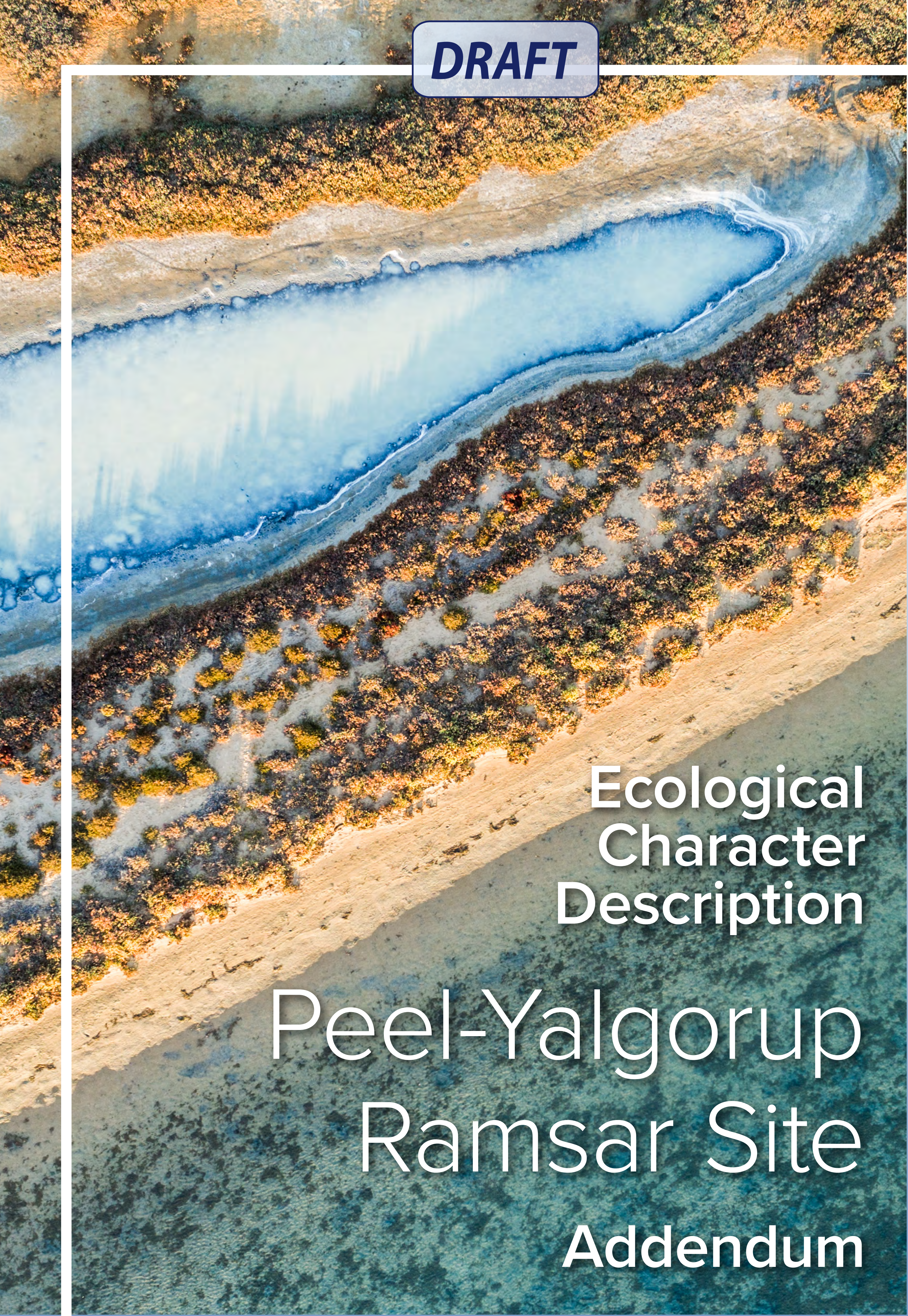

DRAFT

Ecological Character Description

Peel-Yalgorup Ramsar Site

Addendum

We acknowledge the Noongar people as Traditional Custodians of this land and pay our respects to all Elders past and present.

Citation:

Peel-Harvey Catchment Council (2019), *Ecological Character Description for the Peel-Yalgorup Ramsar site: Addendum*. A report by Jennifer Hale for the Peel-Harvey Catchment Council, Mandurah Western Australia.

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- Elder Harry Nannup - Traditional Owner
- Heidi Bucktin - Department of Biodiversity Conservation and Attractions
- Dr Michael Coote – Department of Biodiversity Conservation and Attractions
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- Mark Cugley - Department of Biodiversity Conservation and Attractions
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- Dr Frances D'Souza - Department of Water and Environmental Regulation
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- Mike Griffiths – PHCC
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- Bill Russell* - Birdlife Australia – Peel
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- Vicki Stokes - BirdLife Australia WA Branch
- Catherine Thomson - Department of Water and Environmental Regulation
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Australian Government | National Landcare Program

PHCC Working Together
Peel-Harvey Catchment Council

Contents

Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008) and references cited within unless otherwise indicated.

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). See also "Ecosystem Services"
Biodisparity	The range of morphologies and reproductive styles in a community. The biodisparity of a wetland community is determined by the diversity and predictability of its habitats in time and space
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)
Change in ecological character	Defined as the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005)
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)
Conceptual model	Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003)
Contracting Parties	Countries that are Member States to the Ramsar Convention on Wetlands; 170 as at 2019. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialised agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice
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	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 MA definition of ecosystem services as "the benefits that people receive from ecosystems".] (Ramsar 2012)
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	The physical, chemical and biological parts of a wetland from large scale to very small scale, for example habitat, species and genes (Millennium Ecosystem Assessment 2005)
Ecosystem processes	The changes or reactions which occur naturally within wetland systems; they may be physical, chemical or biological. (Ramsar Convention 1996). 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	The benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (for example food and water); regulating (for example flood control); cultural (for example spiritual, recreational) and supporting (for example nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also "Benefits"
Endemic species	(Guidelines for Criterion 7) - a species that is unique to one biogeographical region, i.e., it is found nowhere else in the world. For example, a group of fishes may be indigenous to a subcontinent with some species endemic to a part of that subcontinent (Ramsar Convention 2009)
Endemism	The ecological state of being unique to a geographic location – see endemic species
Fluvial geomorphology	The study of water-shaped landforms (Gordon et al. 1999)
Geomorphology	The study of the evolution and configuration of landforms
Indigenous species	A species that originates and occurs 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 Party 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
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".
Ramsar criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties to identify wetlands that qualify for inclusion on the Ramsar List on the basis of representativeness, rareness, uniqueness or for conserving biological diversity (https://www.ramsar.org/sites/default/files/documents/library/ramsarsites_criteria_eng.pdf)
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
Ramsar Information Sheet (RIS)	The form in 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 and ecological values among others, ownership and jurisdictions, and conservation measures proposed and taken
Ramsar List	The List of Wetlands of International Importance (see List of Wetlands of International Importance above)
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

Waterbirds	Defined by the Convention as "birds ecologically dependent on wetlands" (Article 1.2). Although this definition thus includes any wetland bird species, at the broad level of taxonomic order, it includes especially: • penguins: *Sphenisciformes* • divers: *Gaviiformes* • grebes: *Podicipediformes* • wetland related pelicans, cormorants, darters and allies: *Pelecaniformes* • herons, bitterns, storks, ibises and spoonbills: *Ciconiiformes* • flamingos: *Phoenicopteriformes* • screamers, swans, geese and ducks (wildfowl): *Anseriformes* • wetland related raptors: *Accipitriformes* and *Falconiformes* • wetland related cranes, rails and allies: *Gruiformes* • hoatzin: *Opisthocomiformes* • wetland related jacanas, shorebirds, gulls, skimmers and terns: *Charadriiformes* • coucals: *Cuculiformes* • wetland related owls: *Strigiformes*
Wetlands	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 types	As defined by the Ramsar Convention's wetland classification system

Abbreviations

ASS	Acid Sulfate Soils
CAMBA	China-Australia Migratory Bird Agreement
CMS	The Bonn Convention on the conservation of migratory species of wild animals
DBCA	Department of Biodiversity, Conservation and Attractions (Western Australian Government), formerly Department of Environment and Conservation
DWER	Department of Water and Environmental Regulation (Western Australia), formerly Department of Water
DEWHA	Department of Environment, Water, Heritage and the Arts, now Department of the Environment, and Energy (Australian Government)
DoEE	Department of the Environment and Energy (Australian Government)
ECD	Ecological Character Description
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
LAC	Limit of Acceptable Change
PHCC	Peel-Harvey Catchment Council
RIS	Ramsar Information Sheet
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement

EXECUTIVE SUMMARY

The Peel-Yalgorup Ramsar Site is located in south-western Australia, approximately 80 kilometres south of Perth within the South West Coast Drainage Division bioregion. The site covers more than 26,000 hectares and spans four municipal boundaries: City of Mandurah and the Shires of Murray, Waroona and Harvey (Figure 1).

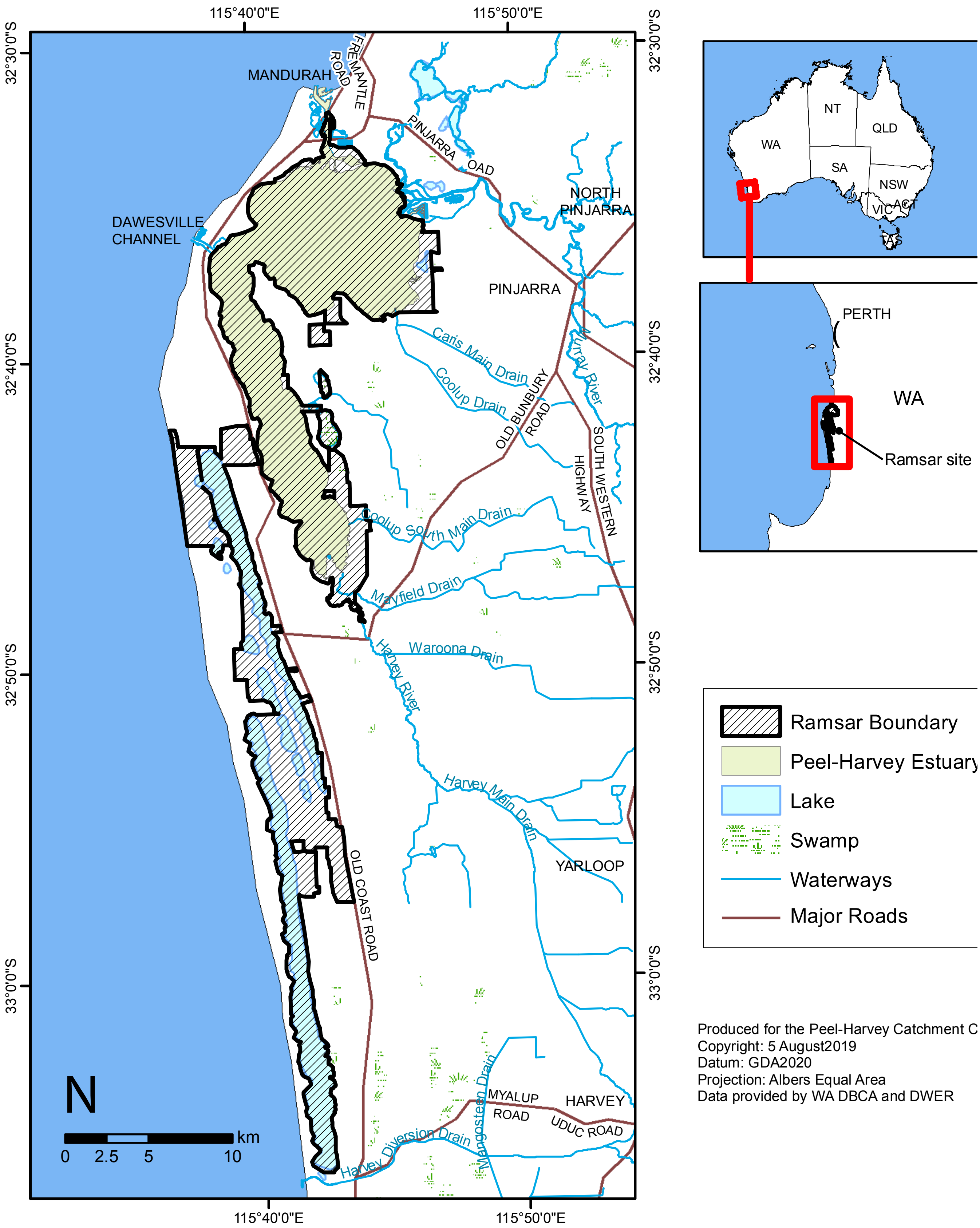

Figure 1: **Peel-Yalgorup Ramsar Site**

Ramsar criteria

An assessment against the current Ramsar criteria indicates that the Peel-Yalgorup Ramsar Site would have met seven of the nine criteria at the time of listing and continues to do so:

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.

