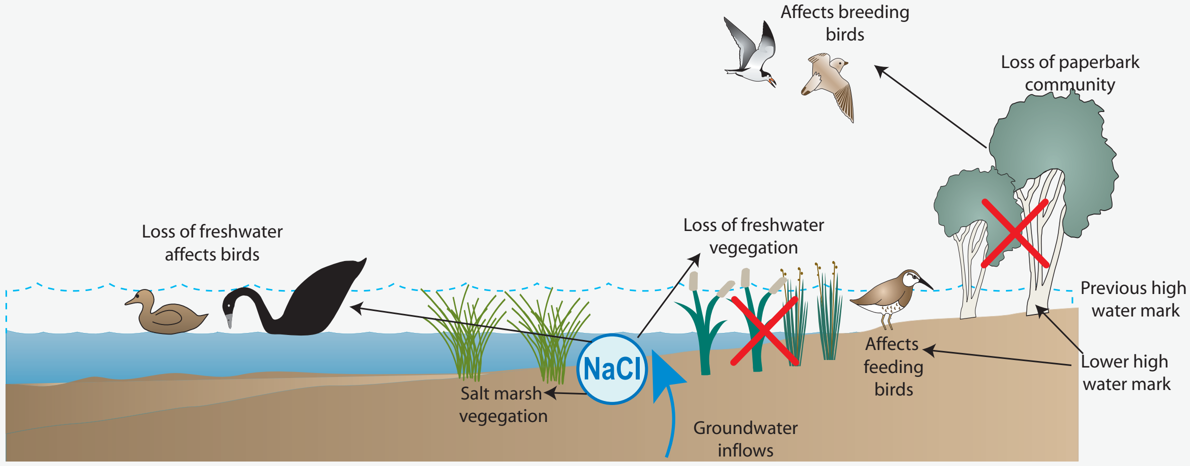

Figure 49: Conceptual model of the effects of increased salinity and decreased water level on Lakes McLarty and Mealup.

5.2.4 HABITAT

The word "habitat" can be defined as "the resources and conditions present in an area that produce occupancy (including survival and reproduction) by a given organism" (Hall et al. 1997). Therefore, in the broadest sense habitat includes all of the abiotic and biotic components and processes that an individual, population or community requires for survival. Habitat changes will affect other biota in two ways; firstly via trophic relationships, through the food chain and secondly via changes to structural habitat for fauna.

Trophic relationships

Hodgkin *et al*. (1981) provided a simplified food web of the Peel-Harvey Estuary, which is useful for understanding the tropic relationships between the biota in the system (Figure 50). This model shows both the well recognised pelagic system and also the important, but often under recognised, detrital system. This provides an example of one method by which primary producers within the system are a primary determinant of ecological character. Plant taxa form the basis of the food chain for all of the key biota within the Peel-Yalgorup and any changes or impacts to phytoplankton or aquatic plants within the system, will have affects to invertebrate, fish and waterbird communities and populations.

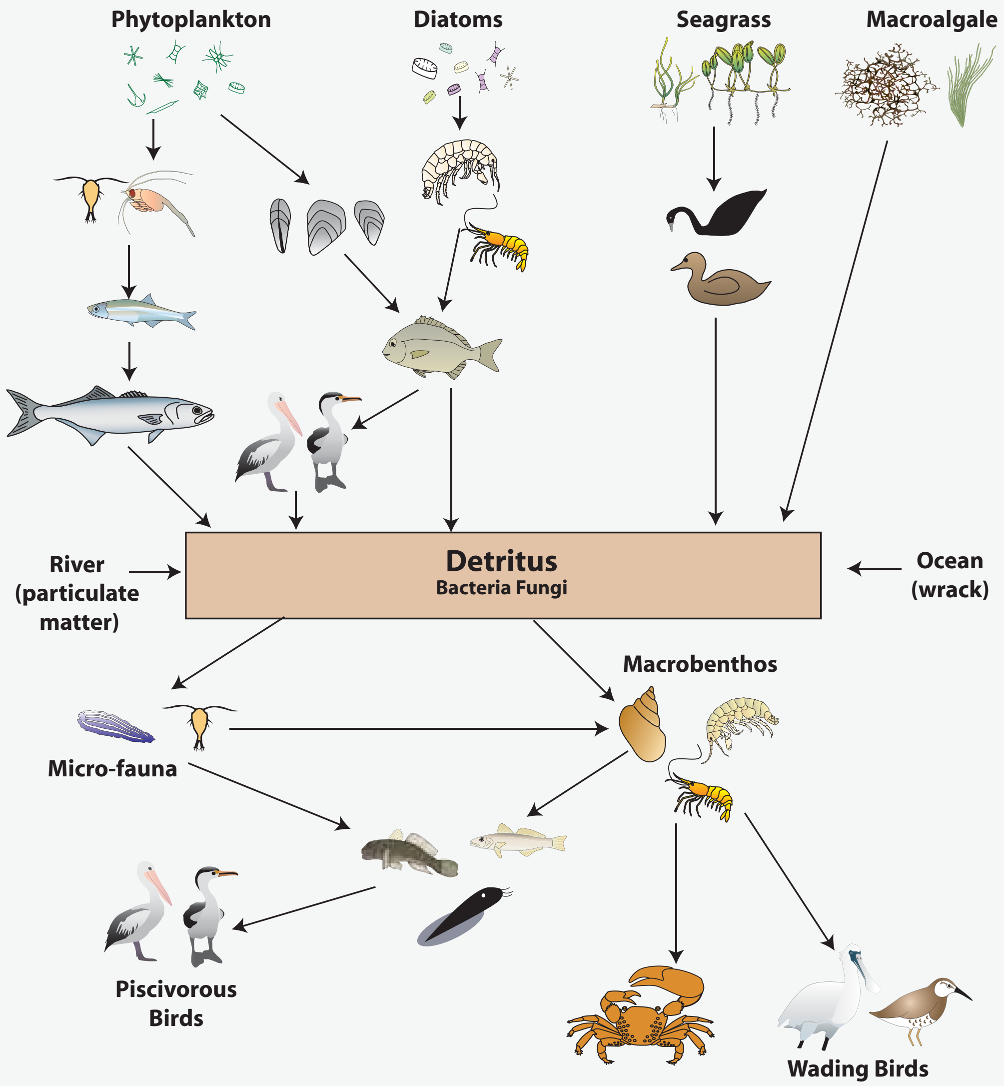

Figure 50: Simplified food web of the Peel-Harvey Estuary (adapted from Hodgkin et al. *1981).*

Habitat type and availability

The term "habitat type" is often used to describe an aspect of habitat, the vegetation that organisms require for survival and reproduction (Daubenmire 1968 as cited in Hall *et al.* 1997). In the context of the Peel-Yalgorup ecological character description, this definition of habitat types has been expanded to include all physical habitats, not just that provided by vegetation. The following physical habitat types provided by both vegetation and abiotic environments have been identified as primary determinants of ecological character in the Peel-Yalgorup Ramsar site:

- Open water
- Mudflats
- Aquatic vegetation
- Samphire
- Paperbark community
- Freshwater sedgeland

It is not just the presence of these habitat types that is important for maintaining ecological character of the site, but also the variety, accessibility to relevant species, extent, condition and temporal and spatial connectivity. Many species rely on more than one habitat type. Waterbirds in particular may use one habitat for feeding, another for roosting and another for breeding (Appendix B).

The extent, condition and use of habitat types have not been consistently or recently assessed across the Peel-Yalgorup site. What is known, or can be deduced through ecological principles about habitat types within the system is contained in Table 39.

Table 39: Probable habitat usage within the Peel-Yalgorup Ramsar site.

HABITAT TYPE	LOCATION	DESCRIPTION	KEY BIOTA
Open water	Peel-Harvey Estuary	Approximately 130 km^2 Small tidal variation Available all year	Fish, macroinvertebrates, waterbirds foraging (mainly ducks, coots, terns, gulls)
	Yalgorup Lakes	Ten lakes of varying sizes all with large open water component. Seasonal variation, but some open water available year round	
	McLarty and Mealup	Maximum of 200 ha when fully inundated (variable due to extent of sedge cover) Seasonal – open water only during winter months Together with minor swamps, these are the only "fresh" wetlands in the Peel-Yalgorup system	
	Goegrup and Black	Open water available yearly, but with seasonal and tidal fluctuations	
Mudflats	Peel-Harvey Estuary	Intertidal (also under samphire communities)	Invertebrate communities, foraging for wading species of birds
	Yalgorup Lakes	Seasonal with greatest extent in late autumn when water levels are lowest	
	McLarty and Mealup	Seasonal, mid to late summer as water levels recede	
	Goegrup and Black	Intertidal (also under samphire community)	
Aquatic plants	Peel-Harvey Estuary	Seagrass – seasonal, with greatest extent during summer. Last measured in 2000, where extent was approximately 70 km^2 at its maximum	Juvenile fish Macroinvertebrates Foraging for waterbirds (Black Swans, Ducks) Nesting for Black Swans
	Yalgorup Lakes	Lake Pollard is the only lake to have extensive aquatic plants (no recent data)	Black Swans and Australian Shelducks in large numbers (up to 5000). Nesting habitat for Black Swans
Samphire	Peel-Harvey Estuary	Approximately 600 ha in 1994 (no recent data)	Foraging for shorebirds Nesting sites for a few waterbirds. Roosting for waterbirds Cover from predators for waterbirds
	Yalgorup Lakes	Small amounts fringing the fresher systems	
	Goegrup and Black	Approximately 83 ha as mapped and measured in 2005	
Paperbark	Peel-Harvey Estuary	Small areas located in the south of the Harvey Estuary. Condition and extent not recent assessed.	Roosting sites for waterbirds. Nesting sites for species such as cormorants and darters, herons, and some ducks
	Yalgorup Lakes	Narrow fringe along the shorelines, < 20 m wide in places.	
	McLarty and Mealup	Extensive paperbark community around wetlands	
	Goegrup and Black	Salt and freshwater paperbark communities	
Sedgeland	Peel-Harvey Estuary	Minor area in saltmarsh, dominated by *Juncus krassii*	Important nesting habitat for Eurasian Coot, Purple Swamphen, Dusky Moorhen, Spotless Crake. Foraging for waterbirds Protection from predators
	McLarty and Mealup	Extensive freshwater sedgelands	
	Goegrup and Black	Minor area in saltmarsh, dominated by *Juncus krassii*	

6. THREATS TO THE ECOLOGICAL CHARACTER OF THE PEEL-YALGORUP SITE

A framework for the evaluation of threats to wetland environments is provided in Figure 51. This framework separates threatening activities from the threats they induce and the impacts caused to the natural assets. By identifying the activities that contribute to the threats rather than focussing on the induced threats themselves, the causes of impacts to natural assets are made clear. This in turn provides clarity for the management of natural resources by focussing management actions on tangible threatening activities. For example, erosion may be identified as a threat for wetlands in the Ramsar site. However, management actions cannot be targeted at erosion without some understanding of why erosion is taking place. By identifying the threatening activities that could contribute to erosion (eg boating, urban development) management actions can be targeted at these threatening activities and reduce the impact to the wetland.

Although this ecological character description is not a management plan and does not provide or recommend specific management actions, it is designed to be a tool for use in the development of a management plan for the Ramsar site. Therefore, it is useful to illustrate the linkages between these induced threats and impacts and the activities that contribute to threats.

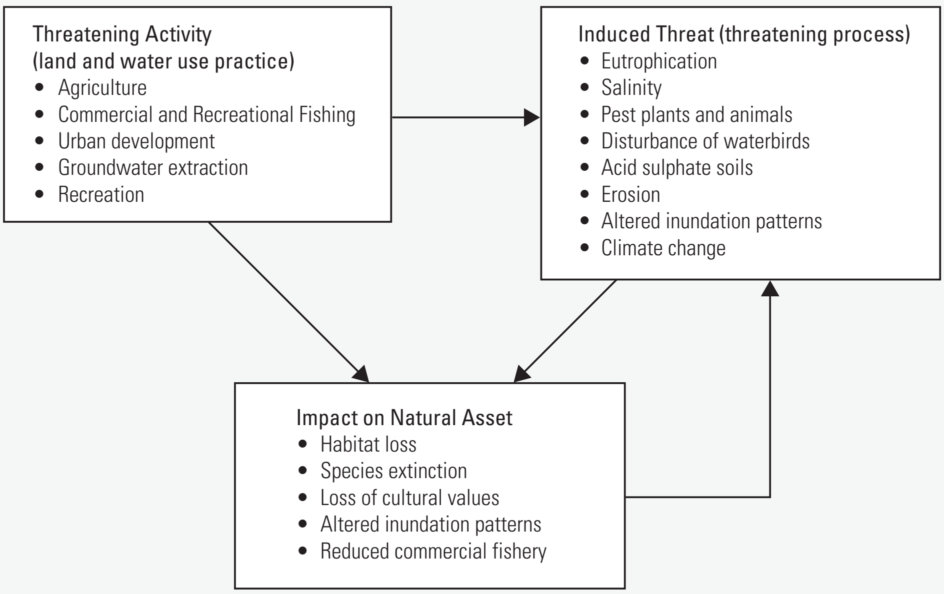

Figure 51: Relationships between threatening activities, induced threats and impacts (Goulburn CMA 2003).

The major threatening activities, which could impact on the ecological character of the Peel-Yalgorup Ramsar site, are:

- Agricultural activities in the catchment;
- Water use and groundwater extraction
- Urban and peri-urban development;
- Commercial and recreational fishing;
- Recreation; and
- Climate change

These are discussed blow, together with the special case of cattle grazing at Lake McLarty.

Photo: The Dawesville Cut

6.1 AGRICULTURE

The Peel-Harvey Estuary has suffered the effects of cultural eutrophication for a number of decades. The construction of the Dawesville Channel was a component of a three part strategy to address the excessive nutrients entering the system. Although the nutrient concentrations within the estuary basins have decreased significantly since the opening of the Channel in 1994, there is no evidence that there has been a corresponding reduction in nutrient loads entering the system from the catchment.

Nutrient concentrations in the water column and the sediment of the river mouths and Lakes Goegrup and Black remain high and this has resulted in excessive algal growth in the form of both phytoplankton and macroalgae. Although flushing of the system to the Indian Ocean through the Dawesville Channel is keeping concentrations of inorganic nutrients within the estuary basins low, this is not a panacea and if nutrient loads form the catchment continue at current levels, or increase, it is likely that the system could turn eutrophic once more.

To address the problem of eutrophication in the estuary, targets of been set for phosphorus and dissolved oxygen in the Draft Water Quality Improvement Plan (EPA 2007). These set a target for the load of total phosphorus entering the system of 75 tonnes per annum, with a target concentration of total phosphorus of 30 µg/L. Dissolved oxygen concentration targets of 70–80 % saturation are also proposed.

These targets have been established in order to manage the nutrient run-off from the catchment and the total load entering the Peel-Harvey Estuary. However, measures of total phosphorus (and nitrogen) are not indicative of the amounts of nutrients available for uptake by phytoplankton and other plants. As such, when assessing the condition of a wetland system, inorganic nutrients should also be considered (Harris 1999).

Increased nutrient concentrations as a result of surrounding landuse also have the potential to affect the Yalgorup Lakes and the freshwater wetlands Lakes McLarty and Mealup (see section 5.2.1 above). These nutrients may enter the system through overland flow, and in the case of the Yalgorup Lakes there is little vegetated buffer to intercept any nutrients entering the system in this manner. However, it is more likely that nutrients will enter these systems through groundwater. The aquifer that provides the majority of the water for both the saline and freshwater wetland systems is unconfined and as such vulnerable to inputs from activities on the land under which it flows. The agricultural and rural residential catchment surrounding the lakes is a source of nutrients from animals and fertilizer applications.

6.2 WATER USE AND GROUNDWATER EXTRACTION

Hydrology is a key driver of wetland ecology and has an affect on both abiotic and biotic components. Of particular concern in the Peel-Yalgorup Ramsar site is the alteration of river flows into the Peel-Harvey Estuary and the reduction in groundwater flow into the Yalgorup Lakes and Lakes McLarty and Mealup.

The Peel-Harvey Estuary is reliant on river flows from the Serpentine, Murray and Harvey Rivers both as a source of carbon and nutrients and also to maintain the salinity regime of the system. As mentioned previously, the effects of increased salinity due to the opening of the Dawesville Channel are permanent and cannot be managed. However, the system is an estuary and relies on freshwater inflows into the system to maintain ecosystem function and processes such as reproduction. The *Draft Water Quality Improvement Plan* (WQIP, EPA 2007) sets a river flow objective for the tidal reaches of the Serpentine, Murray and Harvey Rivers to "maintain current flow variability". However, this is not explicitly quantified in terms of discharge volumes.

The main source of water for the Yalgorup Lakes is the shallow, unconfined groundwater aquifer. Shams (1999) suggested that this was being affected by extraction for horticultural, agricultural and rural residential purposes. However, the changes in volume have not been quantified. Similarly, there is indirect evidence of a reduction in groundwater entering Lakes McLarty and Mealup, however, no quantitative data on groundwater levels could be found.

6.3 URBAN DEVELOPMENT

A large proportion of the Peel-Yalgorup Ramsar site is located within the City of Mandurah, which is experiencing rapid population growth. In addition, there are current and planned urban and high density rural developments, under the Peel Regional Scheme which are adjacent to the Peel-Harvey Estuary, Lakes McLarty and Mealup and the Yalgorup Lakes. There are a number of potential induced threats associated with increased development around the wetlands that could impact on the primary determinants of ecological character of the site. These include:

- Clearing of native vegetation (including saltmarsh and paperbark communities);
- Increased nutrient and contaminant run-off;
- Disturbance of acid sulfate soils; and
- Increased recreational pressure on the wetland sites.

Clearing

There are no specific statistics available for clearing of native vegetations for residential development in the Peel Region. However, it is thought that there has been significant removal of deep-rooted perennial vegetation both historically and in the recent past (URS 2007). This includes vegetation buffer zones from around wetland areas as well as the saltmarsh and paperbark communities that provide habitat for the fauna of the Ramsar site.

Increased Nutrient and Contaminant Run-off

Residential development can result in large loads of nutrients in surface and groundwater. Zammit *et al.* (2005) estimated that the phosphorus load from residential land use was 2.275 kg/ha/year, which is more than twice that for agricultural landuses. Any increase in nutrient loads to the wetlands in the system will potentially contribute to eutrophication.

There is little information on the contaminant loads entering the system or the loads that could be expected from urban run-off. The overall threat of contaminants on the waterways in the area is not understood and is an area where monitoring and/or research are required (URS 2007).

Acid Sulfate Soils

Acid sulfate soils (ASS) are common in coastal areas of Australia (Sammut and Lines-Kelly 2000) and are benign unless disturbed. The extent of potential acid sulfate soils in the area surrounding the Ramsar site is provided in Appendix E. A conceptual model of the potential effects of exposure of ASS is presented in Figure 52. Dredging in the Peel Inlet has disturbed the ASS and exposure these disturbed soils to the air, either from disposal of dredge spoil or intertidal water level variation, can result in the formation and release of sulphuric acid into the water column. The carbonate concentrations in seawater should be sufficient to buffer this effect (Sullivan 2006) and in effect neutralise any pH changes. However, if this occurs during times when freshwater inflows are dominant and carbonate concentrations are low, there is potential for the pH to decrease. This decrease in pH affects the immune system of fish and has been shown to cause skin lesions and increased infection (Sammut and Lines-Kelly 2000).

In addition, the acidic conditions within the sediment can result in the release of toxicants into the water column. Although the concentrations of most heavy metals and toxicants are low within the sediments of the Peel Inlet, there are particularly high levels of selenium (Sullivan 2006). Selenium is potentially toxic to marine fauna and can bioaccumulate through the food chain causing effects on health and reproduction of fish and birds (US Department of the Interior 1998).

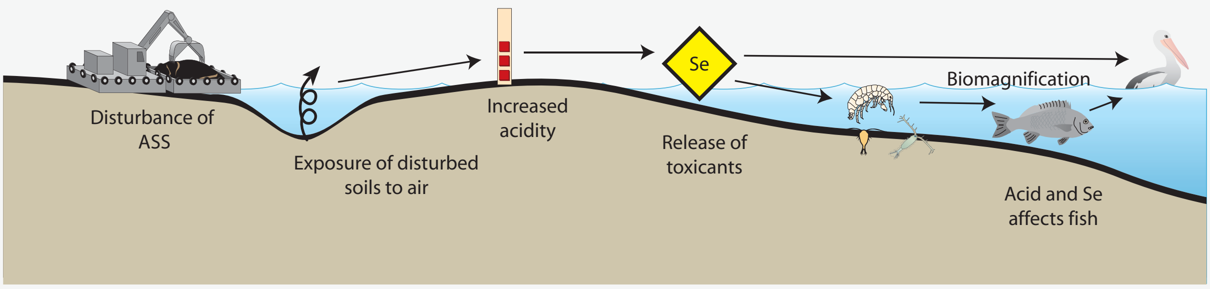

Figure 52: Conceptual model of the effects of ASS on the Peel-Harvey Estuary.

6.4 COMMERCIAL AND RECREATIONAL FISHING

Commercial Fishing

There are eleven commercial licences for fin-fish in the Peel-Harvey Estuary. A target catch is set annually (based on control charting techniques) to allow catch levels to fluctuate in response to natural variation in fish stocks. The target for 2005/6 was 75–220 tonnes (Fisheries WA 2006). The major species caught are Sea Mullet, Yelloweye Mullet and Western Sand Whiting. Although Cobbler, Black Bream and King George Whiting were previously significant proportions of the catch, the numbers of these taxa have declined.