The Yalgorup Lakes are a series of interdunal groundwater dependent, saline to hypersaline lakes that are likely rare in the South West Coast bioregion. In addition, three of the lakes (Lakes Hayward, Newnham and Yalgorup) are globally rare with respect to their thermal properties.

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

The site regularly supports two threatened ecological communities and seven threatened waterbird species listed nationally (EPBC) and/or internationally (IUCN).

Criterion 3: 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.

The Peel-Yalgorup Ramsar Site represents the most species rich Ramsar site in the South West Coast Drainage Division with respect to waterbirds when compared to other large marine and costal wetland systems in the bioregion.

Criterion 4: 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.

The site supports fauna during the following critical life stages:

Migration – regularly supports 20 international migratory waterbird species and the Peel-Harvey Estuary is important for migratory fish (pouched lamprey) and marine invertebrates.

Drought refuge - the permanent freshwaters of Lake Mealup provide valuable habitat for waterfowl and other native species.

Breeding – 30 species of wetland dependent birds, extensive nursery areas for native fish, breeding of bottlenose dolphins.

Moulting - Lake McLarty and Yalgorup Lakes annually support large numbers of moulting waterfowl, most notably, Australian Shelduck.

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

The site has supported > 20,000 waterbirds almost every year since 1995 with a maximum of over 80,000 in 2013.

Criterion 6: 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.

The site regularly supports greater than one percent of the population of eight species of waterbird.

Criterion 8: 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.

The Peel-Yalgorup Ramsar Site provides important habitats, feeding areas, dispersal and migratory pathways, and spawning sites for numerous fish species of direct and indirect fisheries significance.

Critical components, processes and services

A simple conceptual model for Peel-Yalgorup Ramsar Site (Figure 2) illustrates the components, processes and services that are critical to the ecological character of the site, the interactions between them and their role in contributing to the Ramsar listing criteria. A summary of the components and processes important to the ecological character of the Ramsar site is provided below. This includes those that are considered supporting components and processes (Table 1) as well as those identified as critical to the ecological character of the site, and for which Limits of Acceptable Change (LAC) have been developed (Table 2 and Table 3).

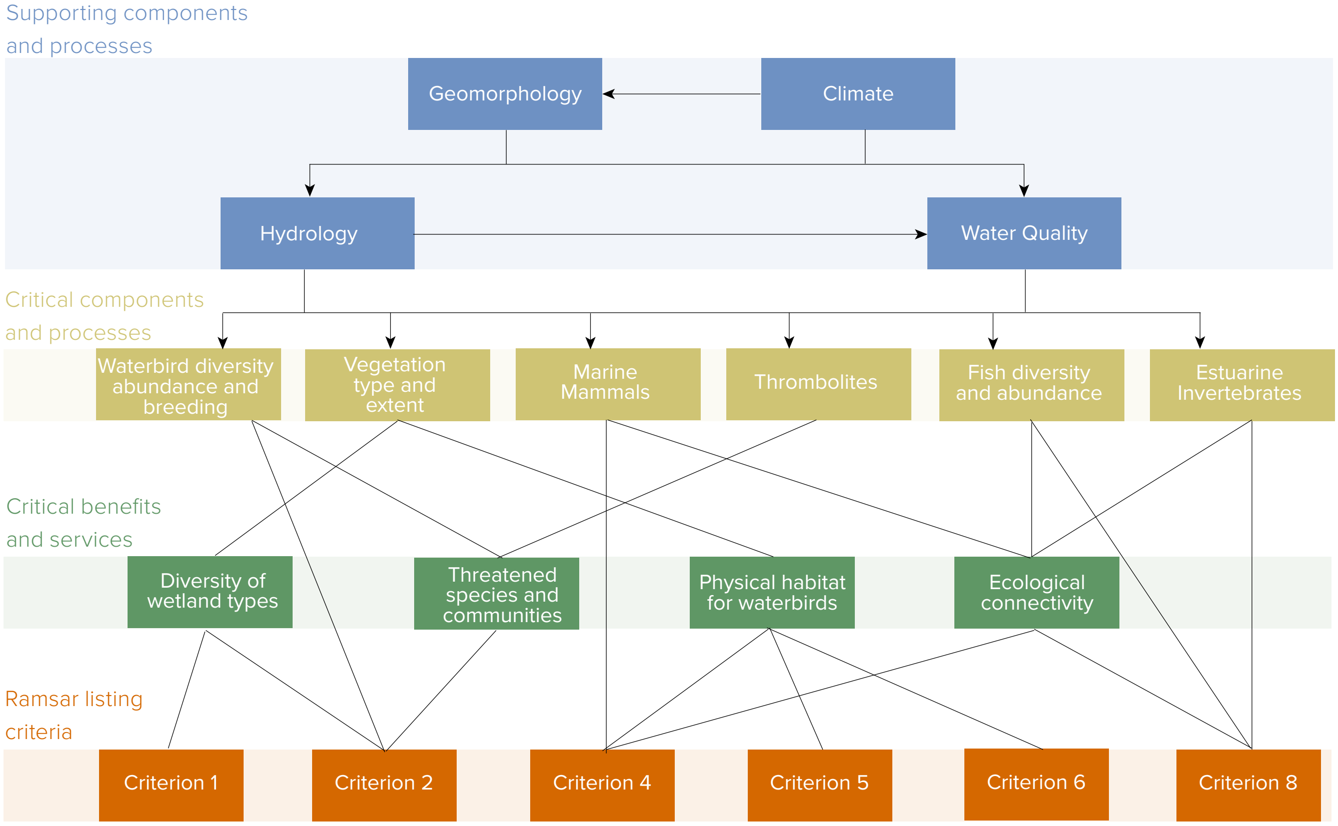

Figure 2: Simple conceptual model showing the key relationships between components and processes; benefits and services and the reasons for the site being listed as a Wetland of International Importance (note all relationships between critical components, processes and services are not shown)

Table 1: Summary of supporting components and processes within the Peel-Yalgorup Ramsar

COMPONENT / PROCESS	DESCRIPTION
Climate	Rainfall is winter dominated with two thirds of the annual rainfall occurring between May and August. Evaporation is high in summer months and, on average, annual evaporation exceeds rainfall.
Geomorphology	The site is located within a series of parallel dunes systems between the Darling Scarp and the Indian Ocean. The Peel-Harvey Estuary comprises two large shallow basins with average water depths of less than 2 metres. The Yalgorup Lakes (within the Ramsar site boundary) comprise ten shallow wetlands, situated in the depression between a series of linear coastal dunes. Lakes McLarty and Mealup are shallow; moderate sized depressional wetlands on the plain to the east of the Harvey Estuary.

Hydrology	The Peel-Harvey Estuary receives riverine inflows from three river systems, with 95 percent of surface inflows occurring between May and October. Average river inflow is around 380 gigalitres per year, but interannual variability is high. Exchange with the Indian Ocean is through the artificial Dawesville Channel and the Mandurah Channel. The Yalgorup Lakes are groundwater-fed having no substantive surface water inflows. They are connected to the surficial unconfined freshwater aquifer which delivers water mainly during spring. Lakes McLarty and Mealup are seasonal wetlands, the former receiving the majority of inflows via a small local catchment and direct rainfall, and the latter, at the time of listing, through artificial drainage lines as well as groundwater.
Water quality – salinity, nutrients, pH, turbidity	At the time of listing there was a gradient of salinity from the saline Yalgorup Lakes to the estuarine conditions of the Peel-Harvey Estuary and the freshwater to brackish wetlands of Lakes McLarty and Mealup. Alkalinity at the site ranged from the periodically acidic Lake Mealup through the mainly neutral Lake McLarty to the slightly alkaline Peel-Harvey Estuary and the more highly alkaline Yalgorup Lakes. Since the opening of the Dawesville Channel (1994) the Peel-Harvey Estuary is characterised by relatively low concentrations of bioavailable nutrients and phytoplankton. While the Yalgorup Lakes and Lake McLarty could be considered mesotrophic. At the time of listing, Lake Mealup was periodically eutrophic due to the effects of activated acid sulfate soils during dry periods releasing nutrients, particularly ammonium, from the sediments.

Table 2: Summary of critical components and processes within the Peel-Yalgorup Ramsar Site

COMPONENT / PROCESS	DESCRIPTION
Vegetation type and extent	*Seagrass and macroalgae* – the sediment of the Peel-Harvey Estuary is covered with a mixture of seagrass and macroalgae. In 2009 there was 8500 tonnes of macroalgae and 3700 tonnes of seagrass. The highest density of seagrass occurred adjacent to marine water influences, while macroalgal growth was greatest closer to river inflows. *Saltmarsh* – there was an estimated 684 hectares of saltmarsh in the Ramsar site in 2007. Community composition varied with location: beaded glasswort being common in the Peel Inlet and Lake Preston, with sea rush dominating at Lake Clifton and parts of the Harvey Estuary. *Paperbark* – there was an estimated 646 hectares of paperbark within the Ramsar Site in 2007. Saltwater paperbark is the dominant canopy species at the Yalgorup Lakes, while freshwater paperbark is prevalent at Lakes McLarty and Mealup. The tree communities in the Peel-Harvey Estuary vary considerably with location. *Freshwater wetland vegetation* – at the time of listing both Lakes McLarty and Mealup supported extensive stands of emergent rushes and reeds. In 2007, there was 40 hectares of emergent wetland vegetation in the inner margins of Lake McLarty and 51 hectares at Lake Mealup.
Thrombolites	At the time of listing, Lake Clifton supported an expanse of living thrombolite communities including a "reef" 6.5 kilometres long and 120 to 30 metres wide comprised mainly of the cyanobacteria *Scytonema* sp.
Estuarine invertebrates	At the time of listing the Peel-Harvey Estuary supported three commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. From commercial catch data, the total catch of blue swimmer crab was estimated to be from 40 to 100 tonnes annually.
Fish diversity and abundance	Over 80 species of native fish have been recorded in the Peel-Harvey Estuary. Abundance estimates are highly variable, with mean densities (2005 – 2007) of 360 fish per 100 square metres. The most common species are banded blowfish, sandy sprat and elongate hardyhead. The estuary also supports important commercial and recreational fisheries.
Waterbird diversity and abundance	A total of 104 wetland dependent bird species have been recorded within the Ramsar site. Average annual abundance across the site (1995 to 2010) was around 45,000. The site regularly supports greater than 1 percent of the population of eight species.