There is a commercial fishery in the Peel-Harvey Estuary for Blue Swimmer Crabs with nine active licences. The catch has been stable over the last five years at approximately 50 tonnes per annum. Fisheries WA (2006) considers that the effect of the blue swimmer crab fishery on the ecosystem is minimal due to:

- The legal size at first capture (127–135 mm CW) is above the size at maturity (85–115 mm CW for males and females) and as such breeding stock levels are expected to be adequate to maintain stocks under normal environmental conditions.
- The shift from using gill nets to traps has resulted in a significant decrease in by-catch with few non-target species collected.
- The commercial collection of crabs represents a small proportion of the total biomass and so trophic level effects are negligible.
- Fishing with traps results in minimal benthic habitat disturbance.

Recreational Fishing

The Peel-Harvey Estuary and the Peel Inlet in particular, are popular recreational fishing locations, both from boat and shore based anglers. A survey of recreational fishing in the Peel Inlet undertaken in 1998/99 estimated that the recreational catch for Blue Swimmer Crabs was five times that of the commercial catch and an estimated 1,360,000 crabs or 290 tonnes (Malseed and Sumner 2001). Most crabs kept by recreational fishers (86%) were male. Although the majority of those surveyed abided by the fisheries regulations, 13% were found to keep undersized crabs.

Recreational fishers also took Australian Herring, whiting other than King George (*Sillago spp.*), Tailor, Skipjack Trevally, trumpeters, King George Whiting, Silver Bream (Tarwhine) and Black Bream. Malseed and Sumner (2001) found high levels of compliance with the size regulations with only ~6% of boat anglers retaining undersized fish and ~9% retaining undersized crabs, compared to 13% of shore-based crabbers keeping undersize crabs. Few boats with two or more people on board attained the daily boat limit of 48 crabs while 30% of boats with only one person on board caught their daily bag limit of 24 crabs. Since that study the quotas for crabs have been twice reduced, the most recently in 2007 with the boat limit (when more than one fisher is on board) reduced to 20 crabs and the individual limit reduced to 10 crabs. Closed season and changes for commercial crabbers have also been implemented

6.5 RECREATION

Tourism and recreation are a strong focus in the Peel region, and it is estimated that tourism brings in $147 million dollars per annum (URS 2007). The increase in residential development and the proposed new Perth Bunbury Highway are likely to increase recreational pressure on the Peel-Yalgorup site. Recreational activities within the wetlands include bushwalking, camping, horse riding, motorbikes, four-wheel drives, boating, jet skiing, water skiing and swimming. While recreational enjoyment of the Peel-Yalgorup site is a service/benefit of the wetlands, it also has the ability to impact negatively on the ecological character. The two major impacts are erosion of the shoreline due to boating and recreational vehicle use, and disturbance of waterbirds at vulnerable stages in their lifecycle.

Erosion

The *Economic Development and Recreation Management Plan for the Peel Waterways* (PIMA 2002) identified erosion of foreshores in the estuary from boat wash as a major threat to the fringing vegetation. The opening of the Dawesville Channel has increased access to the estuary for both a greater number and larger vessels. This has the potential to increase the problem of shoreline erosion and the effect on fringing vegetation will have habitat effects for reliant fauna.

The City of Mandurah has developed and begun implementing the Peel Waterways Foreshore Protection and Rehabilitation Project to protect shoreline vegetation within the estuary and rehabilitate foreshore reserves.

Disturbance of birds

Migratory shorebirds travel over 10,000 km from breeding grounds in the northern hemisphere to non-breeding sites in the southern hemisphere, and return north each year. It has been found that disturbance of birds when feeding or roosting may result in a significant loss of energy. This may even compromise their ability to build up enough reserves to complete the return journey to breeding grounds (DEH 2005). Disturbance of migratory shorebirds may occur as a result of recreational fishing (in some instances), four wheel driving on beaches, unleashed dogs and jet skiing.

In addition to disturbance of migratory shorebirds, there is evidence that increased recreational pressure is leading to the disturbance of breeding birds within the Peel-Yalgorup site. Pelicans on Boundary Island have been observed to be disturbed by boats, campers and dogs during nesting (Lane *et al.* 1997).

Increased lighting at night, either from vessels or onshore activities can also impact on migratory birds and seabirds, particularly those that are nocturnal. Artificial lighting can affect birds by (Brett Lane and Associates 2007):

- Disorientating breeding birds returning to colonies at night;
- Decreasing the time birds attend to nests (and impacting on breeding success); and
- Displacing birds from breeding or feeding grounds.

6.6 CLIMATE CHANGE

The Indian Ocean Climate Initiative (IOCI 2002) sates that the climate in southwest western Australia has already changed (Text Box 2). Predictions indicate that it is likely that there will be further decreases in rainfall and rises in sea level in the future (Hick 2006). This has the potential to impact significantly on the hydrology and hence ecological character of the Ramsar site. Although this is not an issue that can be addressed at the local scale increased knowledge of the potential impacts of climate change to this site, may lead to the identification of management activities that can be applied to help reduce the impacts..

Changes to the climate of the southwest of Western Australia:

- Winter rainfall in the southwest of Western Australia has decreased substantially since the mid-20th century. This has altered the perceptions of regional climate even though a similar, albeit less severe, dry sequence was experienced earlier in the century.
- The recent rainfall decrease was only observed in early winter (May-July) rainfall; late winter (August-October) rainfall has actually increased, although by a smaller amount.
- The winter rainfall sharply and suddenly decreased in the mid-1970s by about 15–20%. It was not a gradual decline but more of a switching into an alternative rainfall regime.
- The reduction in winter rainfall resulted in an even sharper fall in streamflow in the southwest.
- Temperatures, both day-time and night-time, have increased gradually but substantially over the last 50 years, particularly in winter and autumn.

Text Box 2: Changes to the climate in the south west of Western Australia (IOCI 2002).

6.7 CATTLE GRAZING

Controlled cattle grazing is permitted in Lake McLarty and although the management plan indicates that this is limited in both numbers and season, there is no indication of what seasonal patterns of grazing are permitted. Grazing is used to control the spread of emergent plants such as *Typha* and provide more extensive mud flat habitat for wading species of waterbird. While cattle grazing may have some benefits, the consequences of this must also be considered. These include, increased nutrient loads, and corresponding increases in phytoplankton and other opportunistic plant species; decline in palatable species of vegetation and an increase in less palatable vegetation types; an increase in weed species, and trampling and compaction of wetland soils (Figure 53). In addition, cattle have been found to preferentially graze on new and emerging shoots (Price and Lovett 2007) and as such may not only consume the target species, but seedlings of native plants as they emerge. Finally, *Typha* has been shown to be competitively advantaged under conditions of high nutrient loads and disturbed soil surfaces (Drohan *et al.* 2006) and as such may be both controlled and promoted by grazing.

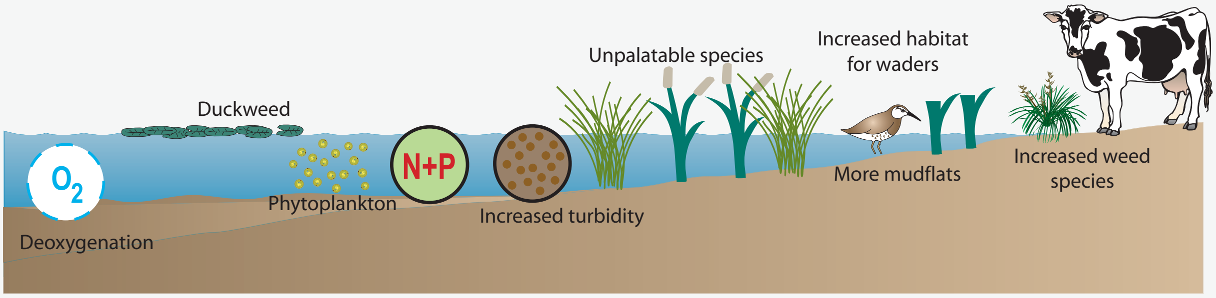

Figure 53: Conceptual model of the effects of cattle grazing on Lakes McLarty and Mealup.

7. LIMITS OF ACCEPTABLE CHANGE

Limits of acceptable change are defined by Phillips (2006) as:

"…the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the site was Ramsar listed. In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was listed".

Limits of acceptable change and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that limits of acceptable change should be beyond the levels of natural variability (Figure 54). Setting limits in consideration with natural variability is an important, but complex concept. As indicated in Section 5 above, wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability such that trends away from "natural" can be detected with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is far from straight forward.

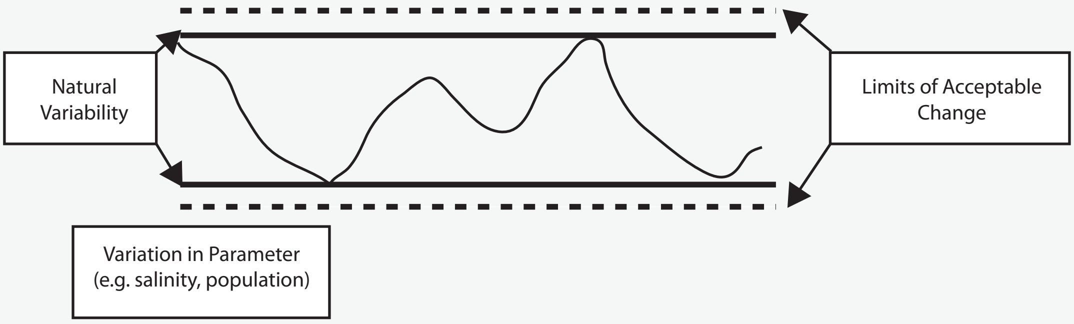

Figure 54: Relationship between natural variability and limits of acceptable change (Phillips 2006).

It is not sufficient to simply define the extreme measures of a given parameter and to set limits of acceptable change beyond those limits (Figure 55). There are many examples where a parameter could change in ways that are detrimental to the ecological character of the site but do not result in a change in the maximum or minimum values. For example, consider the case of salinity in Lake Clifton. This is a parameter that is intimately associated with the ecological character of the lake and maintaining the thrombolite communities. The time series for salinity during 1984 at two sites in Lake Clifton along the eastern shore is provided (Figure 56). If the simple approach of drawing boundaries around this time series were taken, limits of acceptable change might be written, as "salinity must be between 15 and 32 ppt". However, the variability in salinity at this site may be important and a constant 32 ppt would change the ecological character of the site (with the possible demise of the thrombolites) while a constant 15 ppt may also change the wetland such that salt tolerant species are replaced by those more adapted to freshwaters.

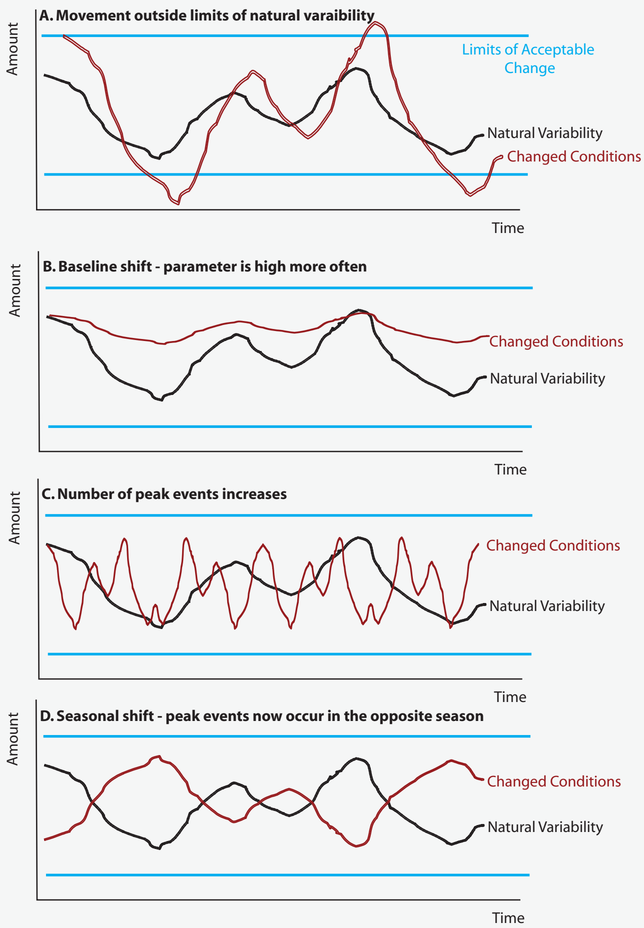

Figure 55: Illustration of the complexity of setting limits of acceptable change. If these are set to be outside the extremes of natural variability (A) then this will only capture a change in maximum or minimum values. Situations that involve a shift in the baseline values, an increase in the number of peak events or a seasonal shift (B – D) will not be captured.

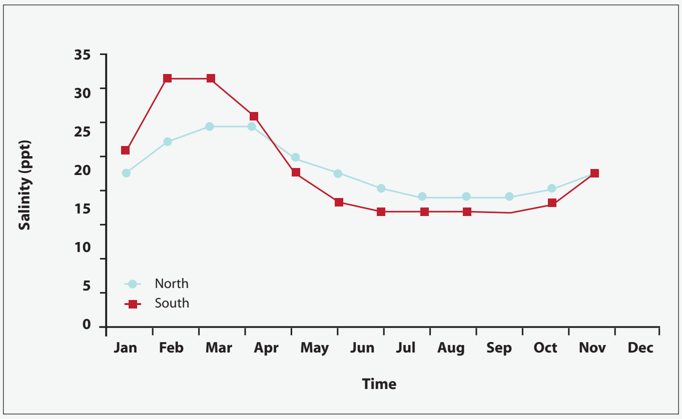

Figure 56: Salinity in Lake Clifton during 1984 (Moore 1987).

What is required is a method of detecting change in pattern and setting limits that indicate a trend away from natural variability (be that positive or negative). This may mean accounting for changes in the frequency and magnitude of extreme events, changes in the temporal or seasonal patterns and changes in spatial variability as well as changes in the mean or median conditions. Added to this is the need to be able to detect changes in the key determinants of ecological character *prior* to irrevocable changes in wetland ecology.

In a perfect world with complete scientific and ecological knowledge, limits of acceptable change could be set to match the tolerances or optimum conditions for the key biological components and processes for which the site was listed. In this manner, limits could be set within these specific tolerances and ecological character maintained. However, this information is rarely available for the most well studied species, let alone the more cryptic organisms.

In the absence of this complete knowledge, a conservative approach is most often adopted. It is in this context that the precautionary principle, originally appearing in the United Nations World Charter for Nature in 1982, has been adopted. The principle states:

"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation."

The application of this principle to the Peel-Yalgorup system would be to proactively implement measures to address threats identified to the system (see Section 6) and to set conservative limits of acceptable change which can be reviewed in light of monitoring and additional information.

Limits of acceptable change are to be used in the management of the system to maintain ecological character. In order to detect if the limits of acceptable change are being met monitoring against these limits needs to occur. As such it is neither practical nor desirable to set limits for every component and process within a wetland system. Accordingly, components and processes for which limits of acceptable change can be established are those:

- For which there is adequate information to form a baseline against which change can be measured;
- For which there is sufficient information to characterise natural variability;
- That are primary determinants of ecological character;
- That can be managed; and
- That can be monitored.

There are a number of critical components and processes within the Peel-Yalgorup Ramsar site that do not meet these criteria. An example of this would be the thrombolites at Lake Clifton. It is not possible to measure the condition of these communities directly and it is likely that any change in extent of the thrombolites (i.e. death of individual mounds) would signify irrevocable change. In an attempt to address this situation, a hierarchical approach to establishing limits of acceptable change is proposed (Figure 57).

This approach sets short-term limits of acceptable change (with a corresponding intensive monitoring program) on the key abiotic factors within the system. Abiotic components and processes impose a strong influence on the biotic components of wetland systems and are often considered the primary control factors (Mitsch and Gosselink 2000; Batzer and Sharitz 2006). These are usually the easiest to monitor and change can be detected in the short term (within 1 or 2 years). The approach adopted with respect to abiotic components, follows the ANZECC (2000) guidelines for water quality in freshwater and marine systems. A set of guideline or trigger values[3] has been established for key components, based on site specific information, where possible, and using general values for Australian ecosystems in situations where there is insufficient data for the local system. In the case of the Peel-Yalgorup system there are some data upon which baselines can be set and trigger values established (eg salinity, nutrients) and for others, general values have been used.

The second set of parameters for which limits of acceptable change can be set, is the primary responses to the abiotic components and processes. This includes primary production, littoral vegetation extent and condition and the distribution and condition of aquatic plants. Once again the focus is on the identified key determinants of ecological character. Limits are set against baseline data and the habitat requirements of key fauna detailed in section 5.2 above. The limits of acceptable change for these parameters are set at time scales reflecting the different response times of the flora communities. For example, phytoplankton, which can respond rapidly, has shorter-term limits of acceptable change than woody vegetation communities.

3 Note that the concept of trigger values as described in ANZECC (2000) is that exceedence "triggers" action; be that increased monitoring and investigation or management actions. The management of the system is beyond the scope of the ECD, but it is recommended that this approach to monitoring and management be adopted in the management plan for the site.

Finally the key biological components are considered. For most of these quantitative limits of acceptable change are difficult to determine, either due to a lack of baseline data, inherent high levels of natural variability, or in the case of many waterbird species, factors outside the site affecting their distribution and abundance observed at the site. Maintaining the conditions of the abiotic environment and the primary producers should protect these faunal components and processes. However, as stated above, limits of acceptable change have been set without complete knowledge or understanding of the system. As such, it is important that some of the assumptions made in setting limits for abiotic components and flora are tested and that the linkages between biotic and abiotic factors described in Section 5 above are sound. For this reason, although strict "limits of acceptable change" cannot be set for these components, they form an important element of the monitoring program. Outcomes of the monitoring program are to be reviewed for broad trends and the information used to review and refine the limits of acceptable change for the site (see Section 9).

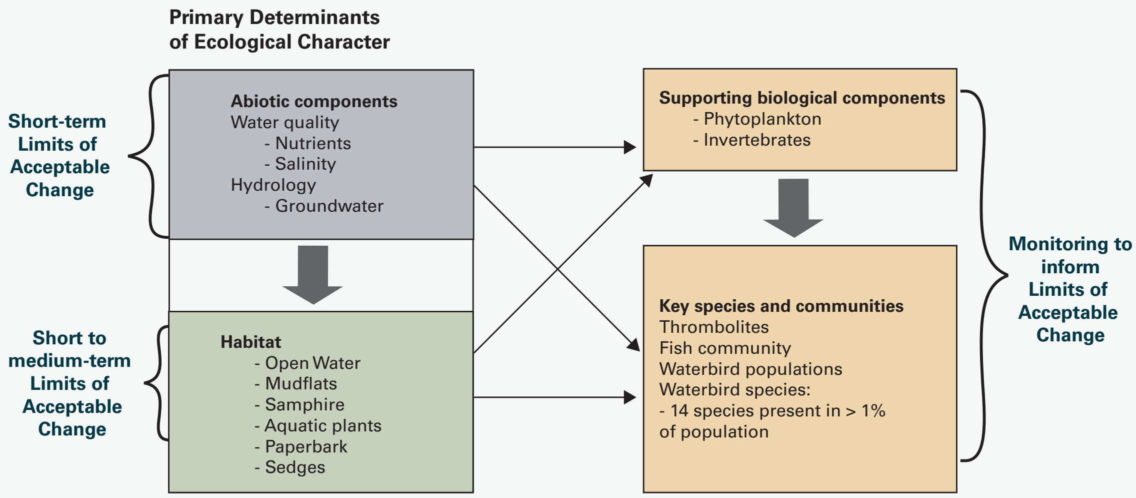

Figure 57: Hierarchical system for setting limits of acceptable change.

Limits of acceptable change for each of the wetland types in the Peel-Yalgorup Ramsar site have been established for each of the key determinants identified in section 5.2 above (Table 40, Table 41, Table 42 and Table 43). In addition to components that have been identified as "primary determinants" of ecological character, limits have also been set for components that are considered to be under threat, such as pH in the Peel-Harvey, which have been identified as a potential threat through the disturbance of acid sulfate soils (Section 6).

Table 40: Limits of acceptable change for the Peel-Harvey Estuary.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
ABIOTIC COMPONENTS		
Nutrients	Total phosphorus limits have been set by the Water Quality Improvement Plan (EPA 2007)	< 30 µg/L (maximum)
	Dissolved inorganic nutrients, which are the form available for uptake. Current baseline suggests peaks in winter, but low concentrations during summer and autumn	PO_4, NH_4, NO_x - median concentrations < 10 µg/L
Dissolved oxygen	Limits have been set by the Water Quality Improvement Plan (EPA 2007)	70–80 % saturation
pH	Although marine systems have a large buffering capacity, disturbance of acid sulfate soils have the potential to lower pH values. Baseline conditions indicate pH typically 7.3 to 8.5	pH > 7 at all times
Salinity	Although the marine influence on the estuary cannot be managed, seasonal salinity fluctuations are important for biota. Fish such as the long-headed river goby require salinities of < 30 ppt to trigger spawning. Some waterbirds require fresh drinking water (< 3 ppt)	Winter salinity in the centre of the Peel Inlet and Harvey Estuary < 30 ppt for a minimum of 3 months. Water in the Harvey River mouth over winter < 3 ppt
PRIMARY RESPONSES		
Phytoplankton	Phytoplankton biomass is typically low in the estuary although occasional blooms occur, but persist for only a matter of weeks	Chlorophyll a – median concentrations < 10 µg/L
Seagrass	Current extent and biomass unknown	Baseline must be set before limits can be made
Macroalgae	Current extent and biomass unknown	Baseline must be set before limits can be made
Samphire	Current extent and biomass unknown	Baseline must be set before limits can be made
Paperbark	Current extent and biomass unknown	Baseline must be set before limits can be made
KEY SPECIES AND COMMUNITIES		
Invertebrates	Insufficient information to set a baseline for most invertebrate communities, the exception being the commercially significant blue swimmer crab. Catch per unit effort (CPUE) provides an indication of changes to the numbers and size of crabs in the estuary. Although recreational fishing comprises a greater proportion of crabs collected, there is no systematic sensus of this. Commercial CPUE for blue swimmer crabs in the Peel-Harvey Estuary (1996–2005) has been between 1 and 1.4 kg/trap lift (Fisheries WA, 2006)	Median CPUE for blue swimmer crabs should not drop below 1.0 kg/trap lift per annum (based on commercial fishing).
Fish	Insufficient information to set a baseline for most fish communities. The exception is the commercial fish taxa. Unfortunately although CPUE is collected for commercial fish in the Peel-Harvey (King George Whiting, Cobbler, Black Bream) this information is not reported publicly and so baseline values cannot be established	Baseline must be set before limits can be made.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
Waterbirds	The Peel-Harvey Estuary: • supports > 20,000 waterbirds regularly; • supports > 1% of the population of twelve species; and • supports breeding of eleven species However, waterbird numbers are highly variable and there has been no systematic, long term monitoring of theses birds within the estuary to enable a numerical baseline to be set. In addition, the high natural variability and strong influence of external factors for most waterbirds presents difficulties when setting limits of acceptable change. In addition, due to incomplete records, many of the bird species that qualified for the > 1 % of the population were based on a small number of observations or counts. It is recommended that this criterion is revised and the limit of acceptable change revised as more data becomes available	It is recommended that these measures be treated as "trigger values" rather than absolute measures. In interpreting results consideration should be given to climatic patterns and their potential effect on bird numbers in the Ramsar site. Support > 20,000 total waterbirds in 4 out of 5 years Support > 1 % of the population of the following birds 3 out of 5 years: Banded Stilt (3000) Red-necked Stint (3200) Red-capped Plover (950) Red-necked Avocet (1100) Fairy Tern (60) Curlew Sandpiper (1800) Sharp-tailed Sandpiper (1600) Musk Duck (250) Australasian Shoveller (120) Eurasian Coot (10,000) Grey Teal (20,000) Breeding recorded for waterbird species (Pelicans, Little Pied Cormorants, Little Black Cormorants, Black Swan, Grey Teal, Darter and Black-winged Stilt) a minimum of once every three years.

Table 41: Limits of acceptable change for the Yalgorup Lakes.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
ABIOTIC COMPONENTS		
Nutrients	Dissolved inorganic nutrients are those that are available for plant uptake and therefore the most indicative of tropic status. Lane and Davies (1993) collected some information from Lake Clifton and this forms the baseline for this limit. It is likely that the limit will need to be refined as more data is collected	PO_4, NH_4, NO_x - median concentrations < 10 µg/L
Salinity	Although many of the lakes are hypersaline, the thrombolite communities are reliant on freshwater.	Lake Clifton salinity < 35 ppt maximum and < 25 ppt during winter and spring
Groundwater discharge	Data deficient	A surrogate based on water levels in the lakes may be able to be developed.
pH	Yalgorup Lakes are within a landscape considered at high risk from acid sulfate soils. Thrombolites rely on alkaline conditions for growth. Natural pH is between 7.2 and 8.5	pH > 7 at all times
PRIMARY RESPONSES		
Phytoplankton	Data deficient	Baseline must be set before limits can be made.
Macroalgae	This is particularly important for the thrombolite communities at Lake Clifton, but is currently data deficient	No sustained epiphytic macroalgal growth on thrombolites at Lake Clifton
KEY SPECIES AND COMMUNITIES		
Invertebrates	Insufficient information to set a baseline for most invertebrate communities. These organisms form a large component of the food source for many of the waterbirds at the lakes	Limit of acceptable change not able to be set. However, Invertebrate populations sufficient to sustain waterbird populations should be maintained.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
Fish	There are only isolated records of fish from Lake Clifton and no other information from other lakes	Baseline must be set before limits can be made.
Waterbirds	The Yalgorup lakes: • support > 1% of the population of five species; and • supports breeding of eight species The high natural variability and strong influence of external factors for most waterbirds presents difficulties when setting limits of acceptable change. Breeding records for some species are well documented (eg Hooded Plover) but for others are based on isolated incidents. The Limits of Acceptable change have been set for species regularly observed breeding at the site only. This should be revised when further information becomes available	It is recommended that these measures be treated as "trigger values" rather than absolute measures. In interpreting results consideration should be given to climatic patterns and their potential effect on bird numbers in the Ramsar site. Support > 1 % of the population of the following birds 3 out of 5 years: Banded Stilt (3000) Red-necked Stint (3200) Hooded Plover (60) Musk Duck (250) Shelduck (2400) Successful breeding recorded for waterbird species (Black Swans, Hooded Plover, Red-capped Plover, Banded Lapwing and Great Crested Grebe).
Thrombolites	The thrombolites are a significant ecological community. However, it is not possible to measure their condition directly, with the exception of bleaching and death. It is recommended that abiotic factors be used as a surrogate for managing these communities	No loss of thrombolites at Lake Clifton.

Table 42: Limits of acceptable change for Lakes McLarty and Mealup.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
ABIOTIC COMPONENTS		
Nutrients	Dissolved inorganic nutrients are those that are available for plant uptake and therefore the most indicative of tropic status. However this is data deficient at Lakes McLarty and Mealup and likely to be highly seasonal as water levels fluctuate. As a consequence, trigger values for south-west Australian wetlands have been adopted (ANZECC 2000)	PO_4 < 30 µg/L NH_4, < 40 µg/L NO_x < 100 µg/L All to be applied only when water levels are > 500mm
Salinity	These represent the only freshwater systems within the Peel-Yalgorup site. However, salinity will fluctuate as water levels rise and fall. Salinity should be based on the tolerances of the water dependant species and as such should be measured at times when these communities are inundated	Salinity under rush and sedge communities < 1 ppt Salinity under paperbark communities < 0.5 ppt
pH	McLarty and Mealup are within a landscape considered at high risk from acid sulfate soils. Natural pH is between 7.2 and 8.5 for McLarty, but has declined to between 3.1 and 4 for Lake Mealup. As such a limit for Lake Mealup has not been set, but will need to be based on further investigative work	pH > 7 at all times in Lake McLarty
Groundwater discharge	Data deficient	A surrogate based on water levels in the lakes may be able to be developed.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
PRIMARY RESPONSES `		
Phytoplankton	Data deficient	Baseline must be set before limits can be made
Aquatic plants	Reports of *Lemna* growth across the water surface which could be a response to eutrophication. Prolonged and extensive growth could reduce dissolved oxygen concentrations	Greater than 50% of open water not covered in floating aquatic plants
Littoral vegetation	Dominated by freshwater reeds, but encroachment of *Typha* sited as a problem at both wetlands. Sedges are and important habitat component for some waterbirds	*Typha* limited to < 20 % of the wetland area Freshwater sedges covering a minimum of 20% of the wetland area
Paperbark	Fringing freshwater paperbark community which is an important habitat for waterbirds No quantitative information	No decline in paperbark health No net loss of extent of paperbark community
KEY SPECIES AND COMMUNITIES		
Invertebrates	Insufficient information to set a baseline for most invertebrate communities. These organisms form a large component of the food source for many of the waterbirds at the lakes	Limit of acceptable change not able to be set. However, Invertebrate populations sufficient to sustain waterbird populations should be maintained
Waterbirds	Lakes McLarty and Mealup: • support > 20,000 waterbirds regularly; • support > 1% of the population of ten species; and • support breeding of twelve species However, waterbird numbers are highly variable and there has been no systematic, long term monitoring of theses birds within the estuary to enable a numerical baseline to be set. In addition, the high natural variability and strong influence of external factors for most waterbirds presents difficulties when setting limits of acceptable change. Due to incomplete records, many of the bird species that qualified for the > 1 % of the population were based on a small number of observations or counts. It is recommended that this criterion is revised and the limit of acceptable change revised and more data becomes available. In addition, breeding records for some species are well documented (eg Dusky Moorhen and Purple Swamphen) but for others are based on isolated incidents. The Limits of Acceptable change have been set for species regularly observed breeding at the site only. This should be revised when further information becomes available.	It is recommended that these measures be treated as "trigger values" rather than absolute measures. In interpreting results consideration should be given to climatic patterns and their potential effect on bird numbers in the Ramsar site. Support > 20,000 total waterbirds in 4 out of 5 years Support > 1 % of the population of the following birds 3 out of 5 years: Banded Stilt (2100) Red-necked Stint (3200) Red-capped Plover (950) Red-necked Avocet (1100) Curlew Sandpiper (1800) Black-winged Stilt (3000) Sharp-tailed Sandpiper (1600) Australian Shelduck (2400) Eurasian Coot (10,000) Breeding recorded for waterbird species (Australian Shelduck, Black Swan, Grey Teal, Pacific Black Duck, Great Crested Grebe, Purple Swamphen, Dusky Moorhen, Spotless Crake, Little Pied Cormorant and Darter) a minimum of once every three years.

Table 43: Limits of acceptable change for Lakes Goegrup and Black.

COMPONENT	BASELINE/SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE
ABIOTIC COMPONENTS		
Nutrients	Dissolved inorganic nutrients, which are the form available for uptake. Current baseline suggests peaks in winter, but low concentrations during summer and autumn	PO_4, NH_4, NO_x - median concentrations < 10 µg/L
Salinity	Although marine systems have a large buffering capacity, disturbance of acid sulfate soils have the potential to lower pH values. Baseline conditions indicate pH typically 7.3 to 8.5	pH > 7 at all times
pH	Although the marine influence on the estuary cannot be managed, seasonal salinity fluctuations are important for biota. Fish such as the long-headed river goby require salinities of < 30 ppt to trigger spawning. Some waterbirds require fresh drinking water (< 3 ppt)	Winter salinity in the centre of the Peel Inlet and Harvey Estuary < 30 ppt for a minimum of 3 months. Water in the Harvey River mouth over winter < 3 ppt
PRIMARY RESPONSES		
Phytoplankton	Phytoplankton blooms are common	Limit should be lower than current conditions, further investigations should be undertaken in order to set realistic limits.
Samphire	Approximately 83 hectares when mapped in 2006. However, there is no information on the natural variability in this community	Extent and distribution of samphire within patterns of natural variation.
Paperbark	Fringing areas of both freshwater (47 ha) and saltwater paperbark (145 ha) communities. These perennial woody vegetation complexes would have low natural variability in extent	No change in the condition of paperbark communities. No loss of extent of paperbark communities.
KEY SPECIES AND COMMUNITIES		
Invertebrates	Insufficient information to set a baseline for most invertebrate communities. These organisms form a large component of the food source for many of the waterbirds at the lakes	Limit of acceptable change not able to be set. However, Invertebrate populations sufficient to sustain waterbird populations should be maintained.
Fish	Fish data for Goegrup is based on records that are > 25 years old. There have been no recent surveys and current populations are unknown	Baseline must be set before limits can be made.
Waterbirds	Waterbird records for Lakes Goegrup and Black are patchy and based on isolated surveys. There is no baseline information, although anecdotal records that the extensive saltmarsh and open water habitats support waterbird communities	Baseline must be set before limits can be made.

8. SUMMARY OF KNOWLEDGE GAPS

Throughout the Ecological Character Description for the Peel-Yalgorup Ramsar site, mention has been made of knowledge gaps and data deficiencies for the system. Scientists and natural resource managers have requirements for knowledge and a desire to fully understand complex wetland systems. There is much still to be learned about the interactions between components and processes in this and other wetlands. In addition, for the Peel-Yalgorup Ramsar site there are a number of key attributes that have yet to be fully described or for which data is limited to that collected in decades past. While it is tempting to produce an infinite list of research and monitoring needs for this wetland system, it is important to focus on the purpose of an ecological character description and identify and prioritise knowledge gaps that are important for describing and maintaining the ecological character of the system.

The key knowledge gaps that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table 44, together with a brief description of the action required to address these gaps. A more detailed monitoring framework for these and assessing against limits of acceptable change is provided in Section 9.

Table 44: Knowledge gaps and recommended actions.

COMPONENT/PROCESS	KNOWLEDGE GAP	RECOMMENDED ACTION
PEEL-HARVEY ESTUARY		
Water Quality – Acid Sulfate Soils	A survey conducted in 2005–2006 indicated that this could be a potential problem. The effect on water quality (pH and contaminant concentrations – selenium) is not known or understood	Comprehensive investigation of the potential and actual threat to water quality and ecological character of the site
Phytoplankton	Current extent, frequency, duration and distribution of algal blooms in the Peel Inlet and Harvey Estuary. Long-term data sets existed for 1970s to 2001. However, there is a gap in the data from 2002 to current	Monitoring of chlorophyll *a* concentrations within the estuary
Aquatic Plants	Community composition, distribution and temporal patterns of seagrass and macroalgal communities within the estuary Final mapping was undertaken in 2001	Mapping of extent, biomass and species composition within the estuary
Littoral vegetation	Current extent and condition of salt marsh vegetation. Last comprehensive survey was undertaken in 1994	Mapping (remote sensing) and condition assessments (on-ground)
	Current extent and condition of paperbark communities. Last investigated in 1998	Mapping (remote sensing) and condition assessments (on-ground)
Fish	Current community composition and abundance of fish communities Last comprehensive survey was undertaken in 1996–97 and this did not include freshwater species	Fish surveys
Waterbirds	While there are waterbird records from the Peel-Harvey stretching back to the 1970s, there has been no systematic survey and reporting of abundance, species composition or breeding There is insufficient data to determine spatial and temporal trends or habitat usage	Regular, systematic, comprehensive waterbird surveys

COMPONENT/PROCESS	KNOWLEDGE GAP	RECOMMENDED ACTION
YALGORUP LAKES		
Hydrology	There is little information on the water levels within the lakes and the inflowing of groundwater There is concern that extraction from the surficial aquifer may be affecting both quality and quantity of water in the lakes	Groundwater monitoring Lake level monitroing
Water Quality	There is no comprehensive data on water quality (salinity or nutrients) from the lakes upon which trends could be assessed. However, investigations from the early 2000s suggest that salinity and nutrients may be increasing and that this could impact on the thrombolites	Regular water quality monitoring
Aquatic plants	There is no recent information on the extent and condition of aquatic plants in the lakes. Of particular concern is the charaphyte in Lake Pollard (which provides a valuable food source to waterbirds) and the *Cladophora* in Lake Clifton (which may be threatening the thrombolites)	Monitoring of the charaphytes at Lake Pollard and the extent and duration of *Cladophora* on the thrombolites
Fish	Black Bream in Lake Clifton pose an unknown threat to the thrombolites. Their feeding patterns and effect on the thrombolites is not known	Investigation into the potential and actual threat that Black Bream pose to the thrombolites
Waterbirds	Trends in waterbird populations at the lakes. While there is an extensive dataset on the waterbirds at the Yalgorup Lakes, this is the result of community monitoring. As such it is under resourced and rarely analysed and published	An analysis of existing data and a formalisation of the survey process
Lakes McLarty and Mealup		
Hydrology	There is little information on the water levels within the lakes and the inflowing of groundwater There is concern that extraction from the surficial aquifer may be affecting both quality and quantity of water in the lakes	Groundwater monitoring Lake level monitoring
Water quality	There is limited data on water quality (salinity or nutrients) from the lakes and that collected has been undertaken by volunteer organisations who require greater support	Regular water quality monitoring
Flora	Extent and distribution of sedgelands is not currently known However, there is evidence that the sedges and rushes that were once extensive at these lakes have declined In addition the impact of cattle grazing on the system is not known	Mapping and condition of sedges/rushes Investigation into the impacts of cattle grazing on the system
	The extent and condition of the paperbark community upon which many bird species are reliant for roosting and nesting is not known	Mapping and condition of paperbark community

COMPONENT/PROCESS	KNOWLEDGE GAP	RECOMMENDED ACTION
Waterbirds	There is no systematic data on waterbirds from the lakes upon which trends in breeding, abundance and habitat usage could be assessed Monitoring is ad hoc and undertaken by interested locals	Formal, systematic, regular bird surveys
LAKES GOEGRUP AND BLACK		
Hydrology	The hydrology of the two lakes is poorly documented	Water levels, tidal fluctuations
Water quality	There is little data on water quality (salinity or nutrients) from the lakes themselves However, monitoring of the Serpentine River suggest that eutrophic conditions prevail for much of the year	Regular water quality monitoring
Fish	Current community composition and abundance of fish communities Last comprehensive survey was undertaken in 1979–81	Fish surveys
Waterbirds	While there are waterbird records from the lakes, there has been no systematic survey and reporting of abundance, species composition or breeding There is insufficient data to determine spatial and temporal trends or habitat usage	Regular, systematic, comprehensive waterbird surveys

9. MONITORING NEEDS

As a signatory to the Ramsar Convention, Australia has made a commitment to protect the ecological character of its Wetlands of International Importance. Under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* a person must not take an action that has, will have or is likely to have a significant impact on the ecological character of a declared Ramsar wetland. While there is no explicit requirement for monitoring the site, in order to ascertain if the ecological character of the wetland site is being protected a monitoring program is required.

While there are existing monitoring programs in place for components within the Peel-Yalgorup site, there is no over-arching monitoring program designed to detect and manage changes to the ecological character of the wetlands. A management plan is currently in preparation for the system, which will act as an overarching guide for decision makers and stakeholders in the region. A robust monitoring program will be a part of this management planning process.

A comprehensive monitoring program is beyond the scope of this ecological character description. What is provided is a brief summary of existing monitoring and an identification of monitoring needs required to both set baselines for key components and processes and to assess against limits of acceptable change.

9.1 EXISTING MONITORING PROGRAMS

9.1.2 WETLAND MAPPING, CLASSIFICATION AND EVALUATION PROGRAM FOR PRIORITY WETLANDS, SOUTH WEST WESTERN AUSTRALIA (SYRINX ENVIRONMENTAL 2007, COORDINATED BY DEC)

The Department of Environment and Conservation (DEC) is undertaking the above project with funding under the Natural Heritage Trust (NHT) and the National Action Plan for Salinity and Water Quality (NAP). The program involves wetland mapping, classification and evaluation within an identified study area, as well as monitoring of 20 wetlands to assist in developing their baseline condition. A monitoring program will be then developed, under guidance of specialist staff from DEC and Department of Water (DoW), to ensure consistency with data from existing monitoring programs. The data will be made available via the Statewide Wetlands database.

This program included Lake McLarty and lake Hayward (Yalgorup Lakes) in the baseline monitoring program and a survey was conducted at the lake in December 2006. Parameters measured included: extent of inundation, pH, dissolved oxygen, salinity, temperature, colour, nutrients (total and dissolved nitrogen and phosphorus), turbidity, chlorophyll *a*, macroinvertebrate diversity and community composition, vegetation structure and composition. Unfortunately, Lake McLarty was close to dry at the time of sampling and the data collected is not indicative of the condition of the wetland when inundated (Syrinx Environmental 2007).

The sampling was a one-off event and it is not known if there will be continued or a more frequent program established.

9.1.3 DRAFT WATER QUALITY IMPROVEMENT PLAN FOR THE PEEL INLET-HARVEY ESTUARINE SYSTEM (EPA 2007)

A monitoring strategy has been developed as a part of the Water Quality Improvement Plan (WQIP) for the estuarine sections of the Peel-Yalgorup Ramsar site. The plan outlines a program for monitoring both in the catchment as well as within the estuary. The monitoring program provides ten specific monitoring outcomes for the Peel-Harvey Estuary (Text Box 3) and a complete program that includes sites, parameters and field techniques is provided in Rose (2003).

There is however, no detailed guidance provided for the biotic components of fish, invertebrates and waterbirds, nor is it clear when these programs will commence.

1. Conduct water quality sampling for nutrients and phytoplankton weekly between October and April, ie for 6 months, reduced to fortnightly between April and September. This could be increased to weekly all year if significant funding becomes available.
2. Phytoplankton sampling will provide the basis for early warning public health surveillance (as such there will be a need to be a service agreement with the Phytoplankton Ecology Unit to process samples within sufficient time to provide advice to the Department of Health and other authorities with health responsibilities).
3. Conduct seasonal macroalgae and seagrass field surveys that include 2x yearly synchronised with aerial photographic runs to allow development of future photographic survey techniques. This seasonal survey work should evaluate the value of incorporating three weekly surveys during the most active growing season between mid-spring and early summer.
4. Process investigations lasting between 24 to 48 hours should be evaluated and undertaken to study metal, nutrient and biological fluxes during certain events or poor water quality periods. Work should be focussed on evaluating how fluxes change, how this will affect future water quality and if management options exist. For example, studying diel nutrient and metal fluxes when hypoxic conditions are chronic during the summer and seeing if any intervention techniques are feasible or necessary and how these fluxes may affect aquatic animal health.
5. Conduct nutrient limitation bioassays for phytoplankton, on a weekly to seasonal basis.
6. Seasonal benthic and zooplankton surveys should be conducted to link water quality and macrophyte conditions with invertebrate communities to determine trophic health and productivity as well as for the general estuarine health of the Peel-Harvey estuarine system.
7. Bird and fish surveys should also be conducted to link these communities with estuarine environmental health and to monitor changes relevant to recreational and commercial fishing as well for international treaty obligations.
8. Sampling analysis plans including data management; analysis framework and reporting will be prepared for operation of the estuarine monitoring program.
9. Encourage and develop an estuarine modelling capacity that is predictive and management oriented and can use estuarine and catchment water quality monitoring data for verification and calibration.
10. Develop and fortify the link and information requirements between the WQIP, estuarine environmental-nutrient targets and catchment – landuse activities.