Waterbird breeding	Evidence of breeding (juveniles, nests, eggs) has been recorded for 34 species of wetland dependent bird in the Peel-Yalgorup Ramsar site. Different areas of the Ramsar site are important for breeding of different types of waterbird. The Yalgorup Lakes supports breeding of several species of Australian resident shorebird including the hooded plover. The Peel-Harvey Estuary is important for breeding of colonial fish-eating species such as cormorants and Australian pelicans, while, Lake McLarty supports a wide diversity of breeding waterbirds.
Marine mammals	The Peel-Harvey Estuary supports Indo-Pacific bottlenose dolphin, with the resident community estimated at around 90 individuals. The estuary is an important feeding, breeding and nursing ground for the species. The year-round resident community uses the estuary to complete their lifecycle. Coastal dolphin communities use the estuary seasonally for feeding and breeding opportunities (pers.comm. Krista Nicholson).

Table 3: Summary of critical services within the Peel-Yalgorup Ramsar Site

CRITICAL ECOLOGICAL SERVICES	DESCRIPTION
Provides physical habitat for waterbirds	The site provides a network of habitats for waterbird feeding, roosting, moulting and breeding. Species that are supported by the site represent a wide range of functional groups (e.g. shorebirds, ducks, fish-eaters, large-bodied waders) each with different habitat requirements
Threatened wetland species and communities	The site provides important habitat for seven species of threatened fauna, including: six international migratory shorebirds and the Australian fairy tern, as well as two ecological communities: coastal saltmarsh and the thrombolites
Ecological connectivity	The Ramsar site has a range of distinct wetland types which are ecologically connected. The connection between the marine, estuarine and freshwater components is significant for fish migration and reproduction. The site also supports significant numbers of international migratory shorebird species
Supports a diversity of wetland types	The site comprises a network of wetland types including intermittent freshwater wetlands, permanent saline coastal lagoons and estuarine waters

Limits of Acceptable Change

“Limits of Acceptable Change” (LAC) is the terminology used to describe complex judgements as to how and to what extent critical components, processes, benefits and services of the site can vary without representing a potential change in the ecological character as defined by the Ramsar Convention. LAC for the Peel-Yalgorup Ramsar Site have been developed for critical components, processes and services and are summarised in Table 4.

Table 4: LAC for the Peel-Yalgorup Ramsar Site

CRITICAL COMPONENTS, PROCESSES AND SERVICES	LIMIT OF ACCEPTABLE CHANGE
Vegetation: seagrass and macroalgae	Seagrass biomass will not decline below 1500 tonnes for a period of greater than 10 continuous years. Benthic habitat will be comprised of a habitat mosaic of both seagrass and macroalgae with no group comprising more than 80 percent of total biomass for more than three continuous years
Vegetation: saltmarsh	Extent of saltmarsh will not decline by more than 20 percent from the 2007 benchmark. That is, saltmarsh will not decline below: • Peel-Harvey Estuary – 230 ha • Yalgorup Lakes – 300 ha

Vegetation: wetland trees	Extent of wetland trees will not decline by more than 20 percent from the 2007 benchmark. That is, paperbark extent will not decline below: • Peel-Harvey Estuary – 65 ha • Yalgorup Lakes – 400 ha • Lake McLarty – 24 ha • Lake Mealup – 24 ha The paperbark community at the Yalgorup Lakes will be dominated by saltwater paperbark *(Melaleuca cuticularis)* and the paperbark community at Lakes McLarty and Mealup will continue to be dominated by freshwater paperbark *(M. rhaphiophylla)*
Vegetation: freshwater emergent	Freshwater emergent macrophyte vegetation will be present within Lakes McLarty and/or Mealup in no less than two in every 10 year period
Thrombolites	No less than 50 percent of the thrombolites within the “reef” along the north eastern shoreline of Lake Clifton to be active (i.e. accreting and growing)
Marine invertebrates	The Peel-Harvey Estuary will continue to support three species of commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. Blue swimmer crab abundance will not fall below limit as set by harvest strategy, for a continuous period of five years or more
Fish	Native fish within the Peel-Harvey Estuary will represent each of the following life history strategies: estuarine, marine-estuarine opportunists, marine stragglers, diadromous and obligate freshwater species
Waterbird abundance	Abundance of waterbirds across the entire site will not decline below the following (calculated as a rolling five-year average of maximum annual count): • Total waterbirds – 22,000 • Migratory shorebirds – 5500 • Australasian shorebirds – 5500 • Ducks – 7500 • Fish eating species – 1500 • Herbivores – 2000
Waterbird diversity	Diversity of waterbirds will not decline below the following (calculated as a rolling five-year average of number of species): • Total waterbirds – 48 • Migratory shorebirds – 13 • Australasian shorebirds – 5 • Ducks – 8 • Fish eating species – 8 • Herbivores – 3 • Large bodied waders – 6 • Other – 4
Waterbird breeding	The following species will be recorded breeding no less than one in every two years: Australian darter, Australian fairy tern, Australian pelican, black swan, hooded plover, red-capped plover, little pied cormorant, little black cormorant
Marine mammals	Bottle-nose dolphin calves to be observed within the Peel-Harvey Estuary no less than once every year

Diversity of wetland types	No loss of wetland type with the following Ramsar wetland types represented within the Ramsar site: • F – estuarine waters • B – marine subtidal beds • Q – permanent saline/brackish/alkaline lake • H – intertidal marshes • P – seasonal /intermittent freshwater lakes • Xf – freshwater, tree-dominated wetlands • G – intertidal mud, sand flats • R – seasonal / intermittent saline/brackish lakes
Physical habitat for waterbirds	See LAC for waterbird abundance, diversity and breeding
Threatened species: waterbirds	Bar-tailed godwit, curlew sandpiper, eastern curlew, great knot, greater sand plover and red knot recorded within the site in three out of five seasons Abundance of Australian fairy tern will not decline below 2.5 percent of the population (calculated as a rolling five year average of maximum annual count; percentages calculated based on the latest Wetlands International Waterbird Population Estimates)
Ecological connectivity	See LAC for fish and waterbird abundance, diversity and breeding

Threats

A number of potential and actual threats may impact on the ecological character of the Ramsar site, as illustrated in Figure 3 and summarised in Table 5.

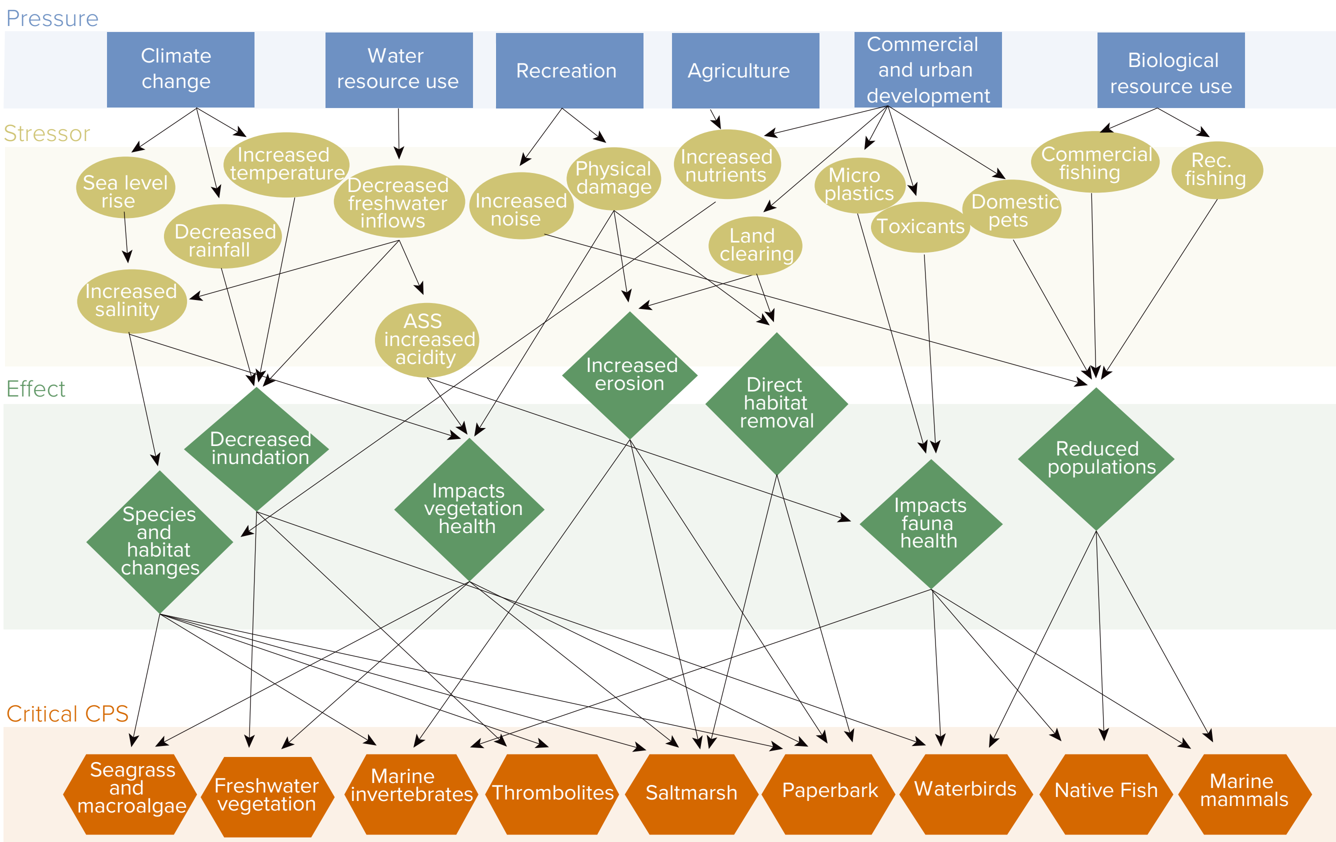

Figure 3: Simple stressor model for the Peel-Yalgorup Ramsar Site

Table 5: Summary of threats to the Ramsar site

THREAT OR POTENTIAL THREAT	POTENTIAL IMPACTS
Commercial and urban development	• Physical habitat loss • Disturbance of ASS • Increased drainage
Climate change Altered hydrological regimes	• Reduced water depth in lakes • Impacts on flora and fauna (e.g. breeding events, vegetation distribution) • Impacts on habitat condition and availability • Increased erosion and habitat destruction • Exposure of ASS
Water resource use	• Altered hydrological regimes (timing, magnitude and frequency of flows) • Changes to water depth • Increased salinity • Exposure of ASS • Impacts on flora and fauna
Agriculture	• Nutrient enrichment • Reduced habitat quality
Biological resource use	• Reduced blue swimmer crab populations, reduced food resources, reduced waterbird abundance
Recreation: Human intrusion and disturbance	• Disturbance of waterbirds • Damage to flora and waterbird habitat

Knowledge gaps and monitoring needs have been identified for the site.

1 INTRODUCTION

1.1 Site details

An ecological character description (ECD) was completed for the Peel-Yalgorup Ramsar Site in 2007 (Hale and Butcher 2008a). The original ECD for the site was completed prior to the release of the final Module 2 of the National Guidelines for Ramsar Wetlands: Implementing the Ramsar Convention in Australia (Department of the Environment, Water, Heritage and the Arts 2008). Since that time there have also been several other developments that affect the form or content of an ECD, including a clarification of Australia's approach to Limits of Acceptable Change (LAC) and guidance on mapping boundary descriptions for Ramsar sites (Department of the Environment 2014). In addition, there have been updates to threatened species and ecological communities' listings, increased knowledge and data from the site and improved understanding in wetland ecology.

This document represents an addendum to the original ECD. However, given the extent of amendments to the original ECD, as a result of new information, this document reproduces the original content with updates to represent more recent data and understanding of the ecological character of the site. This document can therefore be read in isolation from the original ECD. The site details are summarised in Table 6.