Text Box 3: Estuarine monitoring recommendations contained in the Draft WQIP (EPA 2007).

9.1.4 HISTORICAL AND CURRENT MONITORING IN THE PEEL-HARVEY ESTUARY

The Peel-Harvey CD_ROM (Kobryn *et al.* 2002) contains water quality data from the Peel-Harvey Estuary collected over the period August 1977 to June 2001. Frequency varies between weekly and monthly, however the sampling occurred at the same six sites (three in the Peel Inlet and three in the Harvey Estuary. Parameters included: pH, dissolved oxygen, salinity, secchi depth, temperature, salinity, total nitrogen, total phosphorus, nitrate-nitrite, ammonium, phosphate, silicate and chlorophyll *a* from surface and bottom waters.

Currently water quality is assessed at the same six sites, plus additional locations within the Serpentine, Murray and Harvey Rivers, approximately 8 times per year. Samples are analysed for the same water quality parameters listed above as well as for phytoplankton identification and enumeration.

Biomass, community composition and distribution of macroalgae and seagrass in the Peel-Harvey Estuary were also monitored over the period 1977 to 2001. From 1977 to 1993, samples were collected seasonally (four times a year) from 43 sites across the estuary, and for the period 1994–2001 this was reduced to twice annually in spring and summer. Results were entered into a computer program that allowed for calculations of biomass and mapping of distribution.

Extent of saltmarsh was assessed from aerial photography over the period 1957 to 1994 (Glasson *et al*. 1995) and on-ground assessments of saltmarsh condition were conducted between 1994 and 1998 at a number of locations around the estuary (Monks and Gibson 2000).

There is no current monitoring of aquatic plants or littoral vegetation in the Peel-Harvey Estuary.

9.1.5 FISH

The data for fish in the system is a product of two processes, regular monitoring of commercial fisheries (Fisheries WA) and isolated research projects from universities (eg Young and Potter 2000; Sarre and Potter 1999). While this has provided some information on composition and abundance of the fish communities in the Peel-Harvey Estuary, there is little information for other wetlands in the Ramsar site and insufficient data to detect trends in any but the commercial species. Further in the most recent fisheries report (Fisheries WA 2006) concern was raised over the adequacy of monitoring data currently collected even for commercial species (Text Box 4).

> Historically, monitoring of fisheries and fish stocks in the west coast estuaries has been based on monthly catch and effort statistics (CAES) provided by commercial fishers.
>
> This valuable data set has provided consistent, longterm information for monitoring estuarine fish, including recreationally important stocks where they are harvested by both sectors. CAES data are interpreted using the extensive scientific knowledge of the fish stocks in estuaries derived from research by Department of Fisheries and Murdoch University scientists since the 1970s.
>
> In recent years, reduced levels of commercial fishing activity have occurred as a result of voluntary fishery adjustment schemes (i.e. licence buy-backs). As a result, commercial catch and effort data are no longer providing adequate information to assess the status of certain estuarine stocks. Additional monitoring strategies to enable the recreational sector and/or independent surveys to contribute data to assessments of our important estuarine fish and crustaceans are required. The Research Angler Program and annual research surveys of juvenile fish recruitment are among the strategies now being employed by the Department to meet this need. At the same time, even greater co-operation from the remaining commercial fishers is required to provide fine-scale catch and effort data that can be used to derive a CPUE-based index of abundance for target species. A new commercial fishing daily log book to record fine-scale data is being developed in consultation with estuary fishers.
>
> Where only a small number of fishers are actively involved in a particular fishery, the data are subject to the Department of Fisheries' confidentiality policy as it relates to the Fish Resources Management Act 1994 and are not reported separately. While not able to be published here, these confidential data are used by the researchers to monitor the status of the stocks and provide advice to management.

Text Box 4: Extract from 2005/9 Fisheries report on commercial fisheries (Fisheries WA 2006).

9.1.6 WATERBIRDS

There is currently no systematic waterbird monitoring program for the Peel-Yalgorup Ramsar site. There are a number of dedicated volunteer individuals and organisations that undertake surveys of parts of the system and a number of regular surveys conducted at specific locations for private development organisations. In some instances data is passed onto Birds Australia or Birds Western Australia, but not in all instances.

9.1.7 MANAGEMENT PLANS

Although the management plan for the Peel-Yalgorup Ramsar site is currently being developed, there are management plans for some of the wetlands within the system (Yalgorup Lakes; Lake McLarty and Goegrup and Black Lakes). While each of these recognises the need for monitoring of the condition of the wetlands and lakes and there is mention of monitoring of birds and groundwater aquifers, there is no comprehensive monitoring program. In addition, there does not appear to be a system in place for reporting the results of monitoring or for their interpretation and use to improve the management of the site.

9.2 MONITORING OF ECOLOGICAL CHARACTER

The recommended monitoring to meet the obligations under Ramsar and the EPBC Act (1999) with respect to the Peel-Yalgorup Ramsar site are provided in Table 45. While there are some programs in place that will meet these monitoring requirements, there are others that will need to be established or augmented. In recognition that there will be limited funds for monitoring, a priority has been assigned to each component.

Detailed monitoring design is essential to ensure that appropriate and useful data is collected. Although a detailed monitoring program design for each of these components is beyond the scope of an ecological character description, it is recommended that the Ramsar framework for monitoring wetlands be used as a guide in developing monitoring programs (Text Box 5).

Problems/issues - State clearly and unambiguously - State the known extent and most likely cause - Identify the baseline or reference situation

Objective - Provides the basis for collecting the information - Must be attainable and achievable within a reasonable time period

Hypothesis - Assumption against which the objectives are tested - Underpins the objective and can be tested

Methods & variables - Specific for the problem and provide the information to test the hypothesis - Able to detect the presence, and assess the significance, of any change - Identify or clarify the cause of the change

Feasibility/cost - Determine whether or not monitoring can be done regularly effectiveness and continually - Assess factors that influence the sampling programme: availability of trained personnel; access to sampling sites; availability and reliability of specialist equipment; means of analysing and interpreting the data; usefulness of the data and information; means of reporting in a timely manner - Determine if the costs of data acquisition and analysis are within the existing budget

Pilot study - Time to test and fine-tune the method and specialist equipment - Assess the training needs for staff involved - Confirm the means of analysing and interpreting the data

Sampling - Staff should be trained in all sampling methods - All samples should be documented: date and location; names of staff; sampling methods; equipment used; means of storage or transport; all changes to the methods - Samples should be processed within a timely period and all data documented: date and location; names of staff; processing methods; equipment used; and all changes to the protocols - Sampling and data analysis should be done by rigorous and tested methods

Analyses - The analyses should be documented: date and location (or boundaries of sampling area), names of analytical staff; methods used; equipment used; data storage methods

Reporting - Interpret and report all results in a timely and cost effective manner - The report should be concise and indicate whether or not the hypothesis has been supported - The report should contain recommendations for management action, including further monitoring

Text Box 5: Ramsar framework for monitoring wetlands (Annexure to Resolution VI.1: http://www.Ramsar.org/res/key_res_vi.1.htm)

Of interest is the difference between monitoring and surveillance (Finlayson 2001):

"Wetland Monitoring: Collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. (Note that the collection of time-series information that is not hypothesis-driven from wetland assessment should be termed surveillance rather than monitoring.)"

Unfortunately, with the exception of water quality and benthic plants in the Peel-Harvey Estuary, there has been little structured monitoring in this system. The need for co-ordinated, purpose designed, objective driven monitoring of ecological character in the Peel-Yalgorup system must be emphasised.

In addition to the required monitoring; there are a number of areas where there is incomplete understanding of processes and threats. While these may not require the establishment for monitoring programs, there is a need for research or investigations to enable the site to be managed to maintain ecological character. Specifically these are:

1. Acid Sulfate Sediments – High Priority

Based on the severity and extent of acid sulfate soils found by Sullivan *et al*. (2006) in their preliminary investigation of the Peel Inlet, they recommended a immediate investigation of the extent of disturbed acid sulfate soils, the actual and potential future impact of these soils and identification of remedial actions. In addition, the high concentrations of selenium associated with these soils also require investigation. Given that this is a threat that is located within the Ramsar site and has the potential to negatively impact on the ecological character of the site, the recommended investigations of Sullivan *et al.* (2006) are considered a high priority.

2. Threats to the Thrombolites at Lake Clifton – High Priority

The thrombolites at Lake Clifton represent a unique community. Increasing nutrients, increased salinity, *Cladophora* and Black Bream have all been identified as potential threats to the thrombolites at Lake Clifton. However, there is much about their ecological tolerances that remains unknown. As such, investigations into the actual threats and condition of the thrombolites are considered a high priority.

3. Cattle Grazing at Lakes McLarty and Mealup – High Priority

Controlled grazing is used as a management technique at Lake McLarty. However, there is evidence of increased eutrophication and altered vegetation communities at this wetland. Experience from other wetlands in Australia has indicated that cattle can cause damage to wetland systems and result in changes to ecological character. As such a targeted investigation into the effect of cattle grazing on the wetland is considered a high priority.

4. Effect of vegetation changes on non-wading waterbirds at Lake McLarty – Medium Priority

The vegetation at Lake McLarty has changed dramatically since the time of listing, with a loss of the once dominant sedge community. Although this may have benefited wading species of waterbird, it has potentially had a negative impact on others. Specifically, the Australasian Bittern was formerly a regular inhabitant and probable breeding species within the Ramsar site (R. Jaesch, pers. comm.). With the loss of the sedges, it is likely that Australasian Bittern no longer occurs here. This is consistent with an ongoing decline in the western population of Australasian Bittern, driven by habitat loss and changes. Given that there are many other areas within the Ramsar site that provide habitat for migratory waders, but none that offer the sedgeland habitat, an investigation into the effects on non-wading birds and the Australasian Bittern is considered a priority.

Table 45: Monitoring needs for the Peel-Yalgorup Ramsar Site.

COMPONENT/ PROCESS	PURPOSE	INDICATOR	LOCATIONS	FREQUENCY	PRIORITY
PEEL-HARVEY ESTUARY					
Water Quality	Detection of change	pH, salinity, dissolved oxygen, turbidity, secchi depth, total and dissolved nutrients, chlorophyll *a*	At the six historical water quality sites	Weekly over spring and summer, monthly over winter	High
Phytoplankton	Detection of change	Identification and enumeration	At the six historical water quality sites	Weekly over spring and summer, monthly over winter	Medium
Aquatic Plants	Establishment of a baseline and then detection of change	Distribution, composition and biomass	Across the two basins	Seasonally	High
Littoral Vegetation	Establishment of a baseline and then detection of change	Extent and condition of samphire and paperbark communities	Extent via remote sensing across the two basins Condition and composition at historical sites (Monk and Gibson 2000)	Establish a baseline then every 2–5 years	High
Invertebrates	Establishment of a baseline and then detection of change	Composition and abundance	At the six historical water quality sites	Annually in spring	Low
Fish	Establishment of a baseline and then detection of change	Composition and abundance (protocol of Loneragan et al. (1986)	At the six historical fish sites	Annually	Medium
Waterbirds	Establishment of a baseline and then detection of change	Ground and aerial surveys of waterbird species and abundance Targeted surveys of breeding Emphasis on rigorous, objective driven monitoring design	Across the two basins	Bi-annual surveys Weekly within critical periods for species specific information	High
YALGORUP LAKES					
Hydrology	Establishment of a baseline and then detection of change	Lake and aquifer levels	At each of the lakes	Weekly	High
Water Quality	Establishment of a baseline and then detection of change	pH, salinity, dissolved oxygen, turbidity, total and dissolved nutrients, chlorophyll *a*	At Lakes Clifton, Preston and Pollard as well as groundwater – at a minimum	Minimum of monthly	High
Aquatic Plants	Establishment of a baseline and then detection of change	Distribution and composition	Lakes Pollard and Clifton	Seasonally	Medium
Littoral Vegetation	Establishment of a baseline and then detection of change	Extent and condition of samphire and paperbark communities	Extent via remote sensing Condition and composition at ground sites	Establish a baseline then every 2–5 years	Low
Invertebrates	Establishment of a baseline and then detection of change	Composition and abundance	At each of the lakes	Annually in spring	Low
Fish	Establishment of a baseline and then detection of change	Composition and abundance	Lake Clifton	Annually	Low
Waterbirds	Detection of change	Ground and aerial surveys of waterbird species and abundance Targeted surveys of breeding Emphasis on rigorous, objective driven monitoring design	Across all lakes	Bi-annual surveys Weekly within critical periods for species specific information	High

COMPONENT/ PROCESS	PURPOSE	INDICATOR	LOCATIONS	FREQUENCY	PRIORITY
LAKES MCLARTY AND MEALUP					
Hydrology	Establishment of a baseline and then detection of change	Lake and aquifer levels	At both lakes	Weekly	High
Water Quality	Establishment of a baseline and then detection of change	pH, salinity, dissolved oxygen, turbidity, total and dissolved nutrients, chlorophyll *a*	At both lakes	Minimum of monthly	High
Littoral Vegetation	Establishment of a baseline and then detection of change	Extent and condition of sedge, samphire and paperbark communities	Extent via remote sensing Condition and composition at ground sites	Establish a baseline then every 2–5 years	High
Invertebrates	Establishment of a baseline and then detection of change	Composition and abundance	At both lakes	Annually in spring	Low
Waterbirds	Detection of change	Ground and aerial surveys of waterbird species and abundance Targeted surveys of breeding Emphasis on rigorous, objective driven monitoring design	Across both lakes	Bi-annual surveys Weekly within critical periods for species specific information	High
Lakes Goegrup and Black					
Water Quality	Establishment of a baseline and then detection of change	pH, salinity, dissolved oxygen, turbidity, secchi depth, total and dissolved nutrients, chlorophyll *a*	Sites within both lakes	Weekly over spring and summer, monthly over winter	High
Phytoplankton	Detection of change	Identification and enumeration	At water quality sites	Weekly over spring and summer, monthly over winter	Medium
Littoral Vegetation	Detection of change	Extent and condition of samphire and paperbark communities	Extent via remote sensing across the two basins Condition and composition at historical sites (Monk and Gibson 2000)	Every 2–5 years	Medium
Invertebrates	Establishment of a baseline and then detection of change	Composition and abundance	Sites within both lakes	Annually in spring	Low
Fish	Establishment of a baseline and then detection of change	Composition and abundance (protocol of Loneragan et al. (1986)	Sites within both lakes	Annually	Medium
Waterbirds	Establishment of a baseline and then detection of change	Ground and aerial surveys of waterbird species and abundance Targeted surveys of breeding Emphasis on rigorous, objective driven monitoring design	Within both lakes	Bi-annual surveys Weekly within critical periods for species specific information	High

10 COMMUNICATION AND EDUCATION

Under the Ramsar Convention a Program of Communication, Education and Public Awareness 2003-2008 was established to help raise awareness of wetland values and functions. The program calls for coordinated international and national wetland education, public awareness and communication. In response to this, Australia has established the Wetland Communication, Education and Public Awareness (CEPA) National Action Plan 2001-2005. Australia's National Action Plan provides an umbrella for coordinated activities across Australia. It is an evolving plan that will document and provide guidance towards the collaboration of effectively delivered CEPA activities.

Current CEPA activities relevant to the Peel-Yalgorup Ramsar site include:

- The Peel-Harvey Catchment Council, a community based Natural Resource Management Organisation has worked with local governments to install information signs and banners around the wetlands
- Winjan Aboriginal Cultural Centre is open to the public and has a program which includes cultural tours and activities, art workshops, tool-making and weapon demonstration, a bush story trail and 'tucker' tasting
- "Mandurah Samphire, Life on the Estuary Fringe. A resource for teachers" is designed for use in primary and secondary schools. It includes a variety of activities, printable worksheets and electronic templates
- The State Government's Ribbons of Blue Program focuses on working with community groups and schools in waterway conservation projects. The program includes a water quality monitoring project at Lake McLarty (led by the Peel Preservation Group)
- The Peel Waterways Centre is open to the public for the purpose of providing information and resources in relation to the waterways of the Peel-Harvey Catchment. The Centre provides meeting facilities, a library, computer access and other resources to assist those actively involved or interested in protecting our waterways and environment. A monthly workshop series is also held at the Centre (on a Thursday evening) providing presentations on various aspects of Natural Resource Management from around region
- Birds Australia coordinate shorebird monitoring projects throughout the all three subsystems of the Peel-Yalgorup System. Examples include a campaign to "Help Save Yalgorup's Hooded Plovers" and a information booklet on the shorebirds of Lake McLarty
- City of Mandurah program for schools which incorporates messages such as the Blue Crab Stormwater Education Package, Bushcare and Mandurah Samphire - Life on the Estuary Fringe Education Package (by Cedar Woods for Creery Wetlands) - www.creerywetlands.info.

Following on from the identified threats to the ecological character of the Peel- Yalgorup Ramsar site (see Section 6, above), there are a number of communication and education messages that could be given priority in addition to the programs listed above. These include:

- Responsible boating – how to minimise disturbance to foreshores and biota;
- Effect of disturbance on migratory birds – the importance of energy conservation for migratory birds and steps the community can take to minimise shorebird disturbance by walking, boating, recreational vehicles and domestic pets;
- Privacy for nesting birds - the impact of disturbance on nesting birds (particularly species such as pelicans that nest on beaches of accessible islands) and ways in which the community can undertake recreational activities while minimising disturbance to nests; and
- The uniqueness of the thrombolites and their fragility – in addition to the information located at the boardwalk, a broader campaign to inform the community and tourists of the existence and rarity of these communities.

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APPENDIX A: FISH SPECIES

Based on species listed in Loneragan *et al.* (1986, 1987); Potter et al. (1998) and Young and Potter (2003b and 2003c). Percentages are from Young and Potter (2003c) unless otherwise stated Life cycle category based on Potter *et al.* (1990) and Potter and Hyndes (1999) - A-Anadromous, C-Catadromous, E- Breeds in estuaries, F-Fresh water, O - marine estuarine-opportunist, E&M – species represented by separate estuarine and marine populations; S – marine straggler Environment and biological information sourced from FishBase (Froese, R. and D. Pauly. Editors. 2007.FishBase. World Wide Web electronic publication. www.fishbase.org , version (05/2007) (original references not cited).