Table 6: Site details for the Peel-Yalgorup Ramsar Site

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. It includes the Peel Inlet, Harvey Estuary, most of the Lake McLarty Nature Reserve; Lake Mealup and the waters and lands of the Yalgorup National Park Biogeographic region: South West Coast Drainage Division
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, 2, 3, 4, 5, 6 and 8.
Management authority for the site	The water area in the estuary is non-tenured crown land, managed under the Waterways Conservation Act all other lake, ex-direct freehold, national parks, state forest and reserves are vested with the Western Australian Conservation Commission and managed by the Department of Parks and Wildlife. Foreshore areas are vested with the City of Mandurah. Freehold land at Lake Mealup is owned and managed by the Lake Mealup Preservation Society (Inc). A conservation covenant exists on the title, established through the National Trust's covenanting scheme
Date the ECD applies	1990 and 2010[1]
Status of Description	This represents an addendum to the first ECD for the site
Date of Compilation	August 2019
Name(s) of compiler(s)	Jennifer Hale on behalf of the Peel-Harvey Catchment Council (PHCC) all enquires to admin@peel-harvey.org.au
References to the Ramsar Information Sheet (RIS)	2019 [insert cross reference when available]
References to Management Plan(s)	Peel-Yalgorup Ramsar Site Management Plan (Peel-Harvey Catchment Council 2009)

1.2 Statement of purpose

The act of designating a wetland as a Ramsar site carries with it certain responsibilities, including managing the site to retain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have, altered the 'ecological character'. Understanding and describing the 'ecological character' of a Ramsar site is a fundamental management tool. It should form the benchmark for management planning and action and include site monitoring to detect any change in ecological character.

The Ramsar Convention has defined "ecological character" and "change in ecological character" as (Ramsar Convention 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*

1 The benchmark for the majority of the site is 1990, the time of listing. For the Peel-Harvey Estuary, however, the opening of the Dawesville Channel in April 1994 dramatically changed the ecology of the system to such an extent that a new benchmark had to be established (ECD, 2007, p15).

"...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. An ECD forms the foundation on which a site management plan and associated monitoring and evaluation activities are based. A Ramsar Information Sheet (RIS) is also prepared at the time of designation. The information in a RIS, however, may not provide sufficient detail on the interactions between ecological components, processes and functions to constitute a comprehensive description of ecological character. To assist in the management of Ramsar sites in the face of insufficient detail, the Australian and state/territory governments developed a 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* (Department of the Environment, Water, Heritage and the Arts 2008).

In Australia, the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (the EPBC Act) provides a legal framework for 1) regulating actions that will have or are likely to have a significant impact on the ecological character of a Ramsar wetland and 2) managing Ramsar wetlands (Figure 4).

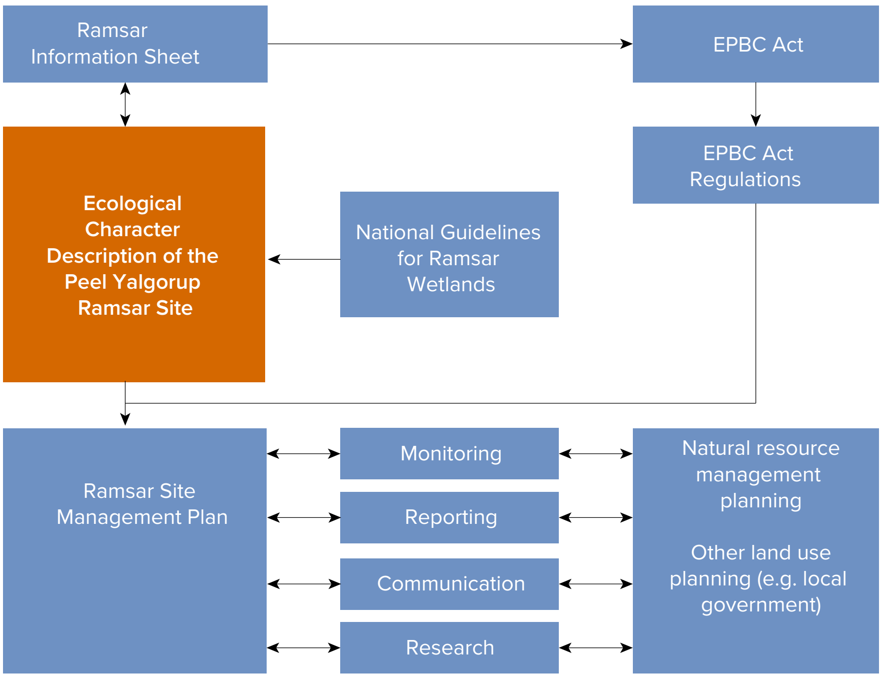

Figure 4: The Ecological Character Description in the context of other requirements for the management of Ramsar sites

he National 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 ecologically significant Limits of Acceptable Change exceedence, of which 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 responsibilities under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the Environment Protection and Biodiversity Conservation Regulations 2000 (Commonwealth):
   a. To describe and maintain the ecological character of listed 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 RIS 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 listed 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 the ecological character of a listed Ramsar wetland.
5. To assist any person considering taking an action that may impact on a listed 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 listed Ramsar wetlands to understand and value the wetlands.

1.3 Relevant Treaties Legislation and Regulations

The following provides a brief listing of the legislation and policy that are relevant to the description of the ecological character of the Peel-Yalgorup Ramsar site.

International

Ramsar Convention: The Convention on Wetlands of International Importance especially as Waterfowl Habitat, otherwise known as the Ramsar Convention, was signed in Ramsar Iran in 1971 and came into force in 1975. It provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands.

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 Ramsar site as various migratory bird species covered in these agreements utilise the site. The bilateral agreements are:

- Japan Australia Migratory Bird Agreement (JAMBA)
- China Australia Migratory Bird Agreement (CAMBA)
- Republic of Korea Australia Migratory Bird Agreement (ROKAMBA)
- The Convention on the conservation of Migratory Species of Wild Animals (CMS)

National

Environment Protection and Biodiversity Conservation Act 1999 (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 s16(1)).

Environment Protection and Biodiversity Conservation Regulations (2000): The Australian Ramsar Management Principles set out in Schedule 6 of the regulation outline the general principles for the management of wetlands of international importance.

Water Act 2007 provides for the management of water resources, and to make provision for other matters of national interest in relation to water and water information, and for related purposes.

West Australian Legislation and Policy

Western Australian legislation that is relevant to Ramsar sites, both in terms of protecting and managing the sites, but also for regulating potential impacts includes:

- *WA Biodiversity Conservation Act 2016*
- *Conservation and Land Management Act 1984*
- *Environmental Protection Act 1986*
- *Aboriginal Heritage Act 1972*
- *Rights in Water and Irrigation Act 1914*
- *Metropolitan Water Supply Sewerage and Drainage Act 1909*
- *Metropolitan Arterial Drainage Act 1982*
- *Planning and Development Act 2005*
- *Bushfires Act 1954*
- *Fish Resources Management Act 1994*
- *Western Australian Marine Act 1982*
- *Marine and Harbours Act 1981*
- *Waterways Conservation Act 1976*
- *Biosecurity and Agriculture Management Act 2007 (enacted 2013)*

The following state, regional and local policies and planning schemes are also relevant to the Peel-Yalgorup Ramsar Site:

Wetlands Conservation Policy for Western Australia 1997: This policy outlines the WA Government's commitment to identifying, maintaining and managing the State's wetland resources, including the full range of wetland values, for the long term. It provides broad objectives for wetlands, waterways, estuaries and shallow marine areas, and provides an implementation strategy specifically for the management of wetlands in Western Australia. It also identifies the agencies involved and their responsibilities.

State Planning Policy. 2.1 The Peel-Harvey Coastal Plain Catchment: This policy includes specific provisions addressing land use changes within the Peel-Harvey estuarine system likely to cause environmental damage to the estuary. The objectives of the policy are to:

- Improve the social, economic, ecological, aesthetic, and recreational potential of the Peel-Harvey coastal plain catchment
- 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
- Balance environmental protection with the economic viability of the primary sector
- Increase high water-using vegetation cover within the Peel-Harvey coastal plain catchment
- Reflect the environmental objectives in the draft Environmental Protection Policy (Peel-Harvey Estuarine System) 1992
- Prevent land uses likely to result in excessive nutrient export into the drainage system

State Planning Policy 2.9 Water Resources: This policy provides guidance to planning decision-makers for consideration of water resources in land use planning strategy. The objectives of the policy are to:

- Protect, conserve and enhance water resources that are identified as having significant economic, social, cultural and/or environmental values
- Assist in ensuring the availability of suitable water resources to maintain essential requirements for human and all other biological life with attention to maintaining or improving the quality and quantity of water resources
- Promote and assist in the management and sustainable use of water resources

Metropolitan Region Scheme: The Peel-Yalgorup Ramsar site is within the Peel Region Scheme and Bunbury Region Scheme and includes reserved Regional Open Space or Waterways.

Coastal and Lakelands Planning Strategy, Dawesville to Binningup, (WAPC, 1999): presents a broad strategy for the future use and development of this important coastal strip and a guide for more detailed planning. Its main aim is to protect the valuable environmental and landscape values of the area while permitting compatible development and rural uses. It should be read in conjunction with the Inner Peel Region Structure Plan. It recognises the strategic importance of this coastal strip. The strategy area incorporates the surface and groundwater catchments of the Yalgorup Lakes.

Local Government Planning Schemes: Local government authorities are responsible for planning for local communities by ensuring appropriate planning controls exist for land use and development. The Peel-Yalgorup System Ramsar site is located in the Shires of Murray, Waroona and Harvey, and the City of Mandurah.

EPA Guidance Statement 28 for the Protection of the Lake Clifton Catchment (May 1998): describes the Environmental Protection Authority's environmental criteria which provides a basis for managing new land uses and changes to certain existing land uses on private land within the catchment of Lake Clifton.

Strategic Environmental Advice on the Dawesville to Binningup Area (Report 1359) (EPA, 2010).

1.4 Preparing the ECD

This ECD Addendum for the Peel-Yalgorup Ramsar Site was prepared using the twelve-step approach provided in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) illustrated in Figure 5.

This ECD Addendum was developed primarily through a desktop assessment and review of unpublished data, grey literature and peer reviewed publications. Technical advice and local expertise contributed to the development of the ECD Addendum.

1. Introduction to the description
Site details, purpose of the description, relevant legislation

2. Describe the site
Site location, climate, maps and images, tenure, criteria and wetland types

3. Identify and describe the critical components, processes, benefits and services
3.1 Identify all possible components, processes, benefits and services
3.2 Identify the critical components, processes benefits and services responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes, benefits & services

4. Develop a conceptual model of the wetland
Depict the critical components & processes of the wetland and their interactions

5. Set limits of acceptable change (LAC)
Determine LAC for critical components, processes and services

6. Identify threats to the ecological character of the site
Identify the actual or likely threats to the site

7. Describe changes to ecological character
Describe changes to the ecological character since the time of listing Include information on the current condition of the site

8. Summarise knowledge gaps
Use information from Steps 3 - 7 to identify knowledge gaps

9. Identify site monitoring needs
Use information from Steps 3 - 8 to identify monitoring needs

10. Identify communication and education messages
Identify any communication & education messages highlighted during the development process

11. Compile the description of ecological character

12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure 5: Twelve step process for developing an ECD (Department of the Environment, Water, Heritage and the Arts 2008)

2 GENERAL DESCRIPTION OF THE PEEL-YALGORUP RAMSAR SITE

2.1 Location

The Peel-Yalgorup Ramsar Site is located in south-western Australia, approximately 80 kilometres south of Perth within the South West Coast Drainage Division bioregion. The site covers more than 26,000 hectares and spans four municipal boundaries: City of Mandurah and the Shires of Murray, Waroona and Harvey (Figure 6).

The South West Coast Drainage Division bioregion covers an area of around 326,000 square kilometres extending from a point approximately 50 kilometres north of Jurien Bay to just short of Esperance on the southern coast. There are 14 river basins within the drainage division including the Moore Hill Rivers to the north, the Swan-Avon catchment in the centre and the southern coastal basins of Esperance, Albany and Busselton. The Peel-Yalgorup Ramsar Site lies within the Murray River Basin of the Peel-Harvey Catchment, which includes the Murray, Harvey and Serpentine Rivers (Bureau of Meteorology 2013).

The Peel-Harvey Catchment covers more than 11,000 square kilometres including the Peel region, the southern coastal part of the Perth metropolitan region and parts of the South West and Wheatbelt regions. The City of Mandurah, with its urban areas hugging the northern and western portions of the estuarine part of the site, has a population of just over 80,000 people (Australian Bureau of Statistics 2019), which is around a 350 percent increase since the time of listing, when the population was around 23,000[2].

Around 56 percent of the catchment has been cleared for agriculture with beef farming the dominant land use. Mining tenements cover around half the catchment, particularly within the Darling Escarpment. Other major landuses include urban and rural residential living, particularly along the coast, forestry on the escarpment and small areas of dairy on the coastal plain. Over 5500 square kilometres of native vegetation remain in the catchment, of which around five percent is within conservation reserves (from spatial data provided by DBCA).

2 Data from the 1991 Census, Australian Bureau of Statistics

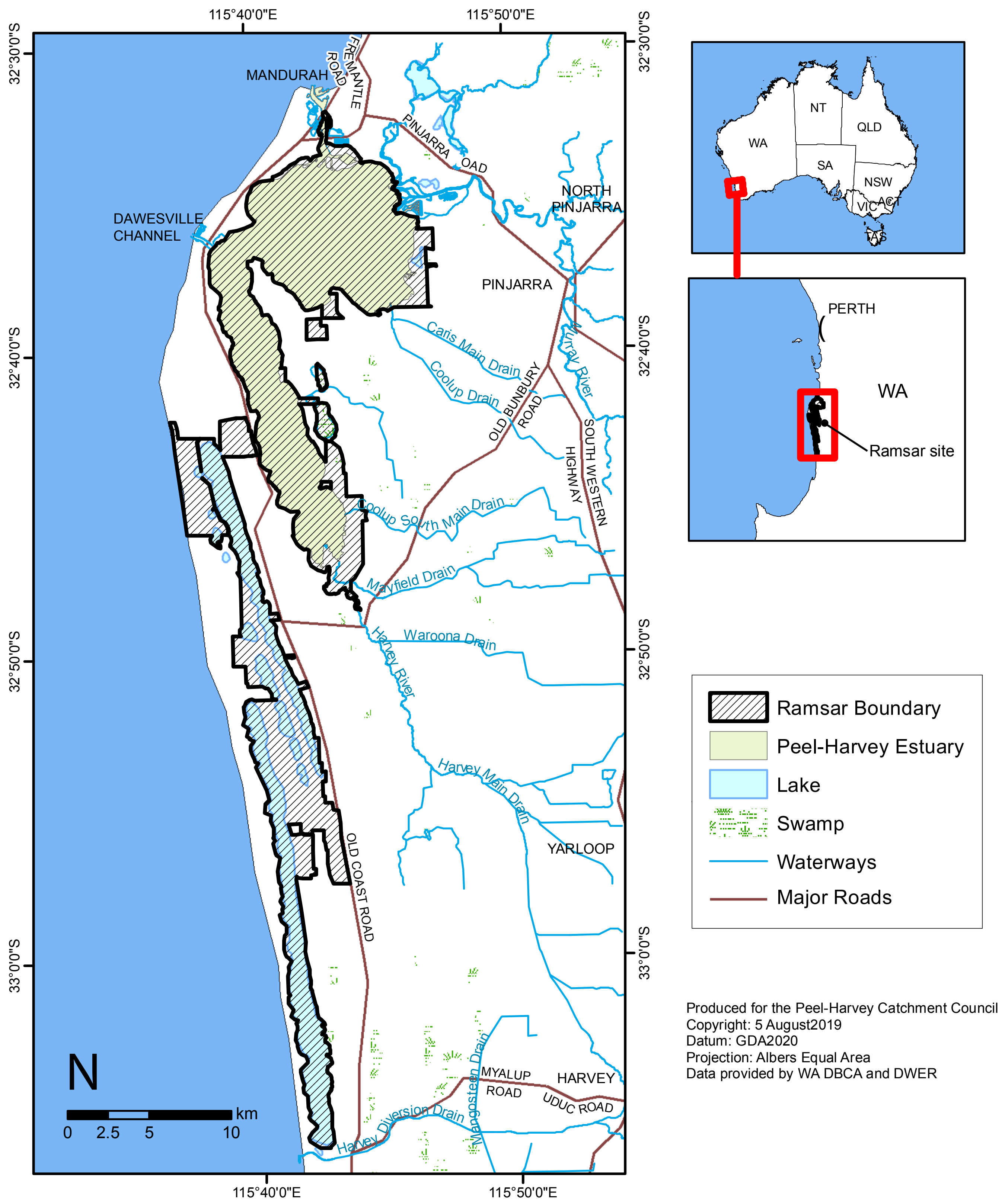

Figure 6: **Peel-Yalgorup Ramsar Site**

2.2 Land Tenure

The Ramsar site is almost entirely within conservation zones. The water area in the estuary is non-tenured crown land, managed under the Waterways Conservation Act. All other lakes, ex-direct freehold, national parks, state forest and reserves are vested with the Western Australian Conservation Commission and managed by the Department of Biodiversity, Conservation and Attractions (Table 7). Foreshore areas are vested with the City of Mandurah. Freehold land at Lake Mealup is owned and managed by the Lake Mealup Preservation Society (Inc); a conservation covenant exists on the title, established through the National Trust's covenanting scheme.

Table 7: Land tenure within the Peel-Yalgorup Ramsar site

NAME	TYPE	AUTHORITY
Len Howard	Conservation Park	Department of Biodiversity, Conservation and Attractions
Mealup Point, Austin Bay, Lake Mealup, Creery Island, Kooljerrenup, Boodalan, Lake McLarty	Nature Reserves	
Yalgorup Lakes	National Park	
Lake Mealup	Conservation Covenant NTWA Bushland covenant (0070)	Lake Mealup Preservation Society

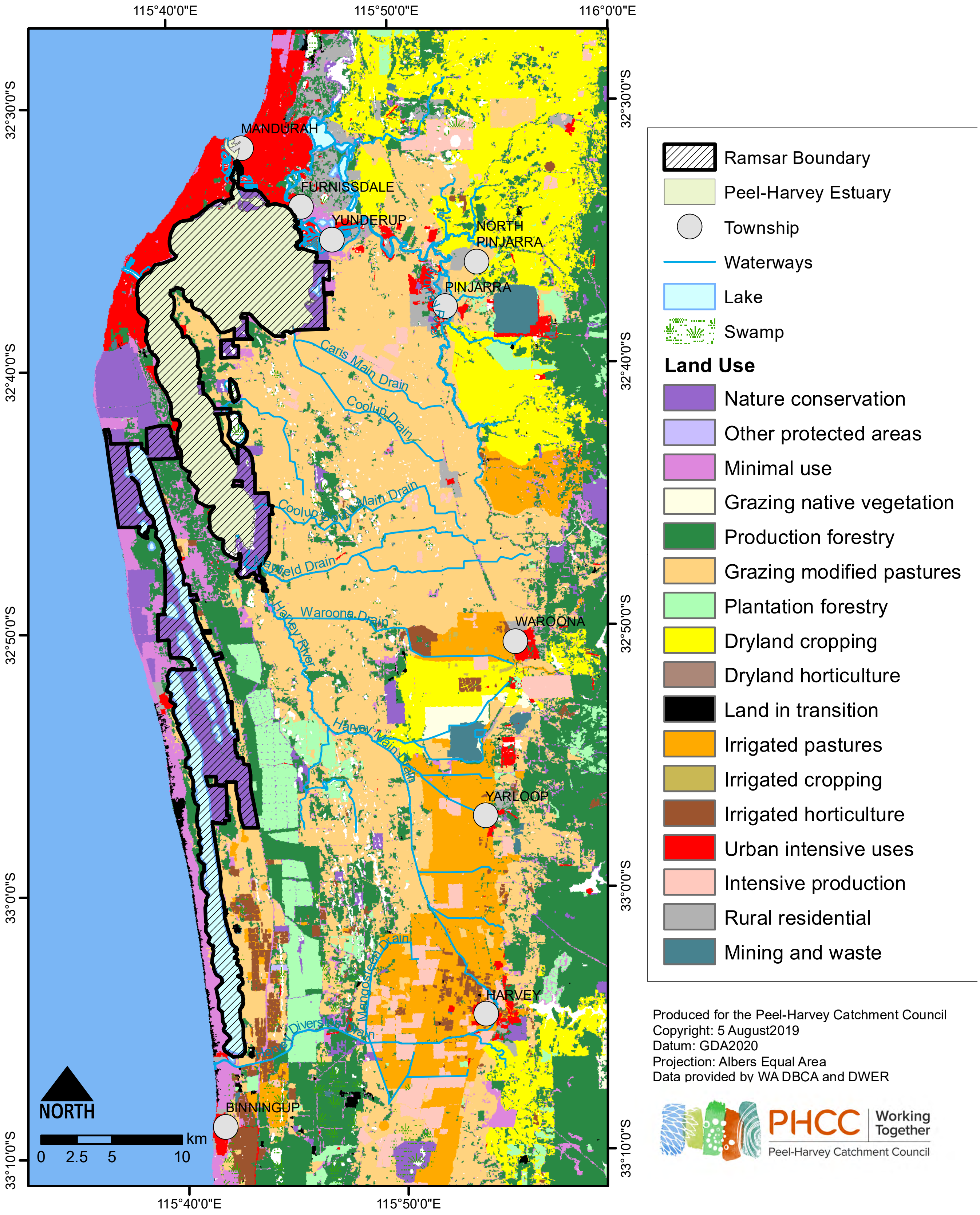

Figure 7: Land use in the Peel-Harvey Coastal Catchment

2.3 Wetland Types

Classification of wetlands into discrete types is a difficult exercise and an inexact science. Clear boundaries are difficult to define or delineate and multiple wetland types could be considered to apply to the same wetland. For example, Type F (estuarine waters) and Type B (marine sub-tidal beds) are applicable to the Peel-Harvey Estuary. For this reason, while a list and a description of wetland types can be provided, there is uncertainty over the extent of each wetland type. Wetland types in likely order of dominance are presented in Table 8.

Table 8: Wetland types within the Peel-Yalgorup Ramsar Site (in descending order of dominance, estimated from multiple lines of evidence, water quality data[3], geomorphic wetland mapping (Hill et al. 1996), vegetation mapping)

RAMSAR TYPE	DESCRIPTION	LOCATIONS WITHIN THE SITE
F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas	Peel-Harvey Estuary
B	Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows	Seagrass and macroalgal beds across the Peel-Harvey Estuary
Q	Permanent saline/brackish/alkaline lakes	Yalgorup Lakes: Lake Clifton, Lake Yalgorup, Lake Hayward, Lake Newnham (North and South), Lake Preston, Martins Tank, Lake Pollard, Boundary Lake
H	Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes	Saltmarshes, most extensive around the Peel-Harvey Estuary
P	Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes	Lake McLarty, Kooljerrenup
O	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes	Lake Mealup
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	Paperbark communities, most extensive around the Yalgorup Lakes
G	Intertidal mud, sand or salt flats	Intertidal areas around the Peel-Harvey Estuary devoid of vegetation
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats	Yalgorup Lakes: Duck Pond, Swan Pond, Carrabungup

3 Salinity thresholds for inland aquatic ecosystems in accordance with the Australian National Aquatic Ecosystem Classification (Aquatic Ecosystem Task Group 2012): fresh (less than 3 ppt); brackish (3 – 5 ppt); saline (5 – 10 ppt); hypersaline (greater than 10 ppt)

Wetland Types


O


P


P


Q


R


Xf

2.4 Ramsar criteria

2.4.1 Criteria under which the site was designated

At the time that the Peel-Yalgorup Ramsar Site was first nominated as a Wetland of International Importance (1990), there were six nomination criteria, of which the Peel-Yalgorup System was considered to meet four (Criteria 1, 3, 5 and 6; Table 9).