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
Apogonidae -Cardinal fishes	Apogon rueppellii	Gobbelguts	E	Reef-associated; brackish; marine. Inhabit inshore reefs and estuaries. Occur in groups in weedy areas. Nocturnal species.	21.4 %	1.7 %
Arripidae	Arripis georgiana	Australian herring (or Tommy ruff)	O	Pelagic; brackish; marine; depth range 1–? m. Endemic to the southern coasts of Australia. Usually found inshore in bays and estuaries over seagrass beds or near areas of seaweed (e.g. kelp), on rocky reefs, and along ocean beaches. Juveniles are found in inshore coastal waters, bays and inlets	Not recorded	< 0.1 %
Atherinidae - Silversides	Atherinosoma elongata	Elongate hardyhead	E	Pelagic; brackish; marine. Endemic to Australia. Found in inshore waters.	3.7 %	12.1 %
	Allanetta mugiloides	Spotted hardyhead	E	Pelagic; brackish; marine. Mainly coastal and estuarine.	Not recorded	< 0.1 %
	Leptatherina presbyteroides (Atherinosoma presbyteroides)	Swan River hardyhead	O	Pelagic; marine. Endemic to Australia. Found in inshore waters	Not recorded	10.9 %
	Atherinosoma vaigiensis (Pranesus ogilby/ A. ogilby)	Ogilby's hardyhead	O	Pelagic; brackish; marine. Found in shallow coastal waters, including bays and estuaries; can tolerate salinity as low as 3 parts per thousand. Usually in schools. Feeds on amphipods, copepods, isopods, crab and barnacle larvae, polychaetes, gastropods, chironomid midges, hymenopterans, ants, foraminiferans, and plant matter. Opportunistic feeder.	3 %	0.6 %
	Leptatherina wallacei[2]	Western hardyhead	E	Pelagic; freshwater; brackish. Endemic to Australia. Occurs in clear, flowing freshwater streams and upper estuaries with reduced salinities. Often schools near the surface or around the shoreline vegetation and log debris. Often seen in shoals near the surface of slow-flowing pools. Feeds mainly on insects and small crustaceans. Spawns during spring and summer. Becomes sexually mature during the first year	0.8%	0.1%
	Allanetta mugiloides	Spotted hardyhead	E	Pelagic; brackish; marine. Mainly coastal and estuarine, often schooling with C. capreoli, Atherinomorus endrachtensis and A. ogilbyi. Diet includes crustaceans and diatoms. Breeds from December to March throughout the southern hemisphere. Appears to have a one year life span. May be food fish for larger commercially important fishes.	0.3 %	0.1 %
Paralichthyidae - Large-tooth flounders	Pseudorhombus jenynsii	Small-toothed flounder	O	Demersal; brackish; marine; depth range?–150 m. Occurs in estuaries and offshore over sand or mud bottoms. Feeds on various benthic animals.	0.4 %	0.4 %
Carangidae - Jacks and pompanos	Pseudocaranx dentex (Caranx georgianus)[1] Note that Loneragan et al. (1987) recorded P. wrighti	White trevally	O	Reef-associated; brackish; marine; depth range 10–200 m. Occur in bays and coastal waters, including estuaries. Juveniles usually inhabit estuaries, bays and shallow continental shelf waters, while adults form schools near the sea bed on the continental shelf. Schools are found at the surface, in mid-water and on the bottom and are often associated with reefs and rough bottom. Schools are sometimes mixed with Caranx koheru and Arripis trutta. Feed on plankton by ram-filtering and suction feeding and on bottom invertebrates.	Not recorded	<0.1 %

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
	Trachurus novaezelandiae (Trachurus mccullochi)[1]	Yellowtail horse mackerel	O	Pelagic; brackish; marine; depth range?–500 m. Occur in coastal waters, including estuaries, mostly in waters shallower than 150 m and warmer than 13°C. Commonly found on the bottom, in midwater and occasionally at the surface, in large schools. Adults are generally found over offshore rocky reefs, while juveniles are generally found in shallow, soft substrate areas.	< 1 % in Loneragan et al. (1987)	Not recorded
Clupeidae - Herrings, shads, sardines	Hyperlophus vittatus	Sandy sprat	O	Pelagic; amphidromous; brackish; marine; depth range 10–13 m. Schools in large numbers in shallow sandy areas of bays and estuaries.	6.5 %	17 %
	Sardinops sagax (Sardinops neopilchardus)[1]	South American pilchard		Pelagic; oceanodromous; marine; depth range 0–200 m. Neritic. A coastal species that forms large schools. Occur at temperatures ranging from 16° to 23°C in summer and from 10° to 18°C in winter. Feed mainly on planktonic crustaceans. Young fish feed on zooplankton such as copepod and adults on phytoplankton. Oviparous, with pelagic eggs, and pelagic larvae. Possibly can live up to 25 years. In the California region, pilchards make northward migrations early in summer and travel back south again in autumn. With each year of life, the migration becomes farther.	0.1 %	not recorded
	Spratelloides robustus	Fringe-scale round herring	O/S	Pelagic; brackish; marine; depth range 0-50 m Eastern Indian Ocean: southern Australia, from Dampier Archipelago, Western Australia to southern Queensland, including Tasmania. Usually inshore schooling fishes. Occurs in midwater in bays, inlets and coastal waters. Also often found around shallow offshore reefs	Not recorded	< 0.1 %
	Nematalosa vlaminghi	Western Australian gizzard shad	A	Pelagic; anadromous; brackish; marine. Abundant in estuaries; also found in coastal embayments. A filter-feeder. Eggs and larvae are pelagic. Used mainly for bait in the rock lobster fishery in Western Australia.	1.3 %	<0.1 %
Engraulidae - Anchovies	Engraulis australis	Australian anchovy	E	Pelagic; brackish; marine; depth range?–65 m. Found mostly inshore: chiefly in bays, inlets and estuaries, sometimes in low salinities. Older individuals tend to move out to sea in winter and back in the spring. Forms compact schools much preyed upon by larger fishes, common dolphins and birds. Feeds on plankton. Spawns in inlets, bays and also estuaries, probably throughout the year but mainly in late spring to early autumn and especially about November to February. The eggs are ellipsoidal.	< 1 %	0.9 %
Gerridae - Mojarras	Gerres subfasciatus	Common silver belly	O	Demersal; brackish; marine; depth range 3–40 m. Found in estuaries, harbors, to fairly deep water along the shores.	12.4 %	4.1 %
Gobiidae - Gobies	Favonigobius lateralis	Long-headed goby	O	Demersal; brackish; marine. Found in shallow sandy estuaries, often in seagrass beds.	3.8 %	2.5 %
	Afurcagobius suppositus (Favinogobius suppositus)		E	Benthopelagic; freshwater; brackish. Found in lower reaches of rivers, estuaries and coastal lakes. Lives on silt or mud bottoms in quiet waters of brackish estuaries and coastal lakes.	< 1 %	< 0.1 %
	Pseudogobius olorum	Swan River goby	E	Demersal; freshwater; brackish. Found in freshwater streams and ponds and brackish estuaries. Usually over mud and rock bottoms, sometimes among weeds. Feeds mainly on insects, crustaceans and algae. Spawns during spring in the upper reaches of estuaries (in less than 30% salinity), where aquatic vegetation is plentiful.	< 1 %	0.2 %

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
	Acentrogobius bifrenatus (Amoya bifrenatus) (Arenigobius bifrenatus)		O	Demersal; brackish; marine. Endemic to southern Australia. Found in muddy coastal areas to upper estuaries, rocky reefs, in sea grass beds and mangroves	<1 %	0.1 %
	Callogobius depressus	Flat headed gogy	O	Reef-associated; brackish; marine. Found in shallow rocky reefs, including estuaries. Very secretive, under rocks or in narrow ledges	Not recorded	< 0.1%
	Callogobius mucosus	Sculptured goby	E&M	Reef-associated; brackish; marine. Found in coastal reefs and estuaries, secretly under rocks or in narrow ledges.	< 1%	Not recorded
Gonorynchidae	Gonorynchus greyi ??? not sure what name Young and Potter gave this one		O	Demersal; brackish; marine; depth range ?–160 m. Adults are benthic fishes in shallow estuaries and outer shelf; juveniles are pelagic in open ocean. They bury themselves head first when disturbed	Not recorded	< 0.1%
Hemiramphidae - Halfbeaks	Hyporhamphus melanochir	Southern sea garfish	E	Pelagic; brackish; marine; depth range 0–20 m. Found inshore in surface waters of estuaries, bays, inlets and gulfs to a depth of about 20 m. In the South Australian gulfs, southern sea garfish may be found in deeper waters during the colder months. Generally herbivorous, seagrasses and algal filaments comprise about 75% of their food. Form schools, generally found near the surface at night and close to the bottom over seagrass beds during the day. Post-larvae or young fish less than 1-year-old live in estuaries from March to July then move to inshore marine waters, remaining there for up to 2 years.	< 1 %	0.1%
	Hyporhamphus regularis	Western river garfish	E	Pelagic; freshwater; brackish. Found inshore.	< 1 %	0.1%
	Brachaluteres jacksonianus)	Pigmy leather-jacket		Reef-associated; brackish; marine. Found in estuaries, coastal reefs and offshore islands.	Not recorded	< 0.1%
	Meuschenia freycineti	Six-spined leather-jacket		Demersal; marine; depth range?–100 m. Adults occur on the continental shelf while juveniles are found in estuaries and shallow bays.	Not recorded	< 0.1 %
	Scobinichthys granulatus	Rough leather-jacket		Reef-associated; marine. Found in seagrass beds and on rocky reefs. Females of this species may be confused with female Penicipelta vittiger [= Acanthaluteres vittiger].	Not recorded	< 0.1 %
Mugilidae - Mullets	Aldrichetta forsteri	Yellow-eye mullet	O	Demersal; non-migratory; freshwater; brackish; marine; depth range 0–50 m. Found over sandy and muddy bottoms of coastal waters, bays, estuaries, and may ascend rivers into freshwaters. Inhabits brackish coastal lakes. Found in schools. Shoal-forming. They are omnivores, feeding mostly on benthic detritus, algae and small invertebrates. Oviparous, eggs are pelagic and non-adhesive. Spawn in coastal waters in summer and autumn, probably in estuaries.	5.8 %	4.2 %

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
	Mugil cephalus	Flathead mullet/sea mullet	O	Benthopelagic; catadromous; freshwater; brackish; marine; depth range 0–120 m. Coastal species that often enter estuaries and rivers. Usually in schools over sand or mud bottom and dense vegetation. Mainly diurnal, feed on zooplankton, benthic organisms and detritus. Adult fish tend to feed mainly on algae while inhabiting fresh waters. Reproduction takes place in the sea, from July to October. Females spawn 5 to 7 million eggs provided with a notable vitellus. Sexually mature at 7 to 8 years. Oviparous, eggs are pelagic and non-adhesive.	< 1 %	0.1 %
Odacidae - Cales and weed-whitings	Haletta semifasciata (Neodax semifasciatus)	Blue weed whiting		Demersal; brackish; marine. Forms large schools in estuaries and other sheltered waters with sand and seagrass bottoms. Considered primarily as an opportunistic carnivore, feeding mainly on polychaetes; also gastropods, crustaceans (crab and amphipods), algae and seagrass (mostly Zostera) are common; forams, bivalves, and ophiuroids were also found in a few stomachs.	< 1 %	< 0.1 %
Platycephalidae - Flatheads	Platycephalus laevigatus Can't see where young and potter put this one	Yank flathead	E&M	Demersal; marine. Found inshore and over reefs. Eastern Indian Ocean: known only from southern Australia, from Western Australia to Victoria and Tasmania. A shallow water species, recorded from surf beaches, estuaries and in bays	Not recorded	< 0.1 %
	Platycephalus speculator			demersal; brackish; marine; depth range ?–30 m	Not recorded	< 0.1 %
Pleuronectidae – right eye flounder	Ammotretis elongatus	Elongate flounder		Chiefly marine; occasionally brackish; rare in freshwater. Predators of benthic invertebrates and fishes. Pelagic spawners. Eggs without oil globule in yolk. Benthic, from a few to more than 1,000 m.	< 1 %	0.1 %
Plostosidae - Eeltail catfishes	Cnidoglanis macrocephalus	Cobbler	O	Demersal; brackish; marine; depth range?–30 m. An inshore marine species which lives in shallow bays and sandy inlets near river mouths. Found most frequently over sand, rocks and weeds in clear to turbid waters. By day, cobbler are most often found in holes and on ledges in banks. They are opportunistic feeders, primarily feeding at night. Food consists of bivalve and univalve molluscs, crustaceans (small prawns and amphipods), polychaete worms, algae and organic debris. Juveniles eat more crustaceans, often from among drifting macrophytic algae. Adults feed mainly on molluscs and polychaetes. They are prey to birds such as cormorants and pelicans. Presence of sharp spines on the dorsal and pectoral fins can inflict painful wounds	< 1 %	< 0.1 %
Pomatomidae - Bluefishes	Pomatomus saltatrix	Tailor	O	Pelagic; oceanodromous; brackish; marine; depth range 0–200 m. Occurs in oceanic and coastal waters. They are most common along surf beaches and rock headlands in clean, high energy waters, although adults can also be found in estuaries and into brackish water. Small fish may be found in shallow coastal waters at least 2 m depth, in schools pursuing and attacking small fishes. Adults are in loose groups, often attacking shoals of mullets or other fishes and destroying numbers apparently far in excess of feeding requirements. Feeds on other fish, crustaceans and cephalopods. Associated with sharks and billfishes. A voracious and aggressive species, reported to bite when handled. Migrates to warmer water during winter and to cooler water in summer.	< 1 %	0.2 %

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
Scianidae - Drums or croakers	Argyrosomus hololepidotus Can't find ref	Madagascar meagre	0	Found in lower reaches of rivers, estuaries, rocky reefs, ocean beaches and on the continental shelf down to 150 m. Caught near the bottom and in mid-water. Feed mainly at night or in turbid waters, preying on cuttlefish, fishes, crabs, prawns, and worms.	Not recorded	Not recorded
Scorpaenidae – Wasp fishes	Gymnapistes marmoratus (Gymnapistes marmaratus)	Devil fish or Bullrout	0	Demersal; brackish; marine; depth range 2–26 m. Occur in inshore waters. Most active at night, lying motionless during the day. Spawn during August-September and seem to be triggered by an increase in water temperature at the onset of spring. Smaller individuals feed mainly on shrimps and crabs, while bigger ones are piscivorous. Adults possess venomous infraorbital, preopercular and dorsal-fin spines.	2.1 %	0.9 %
Sillangidae - Whitings	Sillago bassensis	School whiting	0	Demersal; oceanodromous; marine; depth range ?–60 m. Live close to the sea bed over sandy substrates. Occur in the surf zone of beaches and quiet waters of bays and sandbanks. Are trawled in offshore waters to at least 55 m and possibly deeper. Juveniles may be found in shallow water off white sand beaches, together with accumulations of dead seaweed in the surf zone during spring and summer in Western Australia. Move into shallow waters in large schools during full moon. Feed mainly on crustaceans, amphipods, decapods, mysids and copepods. Juveniles consume mostly copepods. Oviparous, and are multiple spawners with asynchronous development.	1.6 %	0.6 %
	Sillago burrus	Trumpeter sillago	0	Demersal; oceanodromous; brackish; marine; depth range ?–36 m	Not recorded	0.7 %
	Sillago maculata	Trumpeter whiting	0	Demersal; non-migratory; brackish; marine; depth range 0–50 m. Occur on silty and muddy substrates in the deeper water of bays, but also frequenting the mouths of rivers, estuaries, and mangrove creeks. Juveniles abound in estuaries and shallow water during summer, moving deeper as they mature. Diet of juveniles consist largely of small crustaceans and that of the adult fish consist mainly of polychaete worms and bivalve mollusks. Oviparous. Spawn throughout the year with peaks in Dec.-Feb.	< 1 %	Not recorded
	Sillaginodes punctatus (Sillago punctata)	King George whiting	0	Demersal; non-migratory; brackish; marine; depth range 2–200 m. Inhabit shallow inner continental shelf waters, including bays and inlets. For their first few years, they live mainly where seagrasses occur. Small juveniles favor water depths from 2 m to 20 m. Adults inhabit more exposed waters along coastal beaches and reef areas, sometimes to depths as great as 200 m. Spawn in offshore waters from late summer to winter. Juveniles feed on benthic amphipods and other crustaceans. As they grow larger, their diet expands to include polychaete worms, molluscs and peanut worms (Sipuncula). Oviparous.	< 1 %	0.4 %
	Sillago schomburgkii	Yellow-finned whiting	0	Demersal; non-migratory; brackish; marine; depth range 0–30 m. Endemic to Australia. Generally frequent inshore sand banks, bars, and spits, and congregate in sandy hollows. At high tide they move in schools across the sand flats and retreat to the slopes of the banks when the tide falls. These whiting are principally marine residents, and can tolerate upper Spencer Gulf waters with salinity as high as 40-50 ppt. They may also penetrate to the limit of the brackish water in tidal creeks, where salinity is as low as 1 ppt. Juveniles inhabit warmer water, mangrove-lined creeks and inshore protected environments over mud bottoms and seagrass beds. The spawning season commences in September and is completed by January in Shark Bay and slightly later along the coast to the south. Oviparous, and are multiple spawners with asynchronous development.	1.5 %	0.3 %

FAMILY	SPECIES	COMMON NAME	LIFE CYCLE	ENVIRONMENT AND BIOLOGY.	% OF TOTAL CATCH 1979 – 81	% OF TOTAL CATCH 1996–97
Sparidae - Snappers	Acanthopagrus butcheri	Black bream	E	Demersal; freshwater; brackish; marine. Endemic in coastal areas, rivers and estuaries of Australia. Most abundant in river mouths and estuaries. Inhabits brackish waters of coastal rivers and lakes, occasionally penetrating fresh water. Considered as the only true estuarine sparid in Australia. Larvae and small juveniles are most abundant over seagrass beds in shallow estuarine waters. Spawning period varies considerably between estuaries. Remains upstream in sheltered waters to spawn and is not usually found in purely marine habitats. Feed on shellfish, worms, crustaceans, small fish and algae.	< 1 %	Not recorded
	Rhabdosargus sarba	Tarwhine or silver bream	O	Reef-associated; oceanodromous; brackish; marine; depth range?–60 m. Inhabits coastal waters, usually entering estuaries. Abundant in shallow water and often caught at the surf-line or in rock pools. Larger, solitary fish sometimes enter brackish mangrove areas. Juveniles in estuaries move into deeper water with growth. Often in schools. Feeds on benthic invertebrates, mainly molluscs and aquatic macrophytes.	< 1 %	1.2 %
Syngnathidae - Pipefishes and seahorses	Urocampus carinirostris	Hairy pipefish	E&M	Demersal; brackish; marine; depth range ?–3 m. Inhabit lower reaches of rivers, estuaries or other protected inshore habitats.	Not recorded	< 0.1 %
	Stigmatopora argus Couldn't locate in Y & P	Spotted pipefish	O/S	Demersal; brackish; marine; depth range ?–8 m. Eastern Indian Ocean: endemic to southern Australia, from Rottnest Island and Shark Bay, Western Australia to Hawkesbury River, New South Wales. Usually among vegetation in bays and estuaries, but sometimes offshore among floating Sargassum	Not recorded	< 0.1 %
Tetraodontidae - Puffers	Torquigener pleurogramma	Weeping toado/ banded blowfish	O	Demersal; brackish; marine; depth range?–30 m. A shallow water species found in estuaries and coastal waters.	3.6 %	41.4 %
	Contusus brevicaudus		O	Demersal; brackish; marine; depth range?–20 m. Usually observed in estuaries to about 20 m. Nocturnal.	< 1 %	0.1 %
Terapontidae - Grunters or trumpeters	Amniataba caudavittata (Amniataba caudivittatus)	Yellowtail trumpeter	E	Benthopelagic; freshwater; brackish; marine. Occurs inshore, in mangrove areas; in lotic and lentic freshwater bodies. Lives in coastal marine waters, but also found in estuaries and freshwater sections of rivers (particularly in temperate southern latitudes). Benthic omnivore, juveniles feed on algae and a range of small crustaceans, while older fish prey mainly on polychaetes.	1 %	< 0.1 %
	Pelates sexlineatus	Six-lined trumpeter	O	Benthopelagic; marine. Occurs inshore. Omnivorous species.	26.4 %	1 %

APPENDIX B: WATERBIRDS

TABLE B1: WATERBIRD SPECIES PRESENT IN THE RAMSAR SITE.

Note that only species considered to be wetland dependent are included, there are numerous other species that occur in the surrounding landscape which are not dependent on the wetlands.

Key:

PHE = Peel-Harvey Estuary, Y = Yalgorup National Park, G/B = Lake Goegrup and Black Lake, M/M = Lake McLarty and Lake Mealup.

X = species present, B = breeding record, R = rare based on Birds Australia 2005b, E = extinct based on Birds Australia 2005b not included in count for Lake McLarty.

	Listed species	PHE	Y	G/B	M/M
DUCKS AND ALLIES					
Australasian Shoveler	M-EPBC*	X	X	X	X
Australian Shelduck	M-EPBC*	B	B	B	B
Australian Wood Duck	M-EPBC*	X	X	X	X
Black Swan	M-EPBC*	B	B	B	B
Blue-billed Duck	M-EPBC*	X		X	X
Chestnut Teal	M-EPBC*	X		X	X
Freckled Duck	M-EPBC*	X			R
Grey Teal	M-EPBC*	B	B	B	B
Hardhead	M-EPBC*	X	X	X	X
Musk Duck	M-EPBC*	X	X	X	B
Pacific Black Duck	M-EPBC*	B	B	B	B
Pink-eared Duck	M-EPBC*	X		X	X
GREBES					
Australasian Grebe		X	X	X	X
Great Crested Grebe		X	B	X	B
Hoary-headed Grebe		X	X	X	X
PELICANS, CORMORANTS, DARTERS					
Australasian Gannet (rare)		X	X		
Australian Pelican		B	X	X	X
Darter		B	X	X	B
Great Cormorant		X	X	X	X
Little Black Cormorant		B	X	X	X
Little Pied Cormorant		B	X	X	B
Pied Cormorant		X	X	X	X
HERONS, IBIS, EGRETS, SPOONBILLS					
Australian White Ibis	M-EPBC, JAMBA	X	X	X	X
Australasian Bittern (last record 1986)					E
Cattle Egret	M-EPBC, CAMBA, JAMBA	X	X		X
Eastern Reef Egret	M-EPBC, CAMBA,	X			
Glossy Ibis	M-EPBC, CAMBA,	X			X
Great Egret (rare)		X	X	X	X
Little Egret		X	X	X	X
Nankeen Night Heron		X			X
Royal Spoonbill (rare)		X		X	X
Straw-necked Ibis		X	X	X	X
White-faced Heron		X	X	X	X
White-necked Heron		X	X		X
Yellow-billed Spoonbill		X		X	X
HAWKS, EAGLES, FALCONS					
Osprey	M-EPBC*	X	X	X	
Swamp Harrier	M-EPBC	X	X	X	X
White-bellied Sea-Eagle	M-EPBC, CAMBA	X	X	R	X

	Listed species	PHE	Y	G/B	M/M
CRAKES, RAILS, WATER HENS, COOTS					
Australian Spotted Crake		X	X	R	X
Baillon's Crake		X			R
Black-tailed Native-hen		X	X		X
Buff-banded Rail		B			X
Dusky Moorhen		X			B
Eurasian Coot		X	X	X	B
Purple Swamphen		X	X		B
Spotless Crake			X		B
SHOREBIRDS					
Asian Dowitcher	M-EPBC, CAMBA				X
Banded Lapwing		X	B	X	X
Banded Stilt	M-EPBC*	X	X	X	X
Bar-tailed Godwit	M-EPBC, CAMBA, JAMBA	X	X	X	X
Black-fronted Dotterel		X	X		X
Black-tailed Godwit	M-EPBC, CAMBA, JAMBA	X	X		X
Black-winged Stilt	M-EPBC	X	X	X	X
Broad-billed Sandpiper	M-EPBC, CAMBA, JAMBA	X			X
Common Greenshank	M-EPBC, CAMBA, JAMBA	X	X	X	X
Common Sandpiper	M-EPBC, CAMBA, JAMBA	X	X	X	X
Curlew Sandpiper	M-EPBC, CAMBA, JAMBA	X	X	X	X
Double Banded Plover					X
Eastern Curlew	M-EPBC, CAMBA, JAMBA	X	X		X
Great Knot	M-EPBC, CAMBA, JAMBA	X	X		X
Greater Sand Plover	M-EPBC	X	X		X
Grey Plover	M-EPBC, CAMBA, JAMBA	X	X	X	X
Grey-tailed Tattler	M-EPBC, CAMBA, JAMBA	X	X	X	X
Hooded Plover		X	B		
Inland Dotterel		X	X		
Lesser Sand Plover	M-EPBC, CAMBA, JAMBA	X	X		X
Little Ringed Plover					X
Little Stint			X		X
Long-toed Stint	M-EPBC, CAMBA, JAMBA				X
Marsh Sandpiper	M-EPBC, CAMBA	X	X	X	X
Oriental Plover (rare – one record)	M-EPBC, JAMBA				X
Oriental Pratincole (rare - one record)	M-EPBC, CAMBA, JAMBA				X
Pacific Golden Plover	M-EPBC		X		X
Pectoral Sandpiper	M-EPBC, JAMBA	X			X
Pied Oystercatcher		X	X		
Pin-tailed Snipe (rare – one record L McLarty nd)	M-EPBC, CAMBA, JAMBA				X
Red Knot	M-EPBC, CAMBA, JAMBA	X	X		X
Red-capped Plover		X	B	X	X
Red-kneed Dotterel		X	X		X
Red-necked Avocet	M-EPBC*	X	X	X	X
Red-necked Stint	M-EPBC, CAMBA, JAMBA	X	X	X	X
Ruddy Turnstone (one record L. McLarty '83)	M-EPBC, CAMBA, JAMBA	X	X		X
Ruff (rare)	M-EPBC, CAMBA, JAMBA	X	X		X
Sanderling	M-EPBC, CAMBA, JAMBA	X	X		X
Sharp-tailed Sandpiper	M-EPBC, CAMBA, JAMBA	X	X	X	X
Terek Sandpiper	M-EPBC, CAMBA, JAMBA	X	X	X	
Whimbrel	M-EPBC, CAMBA, JAMBA	X	X		X
Wood Sandpiper	M-EPBC, CAMBA, JAMBA				X
GULLS, TERNS					
Arctic Tern (rare)		X			

	Listed species	PHE	Y	G/B	M/M
Bridled Tern	M-EPBC, CAMBA, JAMBA		X		
Caspian Tern	M-EPBC, CAMBA, JAMBA	X	X	X	X
Common Tern (rare)	M-EPBC, CAMBA, JAMBA	X			
Crested Tern		X	X	X	
Fairy Tern		X	X	X	
Gull-billed Tern		X	X		X
Roseate Tern (rare)		X			
Pacific Gull			X		
Silver Gull		X	X	X	X
Whiskered Tern		X		X	X
White-winged Tern	CAMBA, JAMBA	X			X
Total number of species		86	73	52	83

* Denotes – not a true migrant. For example, although ducks are listed as migratory under EPBC this is by virtue of the family Anatidae being listed under Bonn/CMS whereas in Australia most ducks are not true migrants.