Table 9: Criteria for Identifying Wetlands of International Importance as at listing date, 1990. Criteria for which the Peel-Yalgorup Ramsar Site has been listed are shaded

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 percent of the individuals in a population of one species or subspecies of waterbird

2.4.2 Assessment based on current information and Ramsar criteria

A number of developments since the time of listing, influence the application of the Ramsar criteria to wetland sites. These include:

- Revision of population estimates for waterbirds (Wetlands International 2012) and the adoption of Hansen et al. (2016) for population estimates for species in the East Asian-Australasian Flyway, which influences the application of criterion six
- A decision with respect to the appropriate bioregionalisation for aquatic systems in Australia, which for inland systems are now based on Australian Drainage Divisions (http://www.bom.gov.au/water/about/riverBasinAuxNav.shtml) and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). This affects the application of criteria one and three
- Updating of threatened species and communities listings, which affects criterion two
- Additional data have been collected for the site, which could potentially influence the application of all criteria

An assessment against the current criteria indicates that the Peel-Yalgorup Ramsar Site would have met seven of the nine criteria at the time of listing and continues to do so (Table 10).

Table 10: Ramsar listing criteria with those currently met by the Peel-Yalgorup Ramsar Site shaded

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 percent 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 percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species

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.

The application of this criterion must be considered in the context of the bioregion within which the site is located. The South West Coast Drainage Division covers the entire southwest corner of Western Australia from 50 kilometres north of Jurien Bay to Esperance and inland almost as far as Kalgoorlie. The Ramsar guidance for this criterion indicates that the justification should be based on wetland type, hydrology and condition. There is no comprehensive wetland inventory for this bioregion. As such the application of the terms “representative” and “rare” are difficult. In terms of “representative”, advice from the Convention (Ramsar 2009) is that contracting parties should select the “best examples” of each wetland type within a bioregion.

The Yalgorup Lakes are a series of groundwater-fed saline to hypersaline coastal lakes within the Ramsar site. These are likely bioregionally rare if not unique. In addition, recent evidence suggests that three of the Yalgorup Lakes (Lakes Hayward, Newnham and Yalgorup) are naturally heliothermal (lakes with a bottom water layer that becomes hot due to absorption of solar energy) (Turner et al. 2018). Heliothermal lakes are rare with only 30 recorded worldwide and Lake Hayward is considered unique in this small group due to its shallow water depth, low groundwater gradient, coastal location and rainfall event distribution (Turner et al. 2018).

This criterion was met at the time of listing and continues to be met.

Criterion 2

> *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.*

In the Australian context, this criterion is applied to nationally threatened wetland dependent species and communities, listed under the EPBC Act 1999 or the International Union for Conservation of Nature Red List (IUCN 2012). The site regularly supports three threatened ecological communities and seven threatened fauna species:

- Subtropical and temperate coastal saltmarsh – vulnerable ecological community (EPBC)
- Thrombolite (microbialite) community of a coastal brackish lake (Lake Clifton)
- Clay pans of the Swan Coastal Plain (Austin Bay, Kooljerrenup, Herron Point)
- Australian fairy tern *(Sternula nereis nereis)* – Vulnerable (EPBC and IUCN)
- Bar-tailed godwit *(Limosa lapponica menzbieri)*[4] – Critically endangered (EPBC)
- Curlew sandpiper *(Calidris ferruginea)* – Critically endangered (EPBC)
- Eastern curlew *(Numenius madagascariensis)* – Critically endangered (EPBC); endangered (IUCN)
- Great knot *(Calidris tenuirostris)* – Critically endangered (EPBC); endangered (IUCN)
- Greater sand plover *(Charadrius leschenaultii)* – Vulnerable (EPBC)
- Red knot *(Calidris canutus)* – Endangered (EPBC)

Although there are historical records for the EPBC listed endangered Australasian bittern *(Botaurus poiciloptilus)* from the Ramsar site, the last record was in 1986. The recovery plan for the species in Western Australia notes that: "conservation management of Lake Mealup (including Typha control) by the Lake Mealup Preservation Society and natural regeneration at Lake McLarty may provide habitat suitable for Australasian bitterns, potentially resulting in their return to this wetland system." (Department of Biodiversity, Conservation and Attractions 2018). As yet there have been no recent records and this species is not included under this criterion at this stage.

The Peel-Yalgorup Ramsar Site met this criterion at the time of listing and continues to meet it on the basis of supporting seven threatened species and two threatened ecological communities.

Criterion 3

> *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.*

Guidance from the Convention indicates that this criterion should be applied to "hotspots" of biological diversity and centres of endemism within a biogeographical region. As with criterion 1, the relevant bioregion is the South West Coast Drainage Division. 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.

The Peel-Yalgorup Ramsar Site supports a high diversity of waterbirds, most likely related to the diversity of habitats provided by the site. A total of 104 species of wetland dependent birds have been recorded within the Ramsar site, noting that this list excludes vagrants and species for which the site does not provide core habitat (e.g. pelagic seabirds). This represents the most species rich Ramsar site in the South West Coast Drainage Division with respect to waterbirds when compared to other systems in the bioregion. For example:

- Vasse Wonnerup supports 83 waterbird species (Wetland Research & Management 2007)
- Muir-Byenup supports 49 waterbird species (Farrell and Cook 2009)
- Toolibin Lake supports 50 waterbird species (McMahon 2006)
- Forrestdale-Thomsons Lakes support 85 waterbird species (Maher and Davis 2009).

This criterion was met at the time of listing and continues to be met.

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4 Two distinct sub-populations of Bar-tailed godwit overwinter in Australia; *Limosa lapponica bauera* (vulnerable EPBC) breeds in Alaska and migrates to eastern Australia and New Zealand; *Limosa lapponica menzbieri* (critically endangered EPBC) breeds in Siberia and overwinters in north western Australia (Wilson et al. 2007). The subspecies in south western Australia is not known; but is assumed to be *Limosa lapponica menzbieri*.

Criterion 4

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.

The basic description of this criterion implies a number of common functions/roles that wetlands provide including supporting fauna during migration, providing drought refuge, supporting breeding and moulting in waterfowl. The Peel-Yalgorup Ramsar site provides all of these functions and roles as described below and clearly meets this criterion.

The critical life stage of migration

All areas within the site support migratory shorebirds, with over 30 species of international migratory shorebirds recorded in the site. Of, these the site regularly supports 20 species (Table 11), most of which utilise the site during the summer non-breeding months. A number of juvenile birds, however, as well as the southern breeding double-banded plover *(Charadrius bicinctus)* utilise the site during winter.

In addition, the Peel-Harvey Estuary provides a migratory corridor for several fish and invertebrate species including:

- the pouched lamprey *(Geotria australis)* from the estuary to spawning grounds in the Serpentine River (Klunzinger et al. 2011)
- blue swimmer crab *(Portunus armatus*[5]*)*, which enter the estuary from the Indian Ocean as juveniles, with adult females returning to the ocean to release their zoea (de Lestang et al. 2003)
- western king prawns *(Penaeus latisulcatus)*, which also enter the estuary as juveniles, using the system as a nursery (Potter et al. 1991).

The critical life stage of drought refuge

The permanent waters of the Peel-Harvey Estuary and several of the Yalgorup Lakes provide important aquatic habitat when surrounding landscapes are dry. In particular, the waters around the Harvey Delta have been historically important for Black Swan during summer months (Lane et al. 2002a, 2002b). In addition, Lake Mealup is now a permanent wetland providing valuable freshwater habitat in the region during the summer months.

The critical life stage of breeding

At least 30 species of wetland dependent bird have been observed breeding within the Peel-Yalgorup Ramsar Site. This includes several regionally important breeding sites such as hooded plover at the Yalgorup Lakes, the cormorant breeding colonies at Len Howard Reserve (OTS 2010, 2016) and Australian pelican *(Pelecanus conspicillatus)* nesting sites on Boundary Island (Lane et al. 1997). Black swans *(Cygnus atratus)*, grey teal *(Anas gracilis)* and red-capped plover *(Charadrius ruficapillus)* regularly breed at several locations in the Ramsar site (Lane et al. 2002b, 2002b, Craig et al. 2006, 2018).

The Peel-Harvey Estuary supports a resident community of bottlenose dolphins *(Tursiops aduncus)*, which breed and raise their young within the waters of the Ramsar site (Nicholson et al. 2017).

The critical life stage of moulting

Lake McLarty and Yalgorup Lakes are important sites for Australian shelduck *(Tadorna tadornoides)* undergoing moult of primary flight feathers (Craig et al. 2018). In addition, the open waters of the Peel-Harvey Estuary are known to support several species of waterfowl during moult (Lane et al. 2002b).

The Peel-Yalgorup Ramsar Site met this criterion at the time of listing and continues to meet it.

5 Formerly *Portunus pelagicus*

Table 11: Migratory shorebirds recorded in the Ramsar site and their frequency of occurrence (percentage). The 20 species that the site is considered to regularly support are shaded.

COMMON NAME	SPECIES NAME	JAMBA	CAMBA	ROKAMBA	FREQUENCY OF OCCURRENCE
American golden plover	*Pluvialis dominica*				4
Bar-tailed godwit	*Limosa lapponica*	X	X	X	64
Black-tailed godwit	*Limosa limosa*	X	X	X	96
Broad-billed sandpiper	*Limicola falcinellus*	X	X	X	16
Common greenshank	*Tringa nebularia*	X	X	X	100
Common sandpiper	*Actitis hypoleucos*	X	X	X	88
Curlew sandpiper	*Calidris ferruginea*	X	X	X	96
Double-banded plover	*Charadrius bicinctus*				16
Eastern curlew	*Numenius madagascariensis*	X	X	X	64
Great knot	*Calidris tenuirostris*	X	X	X	84
Greater sand plover	*Charadrius leschenaultii*	X	X	X	76
Grey plover	*Pluvialis squatarola*	X	X	X	92
Grey-tailed tattler	*Tringa brevipes*	X	X	X	52
Latham's snipe	*Gallinago hardwickii*	X	X	X	4
Lesser sand plover	*Charadrius mongolus*	X	X	X	32
Little curlew	*Numenius minutus*	X	X	X	8
Little ringed plover	*Charadrius dubius*	X	X	X	4
Long-toed stint	*Calidris subminuta*	X	X	X	88
Marsh sandpiper	*Tringa stagnatilis*	X	X	X	84
Oriental pratincole	*Glareola maldivarum*	X	X	X	4
Pacific golden plover	*Pluvialis fulva*	X	X	X	64
Pectoral sandpiper	*Calidris melanotos*	X	X	X	88
Red knot	*Calidris canutus*	X	X	X	80
Red-necked stint	*Calidris ruficollis*	X	X	X	100
Ruff	*Philomachus pugnax*	X	X	X	64
Ruddy turnstone	*Arenaria interpres*	X	X	X	60
Sanderling	*Calidris alba*	X	X	X	32
Sharp-tailed sandpiper	*Calidris acuminata*	X	X	X	100
Terek sandpiper	*Xenus cinereus*	X	X	X	40
Whimbrel	*Numenius phaeopus*	X	X	X	76
Wood sandpiper	*Tringa glareola*	X	X	X	72

Criterion 5

A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Waterbird data from around the time of listing are limited. There is, however, relatively good quality data from around 1995 onwards and there have been regular and consistent counts conducted as part of the Shorebirds 2020 program since 2008. Available data have been used to assess this criterion within the definition of "regularly supports" (see Text Box 1). A sum of maximum annual abundance indicates that the site has supported greater than 20,000 waterbirds every year since 1995, with the exception of a single year. It should be noted that count data were limited for 2001 (with no comprehensive counts of Lake McLarty in that year) and it is likely that total waterbird abundance exceeded 20,000 in that year as well.

The Peel-Yalgorup Ramsar Site met this criterion at the time of listing and continues to meet it.

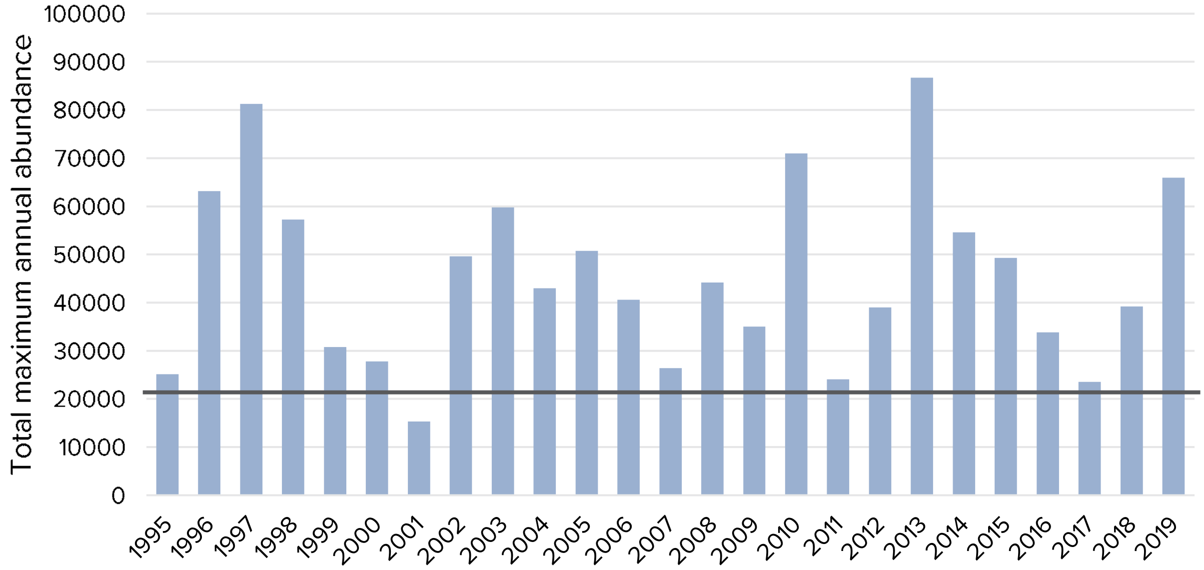


Figure 8: Total maximum waterbird abundance (1995 – 2019; data from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002 a, b; Mr. B. Russell and Mr. D. Rule)[6]

6 Note that total maximum annual abundance is the sum of individual species maximum abundances. These are summed across locations at the site if counted at the same time (e.g. Shorebirds 2020) or taken as the single maximum abundance at a location, whichever is the greater.

Regularly (Criteria 5 and 6) - as in supports regularly - a wetland regularly supports a population of a given size if:

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

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.

Text Box 1: Definition of regularly supports (Ramsar 2009, 2012)

Criterion 6

A wetland should be considered internationally important if it regularly supports one per cent of the individuals in a population of one species or subspecies of waterbird.

Assessment of this criterion must be made using the most recent official population estimates (Wetlands International 2012, Hansen et al. 2016) and an application of the definition of "regularly supports" (Text Box 1). Data indicate that eight species meet this criterion (Table 12)[7].

In recent years (post 2010) the site has supported greater than 1 percent of the population of little pied cormorant (average 2010 – 2019 of 1180; equal to 1.1 percent of the population). If data over a longer time frame is included the averages drop below the thresholds. Additional data is required to determine if this species is consistently supported in numbers greater than the 1 percent population threshold.

The Peel-Yalgorup Ramsar Site met this criterion at the time of listing and continues to meet it.

7 Note that the 2007 ECD identified 14 species over the one percent threshold, but this was applied to isolated records and did not apply the Ramsar definition of "regularly supports".

Table 12: Species for which the Peel-Yalgorup Ramsar Site regularly supports greater than 1 percent of the population (average counts 1995 to 2019 from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002 a, b; Mr. B. Russell and Mr. D. Rule)

COMMON NAME	SPECIES NAME	MEAN MAXIMUM COUNT	PERCENT OF POPULATION
Australian fairy tern	*Sternula nereis nereis*	112	7.5
Banded stilt	*Cladorhynchus leucocephalus*	6640	1.8
Hooded plover	*Thinornis cucullatus*	83	2.0
Red-capped plover	*Charadrius ruficapillus*	964	1.0
Red-necked avocet	*Recurvirostra novaehollandiae*	1200	1.2
Red-necked stint	*Calidris ruficollis*	6400	1.3
Sharp-tailed sandpiper	*Calidris acuminata*	2300	2.7
Pied stilt[8]	*Himantopus leucocephalus*	2400	1.4

Criterion 7

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.

Guidance from the Ramsar Convention (Ramsar Convention 2009) indicates that in order to meet this criterion, a site should have a high degree of endemism or biodisparity in fish communities. While the Peel-Yalgorup Ramsar Site supports a wide variety of marine, estuarine and freshwater fish species, there is no evidence to suggest that these species are unique to the Ramsar site. In addition, there is no indication of high biodisparity in fish communities within any of the locations. Therefore, this criterion was not likely to be met at the time of listing and is not currently met.

Criterion 8

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.

The Peel-Harvey Estuary portion of the Peel-Yalgorup Ramsar Site provides important habitats, feeding areas, dispersal and migratory pathways, and spawning sites for numerous fish species of direct and indirect fisheries significance. The estuary supports both commercial and recreational fisheries that are economically and socially important and have recently been certified by the Marine Stewardship Council as a sustainable fishery for blue swimmer crab *(Portunus armatus)* (commercial and recreational fishery) and sea mullet *(Mugil cephalus)* (commercial fishery only).

Prawn species also utilise the estuary for parts of their lifecycle, with the western king prawn *(Penaeus latisulcatus)*, spawning in the ocean, but using the estuary as nursery habitat and the western school prawn spawning in the upper river reaches (Potter et al. 1989, 1991).

The Peel-Yalgorup Ramsar Site met this criterion at the time of listing and continues to meet it.

Criterion 9

A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

The application of this criterion relies on estimates of the total population of non-avian wetland dependent 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.

8 Formerly black-winged stilt *(Himantopus himantopus)*, the Australian species recently re-classified as pied (or white-headed) stilt.

3 COMPONENTS, PROCESSES, SERVICES AND BENEFITS

3.1 Definitions

In the context of this ECD the following definitions are adopted.

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) (Ramsar Convention 2005, Resolution IX.1 Annex A).

Ecosystem processes are changes or reactions which occur naturally within wetland ecosystems. They may be physical, chemical or biological. In laymen's terms, this equates to processes such as carbon cycling, denitrification, acidification, sedimentation, migration, breeding, reproduction, etc. (from Ramsar Convention, Resolution V1.1).

Ecosystem benefits and services are "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. **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.
4. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics.

3.2 Identifying critical components, processes, benefits and services

The basis of an ECD is the identification, description and where possible, quantification of the critical components, processes, benefits and services 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. 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 without clearly defining what is important about the system and how to best manage it. What is required is to identify the key components, the benchmark state of the systems, and the basic rules that link the key components and cause changes in state. Thus, an ECD identifies and characterises the key or critical components, processes, benefits and services 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.

DEWHA (2008) suggest the minimum components, processes, benefits and services, which should be included in an ECD are those:

1. that are important determinants of the site's unique character;
2. that are important for supporting the Ramsar criteria under which the site was listed;
3. for which change is reasonably likely to occur over short to medium time scales (less than 100 years); and/or
4. that will cause significant negative consequences if change occurs.

A simple conceptual model for the Peel-Yalgorup Ramsar Site (Figure 9) illustrates the components, processes and services that are critical to the ecological character of the site, and those which are important in supporting the critical components, processes and services the site provides.

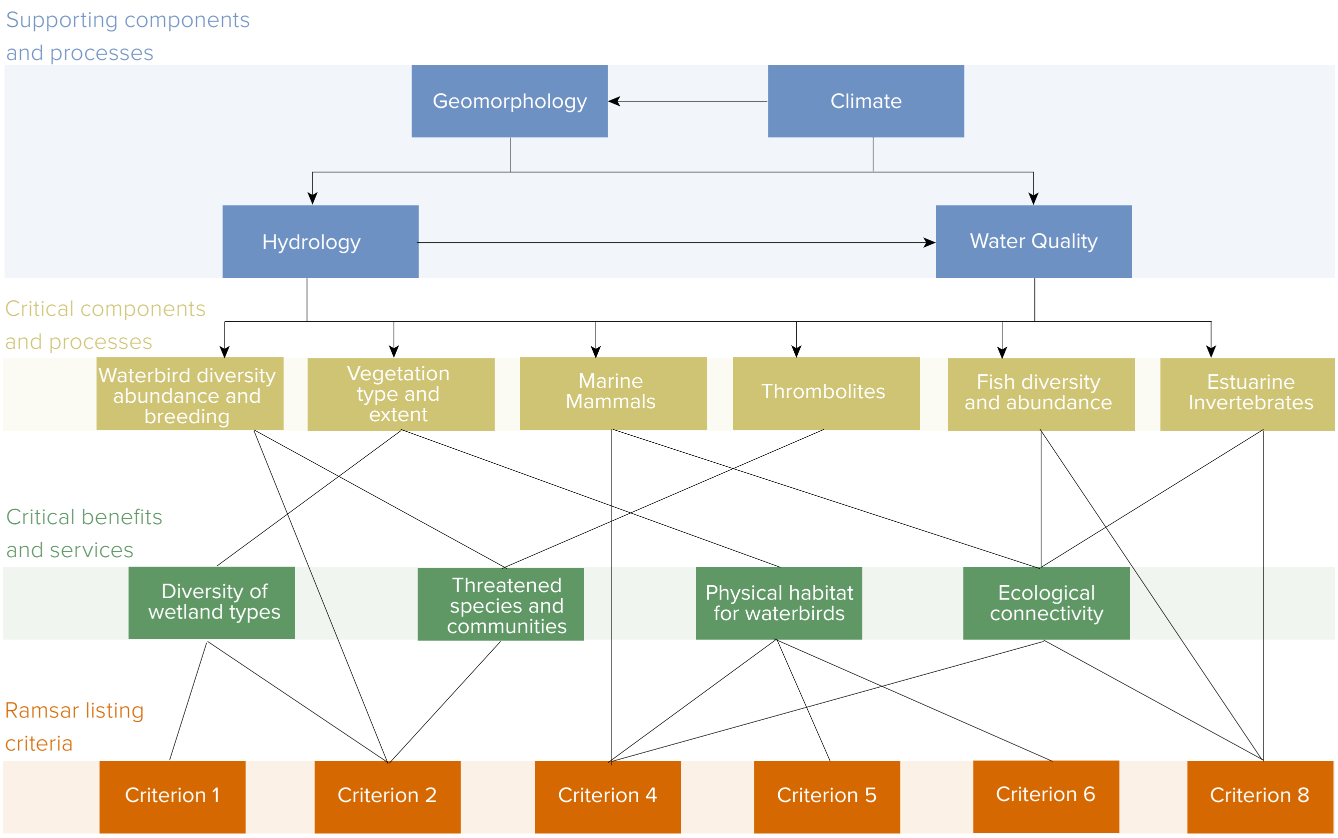


Figure 9: Simple conceptual model showing the key relationships between components and processes; benefits and services; and the reasons for the site being listed as a Wetland of International Importance (note all relationships between critical components, processes and services are not shown).