TABLE B2: WATERBIRD FEEDING HABITAT GUILDS.

Data refer to principal or commonly used habitats for feeding. Birds may roost or loaf in certain habitats but not feed there.

	F1 Feed in dense inundated vegetation	F2 Shallows (<0.5m) &/ or mud	F3 Deep water (>1m)	F4 Away from wetland habitats	F5 Saline water	F6 Fresh water
WATERFOWL						
Australasian Shoveler		X	X			X
Australian Shelduck		X		X		
Australian Wood Duck				X		
Black Swan		X	X	X	X	X
Blue-billed Duck			X			X
Chestnut Teal		X	X		X	X
Freckled Duck		X	X		X	X
Grey Teal		X	X		X	X
Hardhead		X	X			X
Musk Duck			X		X	X
Pacific Black Duck		X	X	X	X	X
Pink-eared Duck		X	X		X	X
GREBES						
Australasian Grebe		X	X			X
Great Crested Grebe			X		X	X
Hoary-headed Grebe		X	X		X	X
PELICANS, CORMORANTS, DARTERS						
Australasian Gannet			X		X	
Australian Pelican			X		X	X
Darter			X		X	X
Great Cormorant			X		X	X
Little Black Cormorant			X		X	X
Little Pied Cormorant		X	X		X	X
Pied Cormorant			X		X	X
HERONS, IBIS, EGRETS, BITTERNS, SPOONBILLS						
Australian White Ibis		X		X	X	X
Australasian Bittern	X	X				X
Cattle Egret		X		X		X
Eastern Reef Egret		X			X	
Glossy Ibis		X				X
Great Egret		X		X	X	X
Little Egret		X			X	X
Nankeen Night Heron	X	X		X		X

	F1 Feed in dense inundated vegetation	F2 Shallows (<0.5m) &/ or mud	F3 Deep water (>1m)	F4 Away from wetland habitats	F5 Saline water	F6 Fresh water
Royal Spoonbill		X			X	X
Straw-necked Ibis		X		X		X
White-faced Heron		X		X	X	X
White-necked Heron		X				X
Yellow-billed Spoonbill		X			X	X
HAWKS, EAGLES, FALCONS						
Osprey			X		X	
Swamp Harrier	X	X		X		X
White-bellied Sea-Eagle		X	X	X	X	X
CRAKES, RAILS, WATER HENS, COOTS						
Australian Spotted Crake	X	X			X	X
Baillon's Crake	X	X	X			X
Black-tailed Native-hen	X	X		X		X
Buff-banded Rail	X	X		X	X	X
Dusky Moorhen	X	X		X		X
Eurasian Coot		X	X		X	X
Purple Swamphen	X	X		X		X
Spotless Crake	X	X		X		X
SHOREBIRDS						
Asian Dowitcher		X			X	
Banded Lapwing				X		
Banded Stilt		X	X		X	
Bar-tailed Godwit		X			X	X
Black-fronted Dotterel		X		X		X
Black-tailed Godwit		X			X	X
Black-winged Stilt		X			X	X
Broad-billed Sandpiper		X			X	
Common Greenshank		X			X	X
Common Sandpiper		X			X	X
Curlew Sandpiper		X			X	X
Double Banded Plover		X			X	
Eastern Curlew		X			X	
Great Knot		X			X	
Greater Sand Plover		X			X	
Grey Plover		X			X	
Grey-tailed Tattler		X			X	
Hooded Plover		X			X	
Inland Dotterel				X		
Lesser Sand Plover		X			X	
Little Ringed Plover		X				X
Little Stint		X			X	
Long-toed Stint		X			X	X
Marsh Sandpiper		X			X	X
Oriental Plover		X		X		
Oriental Pratincole				X INFLIGHT		
Pacific Golden Plover		X		X	X	X
Pectoral Sandpiper		X			X	X
Pied Oystercatcher		X			X	
Pin-tailed Snipe		X				X
Red Knot		X			X	
Red-capped Plover		X		X	X	X
Red-kneed Dotterel		X				X
Red-necked Avocet		X			X	X

	F1 Feed in dense inundated vegetation	F2 Shallows (<0.5m) &/ or mud	F3 Deep water (>1m)	F4 Away from wetland habitats	F5 Saline water	F6 Fresh water
Red-necked Stint		X			X	X
Ruddy Turnstone		X			X	
Ruff		X			X	X
Sanderling		X			X	
Sharp-tailed Sandpiper		X			X	X
Terek Sandpiper		X			X	
Whimbrel		X			X	
Wood Sandpiper		X				X
GULLS, TERNS						
Arctic Tern			X		X	
Bridled Tern			X		X	
Caspian Tern			X		X	X
Common Tern			X		X	X
Crested Tern			X		X	X
Fairy Tern		X	X		X	
Gull-billed Tern		X	X	X	X	X
Roseate Tern			X		X	
Pacific Gull		X	X	X	X	
Silver Gull		X	X	X	X	X
Whiskered Tern		X	X		X	X
White-winged Tern	X Skim/inflight	X Skim/inflight	X Skim/inflight		X	X

TABLE B3: WATERBIRD DIETARY GUILDS.

O = occasionally may eat this item (some records from gut analyses); not scored in total.

Note that information on diets of waterbirds is incomplete, best known for certain groups, poorly known for others, and not necessarily based on studies from this Ramsar site.

	D1 PLANTS AND ANIMALS	D2 MAINLY PLANTS	D3 MAINLY ANIMALS	D4 FISH	D5 FRESHWATER CRAYFISH
DUCKS AND ALLIES					
Australasian Shoveler	X				
Australian Shelduck	X				
Australian Wood Duck	X				
Black Swan		X			
Blue-billed Duck	X				
Chestnut Teal	X				X
Freckled Duck	X				
Grey Teal	X				X
Hardhead	X			O	X
Musk Duck	X			O	X
Pacific Black Duck	X				X
Pink-eared Duck	X				X
GREBES					
Australasian Grebe			X	X	
Great Crested Grebe		O	X	X	
Hoary-headed Grebe			X	X	
PELICANS, CORMORANTS, DARTERS					
Australasian Gannet			X	X	
Australian Pelican			X	X	X
Darter	X			X	
Great Cormorant			X	X	X
Little Black Cormorant			X	X	X

	D1 PLANTS AND ANIMALS	D2 MAINLY PLANTS	D3 MAINLY ANIMALS	D4 FISH	D5 FRESHWATER CRAYFISH
Little Pied Cormorant			X	X	X
Pied Cormorant			X	X	X
HERONS, IBIS, EGRETS, SPOONBILLS					
Australian White Ibis			X	X	X
Australasian Bittern			X	X	X
Cattle Egret			X	X	X
Eastern Reef Egret			X	X	
Glossy Ibis			X	0	X
Great Egret			X	X	X
Little Egret			X	X	X
Nankeen Night Heron			X	X	X
Royal Spoonbill		0	X	X	X
Straw-necked Ibis			X		X
White-faced Heron			X	X	X
White-necked Heron			X	X	X
Yellow-billed Spoonbill			X	X	X
HAWKS, EAGLES, FALCONS					
Osprey			X	X	
Swamp Harrier			X	X	
White-bellied Sea-Eagle			X	X	
CRAKES, RAILS, WATER HENS, COOTS					
Australian Spotted Crake	X				
Baillon's Crake	X				
Black-tailed Native-hen	X				
Buff-banded Rail	X				
Dusky Moorhen	X				
Eurasian Coot	X				
Purple Swamphen	X			X	possibly
Spotless Crake	X				
SHOREBIRDS					
Asian Dowitcher	X		X		
Banded Lapwing	X				
Banded Stilt	X			0	
Bar-tailed Godwit	X		X		
Black-fronted Dotterel	X				
Black-tailed Godwit		0	X		
Black-winged Stilt		0	X	0	
Broad-billed Sandpiper			X		X
Bush Stone-curlew			X		
Common Greenshank	X				
Common Sandpiper	X				
Curlew Sandpiper			X		X
Double Banded Plover			X		
Eastern Curlew			X		
Great Knot			X		
Greater Sand Plover			X		
Grey Plover			X		
Grey-tailed Tattler			X		
Hooded Plover			X		X
Inland Dotterel	X				
Lesser Sand Plover		0	X		

	D1 PLANTS AND ANIMALS	D2 MAINLY PLANTS	D3 MAINLY ANIMALS	D4 FISH	D5 FRESHWATER CRAYFISH
Little Ringed Plover			X		
Little Stint			X		
Long-toed Stint			X		
Marsh Sandpiper			X		
Oriental Plover			X		
Oriental Pratincole			X		
Pacific Golden Plover	X		X		
Pectoral Sandpiper	X				
Pied Oystercatcher			X		
Pin-tailed Snipe	X		X		
Red Knot			X		
Red-capped Plover	X				
Red-kneed Dotterel	X				
Red-necked Avocet		O	X	O	
Red-necked Stint	X				
Ruddy Turnstone			X		
Ruff			X		
Sanderling	X		X		
Sharp-tailed Sandpiper	X				
Terek Sandpiper			X		
Whimbrel			X		
Wood Sandpiper			X		
GULLS, TERNS					
Arctic Tern			X	X	
Bridled Tern			X	X	
Caspian Tern			X	X	
Common Tern			X	X	
Crested Tern			X	X	
Fairy Tern			X	X	
Gull-billed Tern			X	X	X
Roseate Tern			X	X	
Pacific Gull			X		
Silver Gull	X			X	X
Whiskered Tern			X	X	
White-winged Tern			X		

TABLE B4: WATERBIRD NESTING GUILDS.

	N1 Inundated dead trees	N2 Inundated live trees	N3 In/under inundated shrubs or low vegetation	N4 Ground next to water or on island/ islet	N5 Away from wetlands	N7 Mainly in colonies (in Australia)
DUCKS AND SWANS						
Australian Wood Duck	X	X			X	
Black Swan	X		X	X		O
Grey Teal	X	X	X	X		
Musk Duck			X			
Pacific Black Duck	X	X	X	X	X	
GREBES						
Great Crested Grebe			X			O
PELICANS, CORMORANTS, DARTERS						
Australian Pelican				X		X

	N1 Inundated dead trees	N2 Inundated live trees	N3 In/under inundated shrubs or low vegetation	N4 Ground next to water or on island/ islet	N5 Away from wetlands	N7 Mainly in colonies (in Australia)
Darter	X	X				X
Little Pied Cormorant	X	X				X
Little Black Cormorant	X	X				X
CRAKES, RAILS, WATER HENS, COOTS						
Australian Spotted Crake			X			
Buff-banded Rail			X	X	X	
Eurasian Coot	X	X	X	X		O
Purple Swamphen			X			
Spotless Crake			X			
SHOREBIRDS						
Banded Lapwing					X	
Banded Stilt				X		X
Black-fronted Dotterel				X	X	
Hooded Plover				X		

TABLE B5: WATERBIRD GUILDS: OTHER CRITICAL LIFE STAGES OR HABITS

	B1 Flightless at times, each year, due to moulting	B2 Uses daily communal roost or loafing sites
DUCKS AND SWANS		
Australasian Shoveler	X	X
Australian Shelduck	X	X seasonal aggregations on open water
Australian Wood Duck	X	X
Black Swan	X	X seasonal aggregations on open water
Blue-billed Duck	X	seasonal aggregations on open water
Chestnut Teal	X	X
Freckled Duck	X	X
Grey Teal	X	X
Hardhead	X	seasonal aggregations on open water
Musk Duck	X	seasonal aggregations on open water
Pacific Black Duck	X	X
Pink-eared Duck	X	X
GREBES		
Australasian Grebe	X	seasonal aggregations on open water
Great Crested Grebe	X	seasonal aggregations on open water
Hoary-headed Grebe	X	seasonal aggregations on open water
PELICANS, CORMORANTS, DARTERS		
Australasian Gannet		X
Australian Pelican		X
Darter		X
Great Cormorant		X
Little Black Cormorant		X
Little Pied Cormorant		X
Pied Cormorant		X
HERONS, IBIS, EGRETS, SPOONBILLS		
Australian White Ibis		X
Australasian Bittern		
Cattle Egret		X

	B1 Flightless at times, each year, due to moulting	B2 Uses daily communal roost or loafing sites
Eastern Reef Egret		
Glossy Ibis		
Great Egret		X
Little Egret		X
Nankeen Night Heron		X
Royal Spoonbill		X
Straw-necked Ibis		X
White-faced Heron		X
White-necked Heron		X
Yellow-billed Spoonbill		X
HAWKS, EAGLES, FALCONS		
Osprey		
Swamp Harrier		
White-bellied Sea-Eagle		
CRAKES, RAILS, WATER HENS, COOTS		
Australian Spotted Crake	X	
Baillon's Crake	X	
Black-tailed Native-hen	X	
Buff-banded Rail	X	
Dusky Moorhen	X	X
Eurasian Coot	X	X seasonal aggregations on open water
Purple Swamphen	X	X
Spotless Crake	X	
SHOREBIRDS		
Asian Dowitcher		X
Banded Lapwing		
Banded Stilt		X
Bar-tailed Godwit		X
Black-fronted Dotterel		
Black-tailed Godwit		X
Black-winged Stilt		X
Broad-billed Sandpiper		X
Common Greenshank		X
Common Sandpiper		X
Curlew Sandpiper		X
Double Banded Plover		X
Eastern Curlew		X
Great Knot		X
Greater Sand Plover		X
Grey Plover		X
Grey-tailed Tattler		X
Hooded Plover		X
Inland Dotterel		
Lesser Sand Plover		X
Little Ringed Plover		
Little Stint		X
Long-toed Stint		
Marsh Sandpiper		X
Oriental Plover		
Oriental Pratincole		
Pacific Golden Plover		X

	B1 Flightless at times, each year, due to moulting	B2 Uses daily communal roost or loafing sites
Pectoral Sandpiper		X
Pied Oystercatcher		X
Pin-tailed Snipe		
Red Knot		X
Red-capped Plover		X
Red-kneed Dotterel		
Red-necked Avocet		X
Red-necked Stint		X
Ruddy Turnstone		X
Ruff		X
Sanderling		X
Sharp-tailed Sandpiper		X
Terek Sandpiper		X
Whimbrel		X
Wood Sandpiper		
GULLS, TERNS		
Arctic Tern		X
Bridled Tern		X
Caspian Tern		X
Common Tern		X
Crested Tern		X
Fairy Tern		X
Gull-billed Tern		X
Roseate Tern		X
Pacific Gull		
Silver Gull		X
Whiskered Tern		X
White-winged Tern		X

APPENDIX C: ONE PERCENT THRESHOLD

Information prepared by R. Jaensch, Wetlands International, 27 August 2007

in relation to the Peel-Yalgorup Ramsar Site

Species listed in the Ramsar Information Sheet:

Red-necked Avocet – 1100

Red-necked Stint – 3200

Red-capped Plover – 950

Banded Stilt – 2100

Caspian Tern – 1000

The 4th edition of WPE applies the range 10,000 to 100,000 (class B/C) to the Australian population and, by the WPE methodology (using the upper limit), this equates to a 1% threshold of 1000. Previously, the third edition gave the population estimate as 1000 to 5000 and 1% threshold as 30. Updates incorporate new information and so estimates and thresholds can change over time. The 4th edition took into account recently collated information about important inland sites that each supported several thousand birds, as well as aerial survey data across eastern Australia, concluding that the population most likely exceeded 10,000 (thus range class B) and possibly exceeded 25,000 (thus range class C). In some respects the resultant shift in 1% threshold from 30 to 1000 is unsatisfactory – using the lower limit (100) may be more appropriate – but the point is that the population estimate has been revised substantially upward and so the Caspian Tern numbers at Peel-Yalgorup need to be re-evaluated in terms of their significance.

Fairy Tern (western population) – 60

Other species mentioned in the draft ECD:

Hooded Plover (western population) – 60

(Australian) Black-winged Stilt – 3000

Sharp-tailed Sandpiper – 1600

Curlew Sandpiper – 1800

Marsh Sandpiper – 1000

The 4th edition of WPE applies the range 100,000 to 1,000,000 (class D) to the Flyway population and, by the WPE methodology (using the upper limit), this equates to a 1% threshold of 10,000. The third edition gave the population estimate as 90,000 and 1% threshold as 900. The recent revision, based on Bamford *et al.* (2006), takes into account new information some of which indicates numbers substantially in excess of 90,000 but some uncertainty about the total so it was necessary to apply a range class rather than a numerical estimate. Bamford *et al.* (2006), as the primary source of data on population sizes of migratory shorebirds in the Flyway, should be the preferred reference where there is a difference to WPE4 in methodology for deriving 1% thresholds to apply in Australia: Bamford *et al.* (2006) recommend using the lower limit of the range to derive the 1% threshold, which would therefore be 1000 birds.

Wood Sandpiper – 1000

Other species, with high counts in mid 1970s

Grey Teal – 20,000

No estimate was available the third edition of WPE. The 4th edition recognises a population size in excess of one million.

Eurasian Coot – 10,000

No estimate was available the third edition of WPE. The 4th edition recognises a population size in the order of one million.

Black Swan – 10,000

Whereas the 3rd edition of WPE provided a numerical estimate of population size, generating a 1% threshold of 4000 birds, subsequent analysis of the available data particularly for inland regions suggested that it would be more appropriate at this time to apply a range class (D: 100,000 to 1,000,000) which forces the 1% threshold up to 10,000 birds.

Red Knot – 2200

Other species

Musk Duck (western population) – 250

No estimate was available in the third edition of WPE. The 4th edition recognises a population size, based on a substantial data set from the 1980s and early 1990s, of 10,000 to 25,000 (hence 1% threshold of 250 birds).

Australian Shelduck (western population) – 2400

Australasian Shoveler (western population) – 120

Several species/populations, including certain cormorants and grebes, have population estimates in the range C/D but the methodology for WPE4 prevents a 1% threshold being applied in that situation because of the enormous difference between upper and lower limits. Future fine tuning of the population estimates may result in 1% thresholds being defined and at such time the count data for those species at this Ramsar site could be re-evaluated in terms of significance.

ACTION REQUIRED:

- Check raw data for each of these species/populations against the current recommended 1% thresholds (above).
- Decide whether or not the provisions concerning regular use are satisfied in each case.

FRESH ASSESSMENT OF RAW DATA

Without access to all available raw data, I have not conducted a comprehensive fresh assessment for all species/populations using the above 1% thresholds. Applying my recollection of only the highest-ever count, and taking into consideration that surveys in the 1980s only covered portions of the Ramsar Site (never a complete a count of the estuary, for example), I suspect that **14 of the 19** species listed above met their 1% thresholds in the Peel-Yalgorup Ramsar site in 1990. This includes some species – notably the western populations of Musk Duck (for which the Ramsar site includes the number one site) and Australasian Shoveler – that have not previously been considered in this context. The 5 species that need to be examined more closely but that may not meet their current 1% thresholds are: Caspian Tern, Marsh Sandpiper, Wood Sandpiper, Black Swan, and Red Knot (I do not have the 1977 count for the latter).

REGULAR USE

The Ramsar Guidelines http://Ramsar.org/key_guide_list2006_e.htm#E state (Glossary):

> regularly (Criteria 5 & 6) - as in supports regularly - a wetland regularly supports a population of a given size if:
>
> i) the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or
>
> ii) the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).
>
> In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.
> In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. For some countries or sites where there is very little information, single counts can help establish the relative importance of the site for a species.
>
> The International Waterbird Census data collated by Wetlands International is the key reference source.

In the Australian context, very few areas have been surveyed to the extent that we could say that "adequate data are available". Even where surveys have been conducted over several years, even on a monthly basis, in view of our highly variable climate and highly variable availability of wetland habitat (on-site as well as in surrounding catchments) there are very few datasets that span a long enough period to capture the natural variability of waterbird numbers. In the present case, the range of natural variability is illustrated by the snapshot of the tidal habitats from the mid-1970s versus data from the 1980s and today, and changes observed at freshwater wetlands like Lake McLarty over two decades, but monitoring of waterbirds has been spasmodic and not exhaustive across the site, within the past four decades.

The guidelines do allow use of single counts and in practice this approach has been used extensively for Ramsar designations in Australia. However, I suggest that where substantial – though incomplete – data sets are available, such as in the present case, then some discernment (inspection of the data combined with expert opinion) could be applied to ensure that 1% thresholds are considered to be met only where:

- there is at least one robust confirmed count, from within the site boundary, that exceeds the 1% threshold, AND
- other counts and expert opinion indicate that the threshold is highly likely to have been, or will be, exceeded periodically.

A case in point here is that there was a single count of 1200 Blue-billed Duck from Peel Inlet in the 1980s but normally this has been overlooked because, whereas the birds may have been correctly identified, it is possible that they were a different but similar species (Musk Duck), there were no other counts of that magnitude, and Blue-billed Duck typically prefers freshwater (but may occasionally congregate on estuaries).

APPENDIX D: RAMSAR INFORMATION SHEET

Information Sheet on Ramsar Wetlands (RIS) – 2006-2008 version

Categories approved by Recommendation 4.7 (1990), as amended by Resolution VIII.13 of the 8th Conference of the Contracting Parties (2002) and Resolutions IX.1 Annex B, IX.6, IX.21 and IX. 22 of the 9th Conference of the Contracting Parties (2005).

FOR OFFICE USE ONLY	
DD MM YY	
DESIGNATION DATE	SITE REFERENCE NUMBER

1. Name and address of the compiler of this form:

Compiled by the Western Australian Department of Conservation & Land Management (DCLM) in 1990 and updated by Roger Jaensch, Wetlands International - Oceania, on behalf of DCLM in 1998, by DCLM staff in 2000 and 2003 and by DEC in 2007.

All inquiries should be directed to Michael Coote, DEC, 17 Dick Perry Ave, Technology Park, Kensington, WA 6983, Australia, (Tel: +61-8-9334-0479; Fax: +61-8-9334-0199; email: Michael.Coote@dec.wa.gov.au).

2. Date this sheet was completed/updated:

December 2007

3. Country:

Australia

4. Name of the Ramsar site:

Peel-Yalgorup System, Western Australia

5. Designation of new Ramsar site or update of existing site:

This RIS is for (tick one box only.

a) Designation of a new Ramsar site ☐; or

b) Updated information on an existing Ramsar site ☑

6. For RIS updates only, changes to the site since its designation or earlier update:

a) Site boundary and area

The Ramsar site boundary and site area are unchanged: ☑

or

If the site boundary has changed:

i) the boundary has been delineated more accurately ☐; or
ii) the boundary has been extended ☐; or
iii) the boundary has been restricted** ☐

and/or

If the site area has changed:

i) the area has been measured more accurately ☐; or
ii) the area has been extended ☐; or
iii) the area has been reduced** ☐

** Important note: If the boundary and/or area of the designated site is being restricted/reduced, the Contracting Party should have followed the procedures established by the Conference of the Parties in the Annex to COP9 Resolution IX.6 and provided a report in line with paragraph 28 of that Annex, prior to the submission of an updated RIS.

b) Describe briefly any major changes to the ecological character of the Ramsar site, including in the application of the Criteria, since the previous RIS for the site:

Since the time of designation (1990) an artificial channel (the Dawesville Cut) has been constructed in the Peel-Harvey Estuary. This has increased exchange with the ocean resulting in decreased nutrient concentrations, a reduction in eutrophication and an increase in salinity and tidal fluctuations.

This revision of the RIS, re-assessed the site against the existing 6 Criteria as well as applying the recently added criteria for fish and non-avian biota (Criteria 7, 8 and 9).

7. Map of site:

Refer to Annex III of the *Explanatory Note and Guidelines*, for detailed guidance on provision of suitable maps, including digital maps.

a) A map of the site, with clearly delineated boundaries, is included as:

i) **a hard copy** (required for inclusion of site in the Ramsar List ☑;

ii) **an electronic format** (e.g. a JPEG or ArcView image ☑;

iii) **a GIS file providing geo-referenced site boundary vectors and attribute tables** ☑.

b) Describe briefly the type of boundary delineation applied:

e.g. the boundary is the same as an existing protected area (nature reserve, national park, etc.), or follows a catchment boundary, or follows a geopolitical boundary such as a local government jurisdiction, follows physical boundaries such as roads, follows the shoreline of a waterbody, etc.

The boundary follows existing reserved areas

8. Geographical coordinates (latitude/longitude, in degrees and minutes):

Provide the coordinates of the approximate centre of the site and/or the limits of the site. If the site is composed of more than one separate area, provide coordinates for each of these areas.

Latitude: 32° 32' S to 33° 06' S

Longitude: 115° 37' E to 115° 47' E

9. General location:

Include in which part of the country and which large administrative region(s) the site lies and the location of the nearest large town.

Peel-Yalgorup System is in the City of Mandurah and the Shires of Murray, Waroona and Harvey (local authorities) in the State of Western Australia. It is immediately south of the City of Mandurah within the Swan Coastal Plain bioregion.

The Ramsar Site as originally nominated in February 1990 comprised: Peel Inlet (south of the old Mandurah Estuary Bridge) and Harvey Estuary; Nature Reserves (4990, 24036, 28087 and 2707) adjoining the eastern and southern sides of Peel Inlet; Nature Reserves (2738, 24739, 23756 and 36126) adjoining the eastern and southern sides of Harvey Estuary; most of Lake McLarty (Nature Reserve 39404, which is contiguous with 24739); Lake Mealup (partly in Nature Reserve 6627 and partly freehold owned by the Lake Mealup Preservation Society); and the waters (principally Lakes Clifton, Preston, Boundary, Pollard, Martins Tank, Yalgorup, Hayward and Newnham) and lands of Yalgorup National Park.

The Site was extended in 2001 to include seven additional areas, most of which were recent additions to the conservation reserve system (see maps):

- Extension 1: an addition to Nature Reserve 4990 which includes brackish-saline marsh and shrub-swamp connected by a drain to Peel Inlet at Robert Bay;
- Extension 2: the Nature Reserve 44978 which comprises the western margins and southern part of Lake McLarty;
- Extension 3: an addition to Reserve 11710 (part of Yalgorup National Park) which is dryland that widens the buffer zone for part of the eastern side of Lake Preston;
- Extension 4: an addition to Reserve 11710 (part of Yalgorup National Park) which includes some of the north-western shore of Lake Clifton and also dryland that widens the buffer zone for the north-western side of Lake Clifton;
- Extension 5: the south-eastern part of Reserve 12189 (also part of Yalgorup National Park) which widens the buffer zone for part of the north-eastern side of Lake Clifton;
- Extension 6: Erskine Conservation Park (Nature Reserve 43690), which has two parts and includes shore and associated marshes on the north-western side of Peel Inlet near "The Chimneys".
- Extension 7: an area of salt marsh north of Creery Island ceded to the Crown (and subsequently to be made a conservation reserve) by Cedar Woods Properties Limited as part of the Mariners Cove Development at Mandurah.

Of these components, Extensions 1, 2, 6 and 7 include substantial areas of wetland. The others include shoreline at the edge of the Ramsar Site as originally nominated and / or dryland that provides a buffer zone for the wetlands.

10. Elevation: (in metres: average and/or maximum & minimum)

Sea level

11. Area: (in hectares)

26 530

12. General overview of the site:

Provide a short paragraph giving a summary description of the principal ecological characteristics and importance of the wetland.

The Peel-Yalgorup Ramsar site includes shallow estuarine waters, saline, brackish and freshwater wetlands of the Peel Inlet, Harvey Estuary, several lake systems including Lake McLarty and Lake Mealup and the Yalgorup National Park. The site is geomorphically complex and biologically diverse. Large populations of waterbirds utilise the estuary and lakes and there is a diversity of fish, aquatic invertebrates and fringing salt marsh and paperbark vegetation. In addition, the system contains rare microbial communities in the form of thrombolites.

13. Ramsar Criteria:

Tick the box under each Criterion applied to the designation of the Ramsar site. See Annex II of the *Explanatory Notes and Guidelines* for the Criteria and guidelines for their application (adopted by Resolution VII.11). All Criteria which apply should be ticked.

1	2	3	4	5	6	7	8	9
☑	☐	☑	☐	☑	☑	☐	☑	☐

14. Justification for the application of each Criterion listed in 13 above:

Provide justification for each Criterion in turn, clearly identifying to which Criterion the justification applies (see Annex II for guidance on acceptable forms of justification).

Criterion 1: The site includes the largest and most diverse estuarine complex in south-western Australia and also particularly good examples of coastal saline lakes and freshwater marshes.

Criterion 3: The site is one of only two locations in south-western Australia and one of very few in the world where living thrombolites occur in inland waters.

Criterion 4: The basic description of this criterion implies a number of common functions / roles that wetlands provide and the following apply at Peel-Yalgorup Ramsar site, in most if not all cases both at the date of listing and at present:

- the critical life stage of migration: annual use by large numbers of many species of migratory animals;
- the critical life stage of drought refuge: seasonal influx of large numbers of waterbirds from dried out wetlands in surrounding areas, and periodic massive influx from wider regions during drought;
- the critical life stage of breeding: regionally and nationally significant colonies of cormorants occurred in the 1980s in paperbark swamp in "Carraburmup Swamp Nature Reserve" (Jaensch et al. 1988) on the south-east side of Peel Inlet (and part of the Ramsar site) and small breeding colonies of pelicans breed now and then on islets in Peel Inlet; in addition, the Yalgorup Lakes are a significant site bioregionally for breeding of Hooded Plover (Birds Australia 2005);
- breeding also applies to fishes, crabs and prawns; and
- the critical life stage of moulting: shelducks and Musk Ducks that congregate on the open waters of the Ramsar site outside the breeding season are engaging in moult (hence, the birds are flightless for a short period).

Criterion 5: The site comprises the most important area for waterbirds in south-western Australia, supporting in excess of 20,000 waterbirds annually, with greater than 150,000 individuals recorded at one time (February 1977). Numbers exceeding 20,000 birds have been recorded in all comprehensive surveys conducted in the 1990s in the Peel-Harvey Estuary.

Criterion 6: According to the 4th edition of Waterbird Population Estimates, the site regularly supports 1% of the population of: Red-necked Avocet *(Recurvirostra novaehollandiae)*, Red-necked Stint (*Calidris ruficollis*), Red-capped Plover (*Charadrius ruficapillus)*, Hooded Plover (*Thinornis rubricollis*), Black-winged Stilt (*Himantopus himantopus*), Banded Stilt (*Cladorhynchus leucocephalus*), Curlew Sandpiper (*Calidris ferruginea*), Sharp-tailed Sandpiper (*Calidris acuminata*), Fairy Tern (Sterna nereis), Musk Duck (*Biziura lobata*), Grey Teal (*Anas gracilis*), Australasian Shoveler (*Anas rhynchotis*), Australian Shelduck (*Tadorna tadornoides*) and, Eurasian Coot (*Fulica atra*).

Criterion 8: The Peel-Yalgorup Ramsar Site is important as a nursery and / or breeding and / or feeding ground for at least 50 species of fish as well as the commercially significant Blue Swimmer Crab (*Portunus pelagicus*) and Western King Prawn (*Penaeus latisulcatus*). In addition, the Peel-Harvey Estuary is a migratory route for the Pouched Lamprey (*Geotria australis*).

15. Biogeography (required when Criteria 1 and/or 3 and /or certain applications of Criterion 2 are applied to the designation):

Name the relevant biogeographic region that includes the Ramsar site, and identify the biogeographic regionalisation system that has been applied.

a) biogeographic region:

Swan Coastal Plain

b) biogeographic regionalisation scheme (include reference citation):

Environment Australia 2000. Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the

Development of Version 5.1. Summary Report. Department of Environment and Heritage, Canberra.

16. Physical features of the site:

Describe, as appropriate, the geology, geomorphology; origins - natural or artificial; hydrology; soil type; water quality; water depth, water permanence; fluctuations in water level; tidal variations; downstream area; general climate, etc.

The Peel-Yalgorup Ramsar site comprises of three geographically and hydrologically distinct sections: the Peel-Harvey Estuary, the saline lakes of the Yalgorup National Park and the freshwater, intermittent wetlands Lakes McLarty and Mealup.

The Peel-Harvey Estuary is a bar built estuary comprising of two connected basins, the circular Peel Inlet and the long, narrow Harvey Estuary. The estuary has one natural connection to the Indian Ocean, adjacent to the City of Mandurah. In 1994, a second connection to the Indian Ocean (the Dawesville Channel) was constructed at the junction of the two basins. Three rivers flow into the estuary, the Murray and Serpentine into the Peel Inlet and the Harvey River into the Harvey Estuary. The basins are shallow and predominantly < 2 m deep with large areas < 0.5 m deep. Tidal ranges are approximately 32 cm for the Peel Inlet and 45 cm for the Harvey Estuary (DAL 2002). The system experiences seasonal fluctuations in salinity, with lower salinity during winter (the time of river inflows) and higher during summer (although this is moderated by ocean exchange). Water quality is predominantly good, although nutrient inflows from the catchment are high and there are temporal and seasonal variations in nutrient concentrations, with higher concentrations near the river mouths. Ocean exchange mitigates this and algal blooms, which were once a regular occurrence, are now rare.

The Yalgorup lakes are a series of ten, hypersaline to brackish lagoons in the coastal Spearwood dune system to the south of the Harvey Estuary. The lakes are all shallow (< 3 m deep) and have no defined inlet or outlet channels. Lake Preston is the largest of the wetlands (30km long x 1–1.5 km wide) and Lake Clifton is the second largest (20 km x 0.2–1.5km). The remaining wetlands are small by comparison and form a disconnected chain between Lake Preston and Lake Clifton. Groundwater is the primary water source for the lakes and localised run off is thought to be insignificant contributing < 0.005 % of total lake volume (Davies and Lane 1996). The lakes intersect the freshwater surficial unconfined aquifer that flows from the east towards the sea. The lakes vary between brackish and hypersaline with strong seasonal patterns. The groundwater is fresh, low in nutrients, however moving through the limestone results in alkaline conditions and high concentrations of calcium and bicarbonate are characteristic of all of the lakes (CALM 1995).

Lakes McLarty and Mealup are shallow; moderate sized depressional wetlands on the plain to the east of the Harvey Estuary. Lake McLarty is approximately 2.1 km long and 1.25 km wide and covers approximately 200 ha. The lake is oval in shape with shallow gradient shorelines and a fine layer of silt across the bottom (CALM 2005). Lake Mealup is situated 500 m to the north, has a similar morphology, but is approximately one third the size at 70 ha. They intersect the shallow, surficial freshwater groundwater aquifer, which flows seasonally in response to rainfall. As a consequence, water levels are highest in spring after winter rains and groundwater seepage reach their maximum. They seasonally dry, with evaporation and loss of water back into the groundwater as aquifer levels fall. Lake Mealup experiences strong acid conditions (pH < 4) in years following drying due to exposure of acid sulfate soils (Peel Preservation Society).

17. Physical features of the catchment area:

Describe the surface area, general geology and geomorphological features, general soil types, and climate (including climate type).

The site is situated on the Swan Coastal Plain, which is separated from the ocean by a series of limestone dune systems. The climate is Mediterranean with dry hot summers (maximum average of 30 °C in February) and mild winters (average minimum 9°C in July). Average rainfall at the site is approximately 900mm and is highly seasonal, with 80% falling between May and October. The coastal area is subject to high winds (12–16 km / hour) year round.

18. Hydrological values:

Describe the functions and values of the wetland in groundwater recharge, flood control, sediment trapping, shoreline stabilization, etc.

The Peel-Harvey Estuary receives drainage water from a large number of artificial drainage systems. This serves as flood mitigation and control to surrounding agricultural, urban and peri-urban catchments.

19. Wetland Types

a) presence:

Circle or underline the applicable codes for the wetland types of the Ramsar "Classification System for Wetland Type" present in the Ramsar site. Descriptions of each wetland type code are provided in Annex I of the *Explanatory Notes & Guidelines.*

Marine/coastal: A • B • C • D • E • F • G • H • I • J • K • Zk(a)

Inland: L • M • N • O • P • Q • R • Sp • Ss • Tp Ts • U • Va • Vt • W • Xf • Xp • Y • Zg • Zk(b)

Human-made: 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8 • 9 • Zk(c)

b) dominance:

List the wetland types identified in a) above in order of their dominance (by area) in the Ramsar site, starting with the wetland type with the largest area.

F, Q, O, Ts, G, H, W, Xf, Tp

20. General ecological features:

Provide further description, as appropriate, of the main habitats, vegetation types, plant and animal communities present in the Ramsar site, and the ecosystem services of the site and the benefits derived from them.

The Peel-Yalgorup site provides a number of ecosystem benefits and services including commercial fishing, pollution control (Peel-Harvey Estuary acts as a nutrient sink), recreation and tourism, cultural and spiritual services and biodiversity.

The site provides a number of habitat types for a range of wetland dependant fauna. The Peel-Harvey Estuary contains extensive inter-tidal areas and mudflats as well as permanent open water environments. The Peel Inlet contains extensive benthic flora with both macroalgae (*Cladophora, Chaetomorpha, Hinksia*) as well as the seagrasses *Halophila ovalis* and *Ruppia megacarpa* (Wilson et al. 2000). Tidal saltmarshes are an important component of the fringing vegetation. Samphire (dominated by *Sarcocornia quinqueflora*) is the most extensive of the salt marsh communities and occupies the lowest elevation. The area immediately behind the saltmarsh is dominated by the salt tolerant trees such as *Casurina obesa* (Salt Sheoak) and *Melaleuca cuticularis* (Saltwater Paperbark). The Ramsar site includes some areas of riparian vegetation along the inflowing river systems. These areas contained a mixture of freshwater and estuarine vegetation including tree species such as *Melaleuca rhaphiophylla* (Swamp Paperbark) and sedges such as *Typha orientalis* (Cumbingi).

The Yalgorup lakes contain similar saltmarsh and paperbark vegetation. However, the littoral buffer is very narrow, particularly along the eastern margin of the national park (Davies and Lane 1996). Benthic microbial communities containing both heterotrophic and photosynthetic bacteria and algae dominate the benthos of most of the lakes. Lake Clifton contains extensive thrombolite communities comprised of benthic phytoplankton. Lake Pollard has extensive beds of the charaphyte *Lamprothamnium papulosum*, which provides a valuable food source for Black Swans and ducks.

Lakes McLarty and Mealup were once both dominated by sedges and rushes. However, although Typha orientalis is still common at Lake Mealup, other freshwater species have diminished (CLAM 2005). Freshwater paperbark communities dominate higher elevations at these freshwater wetlands.

The diversity of habitat supports approximately 100 species of waterbird and breeding has been recorded for nineteen species. The Peel-Harvey Estuary provides habitat for over 50 species of native fish and a large number of invertebrates including the Blue Swimmer Crab and the Western King Prawn.

21. Noteworthy flora:

Provide additional information on particular species and why they are noteworthy (expanding as necessary on information provided in 14, Justification for the application of the Criteria) indicating, e.g., which species/communities are unique, rare, endangered or biogeographically important, etc. *Do not include here taxonomic lists of species present – these may be supplied as supplementary information to the RIS.*

The thrombolites at Lake Clifton are considered to be 2,000 years old and are one of only two examples of living thrombolites in Western Australia and a handful in the world (Moore 1991). They cover an area of approximately 400 ha and are predominantly located along the eastern shore (Moore 1987). Thrombolites are rock-like structures that are formed by the activities of benthic microbial communities. Theses communities are diverse and typically comprise of cyanobacteria, diatoms and "true" bacteria. The cyanobacterium most commonly associated with the thrombolites at Lake Clifton is the filamentous *Scytonema*. Other genera include *Oscillatoria, Dichothrix, Chroococcus, Gloeocapsa, Johannesbaptista, Gomphosphaeria* and *Spirulina* (Moore 1991).

The substantial samphire areas at Peel Inlet and Harvey Estuary are significant because much of this community type has been lost from other estuaries in the bioregion. In addition, the samphire Halosarcia indica subspecies *leiostachya* is unique to the Creery Wetlands (DAL 2002). At least one sedge species (*Schoenus natans*) that is of conservation concern ("Priority 4") at State level is also found at the Site.

22. Noteworthy fauna:

Provide additional information on particular species and why they are noteworthy (expanding as necessary on information provided in 14. Justification for the application of the Criteria) indicating, e.g., which species/communities are unique, rare, endangered or biogeographically important, etc., including count data. Do not include here taxonomic lists of species present – these may be supplied as supplementary information to the RIS.

A total of 86 species of waterbirds have been recorded in the Peel-Harvey Estuary including 29 species that are listed under the international migratory agreements JAMBA and CAMBA as well as an additional 32 Australian migratory species that are listed under the Federal Environmental Biodiversity and Conservation Act 1999 (EPBC). In terms of total numbers, Peel Inlet and Harvey Estuary comprise the most important area for waterbirds in south-western Australia, regularly supporting in excess of 20 000 waterbirds: over 150 000 were recorded in February 1977 (Lane and Pearson 2002), 51 000 were recorded in December 1996, and 42 000 were recorded in December 1998 (Lane et al. 2002a, 2002b).

The Peel-Harvey Estuary supports > 1% of the population of eleven species of waterbird:

Red-necked Avocet	*Recurvirostra novaehollandiae*	2 443 Dec 1996
Red-necked Stint	*Calidris ruficollis*	16 436 Dec 1998
Red-capped Plover	*Charadrius ruficapillus*	1 754 Dec 1998
Banded Stilt	*Cladorhynchus leucocephalus*	6 954 Feb 1997
Fairy Tern	*Sterna nereis*	262 Feb 1997
Sharp-tailed Sandpiper	*Calidris acuminata*	1 972 Feb 1977
Curlew Sandpiper	*Calidris ferruginea*	6 260 Dec 1976
Musk Duck	*Biziura lobata*	435 Nov 1989
Grey Teal	*Anas gracilis*	25 077 Feb 1977
Australasian Shoveler	*Anas rhynchotis*	358 Jun 1977
Eurasian Coot	*Fulica atra*	17 039 Oct 1976

The cumulative number of species recorded for the Yalgorup lakes during 1976-2007 is 73 including 24 species listed under the international migratory bird agreements JAMBA and CAMBA as well as an additional, 15 Australian migratory species protected under the EPBC Act. Large flocks of salt tolerant Musk Ducks and Australian Shelduck have been reported on the lakes as well as Black Swans, with 9,000 Australian Shelduck recorded on Lake Preston in 1988 (National Trust of Western Australian 1973; Halse et al. 1990; Halse et al. 1992; CALM 1995). Counts of up to 3200 Musk Duck at Lake Clifton (Jaensch et al. 1993) have been the highest for the western population of this species. The Yalgorup Lakes support at least 1% of the known population size of five waterbird populations; the Banded Stilt, Red-necked Stint, Musk Duck, Australian Shelduck and western Hooded Plover. The lakes are an important breeding site for western Hooded Plovers, and represent the largest known aggregation of breeding efforts in Western Australia (Birds Australia 2005).

A total of 85 waterbird species have been recorded at Lakes McLarty and Mealup including 32 species listed under international migratory bird agreements (JAMBA, CAMBA) and an additional 19 Australian migratory species protected under the EPBC Act. A total of twelve species have been recorded breeding at Lakes McLarty and / or Mealup (Kirkby 1996; Jaensch et al. 1988). Of note, is the provision of habitat for breeding of freshwater birds such as the Spotless Crake, Eurasian Coot and Purple Swamphen; as these lakes represent the only well-studied large freshwater wetlands within the Peel-Yalgorup Ramsar site.

Lakes McLarty and Mealup support > 1% of the population of ten species of waterbird:

Red-necked Avocet	*Recurvirostra novaehollandiae*	5 468
Red-necked Stint	*Calidris ruficollis*	11 500
Red-capped Plover	*Charadrius ruficapillus*	> 1 500
Banded Stilt	*Cladorhynchus leucocephalus*	5 300
Black-winged Stilt	*Himantopus himantopus*	5 400
Sharp-tailed Sandpiper	*Calidris acuminata*	5970
Curlew Sandpiper	*Calidris ferruginea*	3 000
Australian Shelduck	*Tadorna tadornoides*	4 500
Eurasian Coot	*Fulica atra*	10 000
Australasian Shoveler	*Anas rhynchotis*	487

23. Social and cultural values:

a) Describe if the site has any general social and/or cultural values e.g., fisheries production, forestry, religious importance, archaeological sites, social relations with the wetland, etc. Distinguish between historical/archaeological/religious significance and current socio-economic values:

The Peel-Harvey estuary is an important commercial and recreational fishery. Commercial species include King George Whiting, Black Bream, Cobbler, Blue Swimmer Crabs and Western King Prawns. It is estimated that the commercial fishing operations in the estuary are worth about $1 million a year in fish (URS 2007).

The Peel-Harvey Estuary and Yalgorup Lakes also represent important recreational and tourist sites. Tourism in the Peel region contributes approximately $150 million annually to the region, with both domestic and international visitors. The most popular recreational and tourism activities associated with the Ramsar site include: bushwalking, birdwatching, camping, 4W-driving, fishing, boating, crabbing, boating, water skiing, canoeing and swimming (URS 2007).

The Peel-Yalgorup site is of cultural significance to the indigenous Nyoongar, as detailed below.

b) Is the site considered of international importance for holding, in addition to relevant ecological values, examples of significant cultural values, whether material or non-material, linked to its origin, conservation and/or ecological functioning?

If Yes, tick the box ☑ and describe this importance under one or more of the following categories:

i) sites which provide a model of wetland wise use, demonstrating the application of traditional knowledge and methods of management and use that maintain the ecological character of the wetland:

ii) sites which have exceptional cultural traditions or records of former civilizations that have influenced the ecological character of the wetland:

iii) sites where the ecological character of the wetland depends on the interaction with local communities or indigenous peoples:

iv) sites where relevant non-material values such as sacred sites are present and their existence is strongly linked with the maintenance of the ecological character of the wetland:

The Peel-Yalgorup Ramsar site lies within Pinjarup country, a dialect group of the Nyoongar. As with other Indigenous Australians, Pinjarup people were strongly connected to each other, their culture and their country through the Dreaming. In southwest Australia, water is of special significance and the 'Waugal' is the creative and life-giving being associated with all freshwater sources: surface and ground. Although dormant most of the time, it may cause immense harm if disturbed. Hence all fresh water-bodies may be considered to be highly significant mythological sites, with certain areas having particular significance as a place where the Waugal enters or exits the ground, or where it rests. (Dortch et al. 2006).

There are over 356 sites of aboriginal significance in the Peel-Harvey Catchment and 27 specific sites on the Peel-Harvey Estuary have been identified for the proposed heritage trail (Dortch et al. 2006). This includes sites of artefact scatter, camp sites, ceremonial sites, fish traps, skeletal remains and sites of mythological significance.

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24. Land tenure/ownership:

a) within the Ramsar site:

The water in the estuary is non-tenured crown land, and managed by the Department of Water. The majority of all other lake, ex-direct freehold, national parks, state forest and reserves are vested with the WA Conservation Commission and are managed by the Department of Environment and Conservation. A number of lesser foreshore reserves are managed by a variety of agencies including the Shire of Murray, City of Mandurah, the Department of Water, and the Water Corporation. There are also a number of smaller parcels that remain vacant crown land. All areas are Zoned as Regional Open Space or Waterways under the Peel Region Planning Scheme, giving stricter planning controls by the WA Planning commission.

b) in the surrounding area:

Surrounding areas are mostly freehold (privately owned) land or Unallocated Crown Land and there are some other local / State government reserves.

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25. Current land (including water) use:

a) within the Ramsar site:

Peel Inlet and Harvey Estuary are used extensively for public recreation, especially fishing and boating. There are small areas within the Ramsar boundary that are used for residential purposes and along canals. The Yalgorup lakes together with Lakes McLarty and Mealup are used for passive recreation associated with their natural values.

b) in the surroundings/catchment:

The town of Mandurah is on the northern edge of the Inlet and there are a number housing developments along the shores of the Inlet and the north-western part of the Estuary. The area to the east is used principally for cattle farming and there are many farmlets and holiday homes on the western side of the Estuary. Much of the land surrounding the Yalgorup lakes has been cleared for cattle farming and an area on the north-eastern shore of Lake Clifton has been sub-divided for housing. There has been a substantial increase in the population of Mandurah, which has nearly doubled to around 70,000 people since the time of listing and is expected to increase to 150,000 by 2025 (URS 2007). As the population in this area has increased there has been a shift from rural to urban and peri-urban developments in the surrounding lands.

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26. Factors (past, present or potential) adversely affecting the site's ecological character, including changes in land (including water) use and development projects:

a) within the Ramsar site:

The Peel-Harvey Estuary suffered the effects of eutrophication for a number of decades from the 1970s to the mid 1990s with large nutrient loads from the catchment, delivered to the estuary via rivers and drains. On average, approximately 1,200 tonnes of nitrogen and 140 tonnes of phosphorus were discharged annually to the estuary over the period 1977 to 1988 (McComb and Lukatelich 1995). The greatest nitrogen load came from the Murray River and was discharged to the Peel Inlet, while the Harvey Estuary received the greatest phosphorus load from the Harvey River and associated drains. Due to the seasonality of river flow, 80–90 % of the nutrient loads to the estuary occurred in winter (Hodgkin et al. 1981). This discharge of nutrients from river flow led algal blooms of the toxic cyanobacteria Nodularia in the Harvey Estuary and excessive macroalgal growth in the Peel Inlet, with biomass estimates of > 60,000 tonnes dry weight recorded in the 1980s.

To address the problems of eutrophication in the estuary a three part strategy was instigated, comprising (Peel Inlet Management Authority 1994):

1. Reduction of nutrient run-off from the catchment;

2. Continued harvesting of macroalgae as necessary; and
3. Increased flushing to the ocean.

The latter of these was achieved by the constriction of the Dawesville Channel, which opened in 1994. The increased connection to the marine environment has resulted in fundamental and permanent changes to ecological components of the Peel-Harvey Estuary. The estuary has become more marine in nature and there has been an improvement in water quality with a decline in nutrient concentrations, a reduction in phytoplankton and macroalgal biomass.

Current threatening activities within the Ramsar site include commercial and recreational fishing and recreation within the sites. There are eleven commercial licences for fin-fish in the Peel-Harvey Estuary. A target catch is set annually (based on control charting techniques) to allow catch levels to fluctuate in response to natural variation in fish stocks. The target for 2005 / 6 was 75–220 tonnes (Fisheries WA 2006). Although there is potential for this to impact on the fish populations within the system, there is no evidence of significant impacts. There is a significant recreational fishery in the Peel-Harvey Estuary as well and it is estimated that the recreational catch for blue swimmer crabs was five times that of the commercial catch and an estimated 1,360,000 crabs or 290 tonnes (Malseed and Sumner 2001).

Recreational activities within the wetlands include bushwalking, camping, horse riding, motorbikes, four-wheel drives, boating, jet skiing, water skiing and swimming. While recreational enjoyment of the Peel-Yalgorup site is a service / benefit of the wetlands, it also has the ability to impact negatively on the ecological character. The two major impacts are erosion of the shoreline due to boating and recreational vehicle use, and disturbance of waterbirds at vulnerable stages in their lifecycle.

b) in the surrounding area:

The major threatening activities in the surrounding area that may impact on the ecological character of the Ramsar site are:

- Agricultural activities in the catchment;
- Water use and groundwater extraction
- Urban and peri-urban development; and
- Climate change.

Agricultural activities in the catchment impact on the Ramsar site through nutrient inputs and water extraction. Although the nutrient concentrations within the Peel-Harvey Estuary have decreased significantly since the opening of the Dawesville Channel in 1994, there is no evidence that there has been a corresponding reduction in nutrient loads entering the system from the catchment. In fact, there is some evidence that nutrient inflows form the catchment are continuing to increase (EPA 2007). While this has not yet impacted on the estuary itself, the inflowing rivers experience regular algal blooms.

Increased nutrient concentrations as a result of surrounding landuse also have the potential to affect the Yalgorup Lakes and the freshwater wetlands Lakes McLarty and Mealup. While data is scant, there is the potential for impacts to the thrombolites from increased macroalgal growth.

Hydrology is a key driver of wetland ecology and has an affect on both abiotic and biotic components. Of particular concern in the Peel-Yalgorup Ramsar site is the alteration of river flows into the Peel-Harvey Estuary and the reduction in groundwater flow into the Yalgorup Lakes and Lakes McLarty and Mealup. These have the potential to seriously impact on the ecological character of the site

A large proportion of the Peel-Yalgorup Ramsar site is located within the City of Mandurah, which is experiencing rapid population growth. In addition, there are current and planned urban and high density rural developments, under the Peel Planning Scheme which are adjacent to the Peel-Harvey Estuary, Lakes McLarty and Mealup and the Yalgorup Lakes. There are a number of potential induced threats associated with increased development around the wetlands that could impact on the primary determinants of ecological character of the site. These include:

- Clearing of native vegetation (including saltmarsh and paperbark communities);
- Increased nutrient and contaminant run-off;
- Disturbance of acid sulfate soils; and
- Increased recreational pressure on the wetland sites.

The Indian Ocean Climate Initiative (IOC 2002) states that the climate in southwest western Australia has already changed with lower rainfall and higher temperatures. Predictions indicate that it is likely that there will be further decreases in rainfall and rises in sea level in the future (Hick 2006). This has the potential to impact significantly on the hydrology and hence ecological character of the Ramsar site.

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27. Conservation measures taken:

a) List national and/or international category and legal status of protected areas, including boundary relationships with the Ramsar site:

In particular, if the site is partly or wholly a World Heritage Site and/or a UNESCO Biosphere Reserve, please give the names of the site under these designations.

There is a series of Nature Reserves around Harvey Estuary and Peel Inlet (2990, 23756, 24739, 2738, 2707, 2436, 4990, 28087) and there is a Shire reserve where the Murray River enters Peel Inlet. Yalgorup lakes are all within Yalgorup National Park. Since the Site was originally nominated, several new Nature Reserves on or near the edge of Peel Inlet and Harvey Estuary have been declared (44978, 11710, 12189, 43690) and Yalgorup National Park has been extended (some of this is now included in the Site following extensions to the Site in 2001). The conservation value of the "Creery Marshes" (salt marsh immediately north of Creery Island) has been recognised, and the area was ceded to the Crown and reserved in 2002. This area was included in the extensions to the Site made in 2001.

b) If appropriate, list the IUCN (1994) protected areas category/ies which apply to the site (tick the box or boxes as appropriate):

Ia ☐; Ib ☐; II ☑; III ☐; IV ☑; V ☐; VI ☑

c) Does an officially approved management plan exist; and is it being implemented?:

There is currently no management plan for the site.

d) Describe any other current management practices:

Although there is, as yet, no management plan for the entire site, management plans exist for two elements of the System namely: Yalgorup National Park Management Plan 1995-2005 (Department of Conservation and Land Management); (Draft) Lake McLarty Management Plan 2005 (Department of Conservation and Land Management)

The Department of Conservation and Land Management listed the thrombolite reef at Lake Clifton as a critically endangered Threatened Ecological Community (TEC - "Stromatolite-like freshwater community of coastal brackish lakes") in 2002. In 2002, the Department established a recovery team consisting of relevant stakeholders. The recovery team has produced and is implementing an interim recovery plan for the TEC.

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28. Conservation measures proposed but not yet implemented:

e.g. management plan in preparation; official proposal as a legally protected area, etc.

A management plan is currently in preparation for the Ramsar site.

A Draft Water Quality Improvement Plan for the Peel-Harvey Estuary was released in September 2007 for public comment.

Relevant government agencies are considering a proposal to expand the current Ramsar boundary to include Lakes Goegrup and Black on the Serpentine River.

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29. Current scientific research and facilities:

e.g., details of current research projects, including biodiversity monitoring; existence of a field research station, etc.

Extensive research has been conducted on the Peel-Harvey Estuary prior to and following the opening of the Dawesville Channel. This includes work undertaken by State Government Departments as well as universities. Aspects investigated include nutrient dynamics (water column and sediment), hydrology, phytoplankton, benthic plants (seagrass and macroalgae) community composition and extent, saltmarsh vegetation extent and condition, fish populations, invertebrates and waterbirds.

Some research and investigative work has also been undertaken at the Yalgorup Lakes and particularly at Lake Clifton, where the thrombolites are located.

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30. Current communications, education and public awareness (CEPA) activities related to or benefiting the site:

e.g. visitors' centre, observation hides and nature trails, information booklets, facilities for school visits, etc.

A Peel-Harvey Catchment Council public awareness raising project, in partnership with Peel Waterways Centre (a focal point for CEPA), over the past two years includes: banners, brochures, signs, surveys, presentations and displays.

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31. Current recreation and tourism:

State if the wetland is used for recreation/tourism; indicate type(s) and their frequency/intensity.

Peel Inlet and Harvey Estuary are used extensively for recreational fishing and boating. Over 400,000 tourists visit the region annually, with the majority of tourist and recreational activities centred around the estuary. Activities include fishing, prawning, crabbing, canal cruising, boating / jet skiing, water skiing, canoeing and swimming (URS 2007).

There is limited use of Yalgorup National Park and Lakes McLarty and Mealup for passive recreation.

32. Jurisdiction:

Include territorial, e.g. state/region, and functional/sectoral, e.g. Dept of Agriculture/Dept. of Environment, etc.

Territorial: The State Government of Western Australia.

Functional: The Nature Reserves and Yalgorup National Park – The Conservation Commission (vesting) and the Western Australian Department of Environment and Conservation; The waters of Peel-Harvey Estuary – Western Australian Department of Water.

33. Management authority:

Provide the name and address of the local office(s) of the agency(ies) or organisation(s) directly responsible for managing the wetland. Wherever possible provide also the title and/or name of the person or persons in this office with responsibility for the wetland.

Peel-Harvey Catchment Council, Mandurah

Western Australian Department of Environment and Conservation, Perth

Western Australian Department of Water, Mandurah

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Scientific/technical references only. If biogeographic regionalisation scheme applied (see 15 above), list full reference citation for the scheme.

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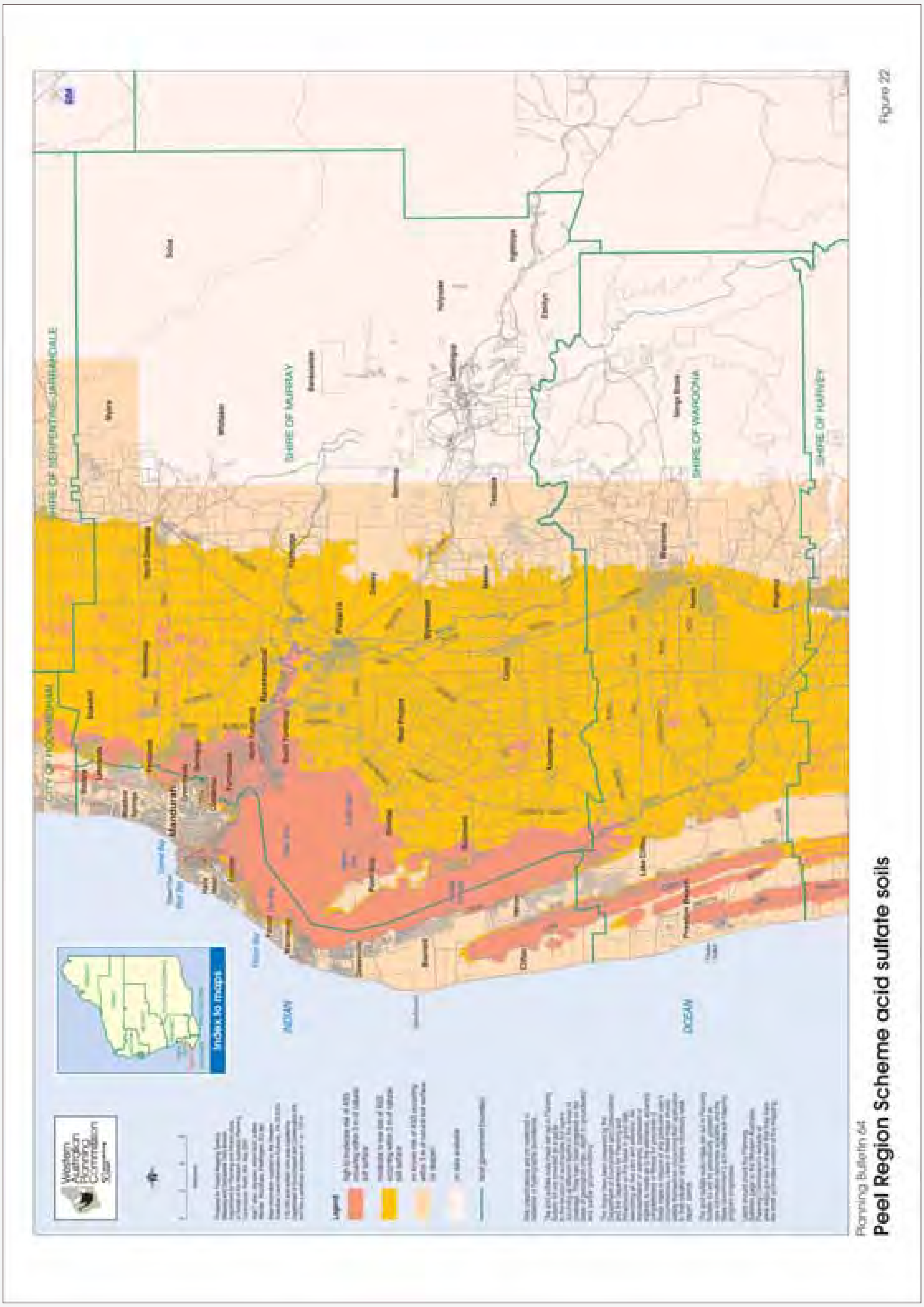
APPENDIX E:
MAP OF POTENTIAL ACID SULFATE SOILS



1 Based on Waterbird Population Estimates, 4th Edition

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