The critical components, processes and services of the site at the time of listing were:

Components:

- Vegetation type and extent
- Thrombolites
- Estuarine invertebrates
- Fish diversity and abundance
- Waterbird diversity and abundance
- Marine mammals

Process:

- Waterbird breeding

Services:

- Supports a diversity of wetland types
- Supports threatened species
- Provides physical habitat for waterbirds
- Ecological connectivity

3.3 The baseline for describing ecological character

In general, the baseline for ecological character, against which changes are assessed, is the time of listing (Department of the Environment, Water, Heritage and the Arts 2008). While 1990 is an appropriate benchmark for most of the Peel-Yalgorup Site (Lakes McLarty, Mealup and the Yalgorup Lakes), this is not the case for the Peel-Harvey Estuary. As recognised in the ECD (2007; p. 15), the opening of the Dawesville Channel in April 1994, provided a large, permanent connection to the Indian Ocean. Prior to the opening of the channel, the Peel-Harvey Estuary suffered from severe eutrophication (see Appendix A). 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 kilometres long, 200 metres wide and between 4.5 and 6.5 metres deep and has associated canal developments that have been constructed over the last two decades.

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. There, however, 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 (see section 2.4 above).

While some changes to the system (hydrology and water quality) occurred rapidly post opening of the Channel, other ecological responses (vegetation, fish communities) took longer to respond and establish a new equilibrium. So while physical components and processes could be described post 1995 we suggest that the period circa 2010 would represent an appropriate benchmark for biological components and processes critical to the ecological character of the Peel-Harvey Estuary (see Potter et al. 2016).

As always, there has been an attempt to capture natural variability, rather than a single year or point in time and data availability plays an important role. So, while we aim to use data from 2000 – 2010 is used for the Peel-Harvey Estuary and the years or decades around 1990 for the rest of the site, in some instances more recent data is all that is available and so is presented here.

3.4 Supporting components and processes

Four components and processes have been identified as being important in supporting the critical components, processes and services. These supporting components and processes are important in managing the site to maintain ecological character and some may provide early warning indicators of change. As such, this section includes a description (at the time of listing) of the following components and processes that are important in supporting the ecological character of the site (Table 13):

- Climate
- Geomorphology
- Hydrology
- Water quality

Table 13: Summary of supporting components and processes within the Peel-Yalgorup Ramsar Site.

COMPONENT / PROCESS	DESCRIPTION
Climate	Rainfall is winter-dominated with two thirds of the annual rainfall occurring between May and August. Evaporation is high in summer months and, on average, annual evaporation exceeds rainfall.
Geomorphology	The site is located within a series of parallel dunes systems between the Darling Scarp and the Indian Ocean. The Peel-Harvey Estuary comprises two large shallow basins with average water depths of less than 2 metres. The Yalgorup Lakes (within the Ramsar site boundary) comprise ten shallow wetlands, situated in the depression between a series of linear coastal dunes. Lakes McLarty and Mealup are shallow; moderate sized depressional wetlands on the plain to the east of the Harvey Estuary.
Hydrology	The Peel-Harvey Estuary receives riverine inflows from three river systems, with 95 percent of surface inflows occurring between May and October. Average river inflow is around 380 380 gigalitres per year, but interannual variability is high. Exchange with the Indian Ocean occurs through the Mandurah Channel, and, since the opening of the Dawesville Channel in 1994, is predominantly through the artificial Dawesville Channel. The Yalgorup Lakes are groundwater fed having no substantive surface water inflows. They are connected to the surficial unconfined freshwater aquifer which delivers water mainly during spring. Lakes McLarty and Mealup are seasonal wetlands, the former receiving the majority of inflows via a small local catchment and direct rainfall, and the latter, at the time of listing, through artificial drainage lines as well as groundwater.
Water quality – salinity, nutrients, pH, turbidity	At the time of listing there was a gradient of salinity from the saline Yalgorup Lakes to the estuarine conditions of the Peel-Harvey Estuary and the freshwater to brackish wetlands of Lakes McLarty and Mealup. Alkalinity at the site ranged from the periodically acidic Lake Mealup through the mainly neutral Lake McLarty to the slightly alkaline Peel-Harvey Estuary and the more highly alkaline Yalgorup Lakes. Since the opening of the Dawesville Channel (1994) the Peel-Harvey Estuary is characterised by relatively low concentrations of bioavailable nutrients and phytoplankton. While the Yalgorup Lakes and Lake McLarty could be considered mesotrophic. At the time of listing, Lake Mealup was periodically eutrophic due to the effects of acid sulfate soils during dry periods releasing nutrients, particularly ammonium, from the sediments.

3.4.1 Climate

Climate plays an important role in wetland ecology; primarily through its effects on hydrology and the hydrological cycle. Attributes of climate which are most important are temperature and rainfall. Temperature determines the rate of biological processes such as decomposition, respiration and photosynthesis; the amount and timing of rainfall determines whether surface water will accumulate (Mitsch and Gooselink, 2000) and whether groundwater will be replenished. Temperatures affect evaporation and transpiration; rainfall has a direct influence on water levels and solar radiation and day length affect the biological components of wetland systems. To describe the climate at the time of listing, a period of historical records up until the year 2000 has been selected.

The Peel-Yalgorup Ramsar Site is in the temperate (distinctly dry and hot summer) climate zone (http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp).

Rainfall is winter dominated with the highest monthly median rainfall in June (178 millimetres) and lowest in February (3 millimetres; Figure 10). Annual average rainfall at Halls Head is approximatley 880 millimetres per year. Unlike many other areas in Australia, variation in annual average rainfall is relatively small (Figure 11). Rainfall exceeds evaporation during the winter months (May to August). For the remaining months, however, evaporation exceeds rainfall and in the height of summer evaporation is on average 20 times greater than rainfall (Figure 12).

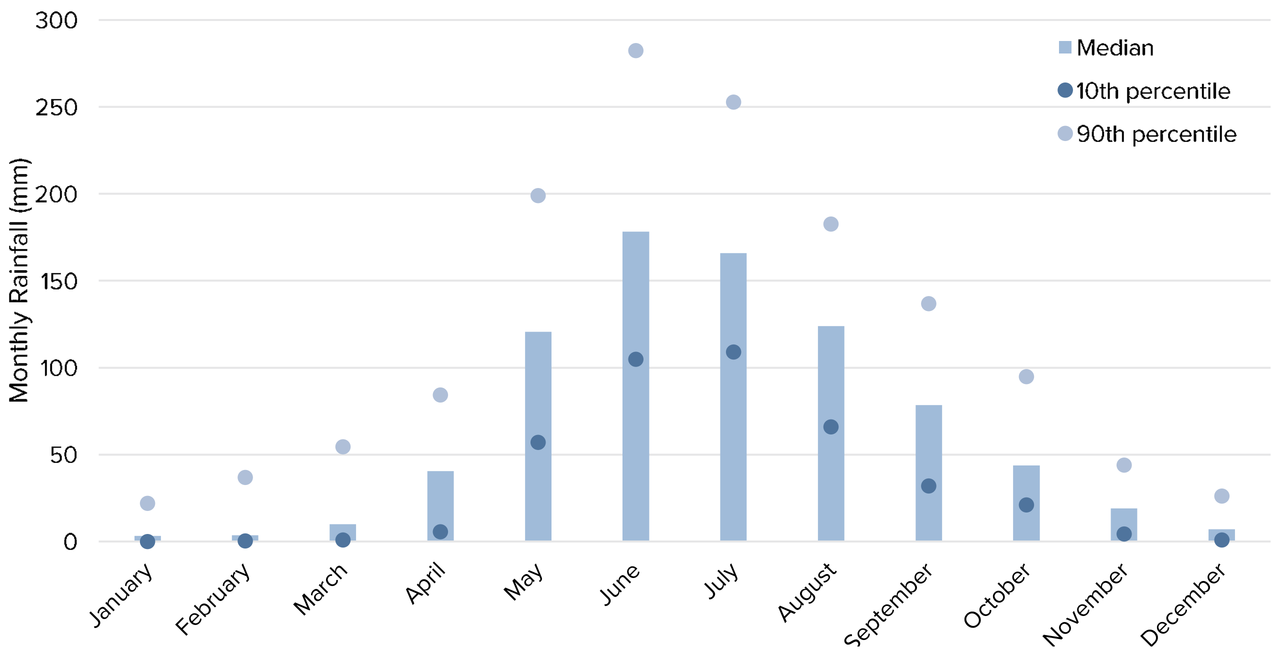


Figure 10: Median, 10th and 90th percentile monthly rainfall at Halls Head (1971 – 2000; Bureau of Meteorology)

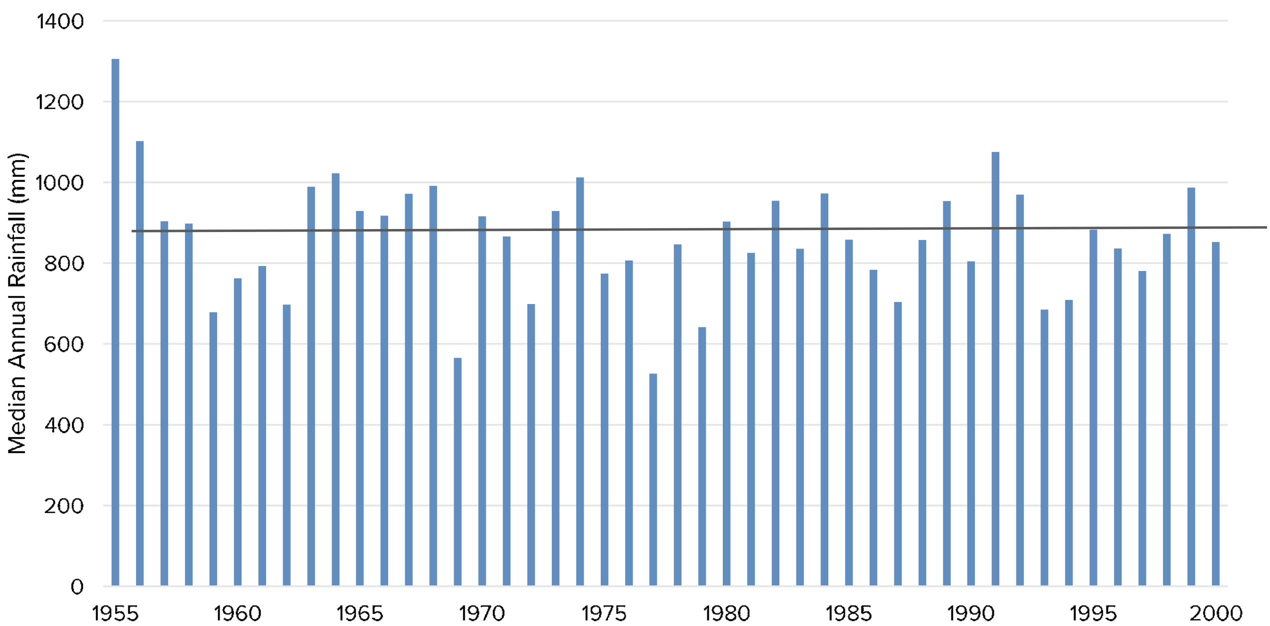


Figure 11: Average annual rainfall at Halls Head (1955 – 2000; Bureau of Meteorology). Note horizontal line shows long term average

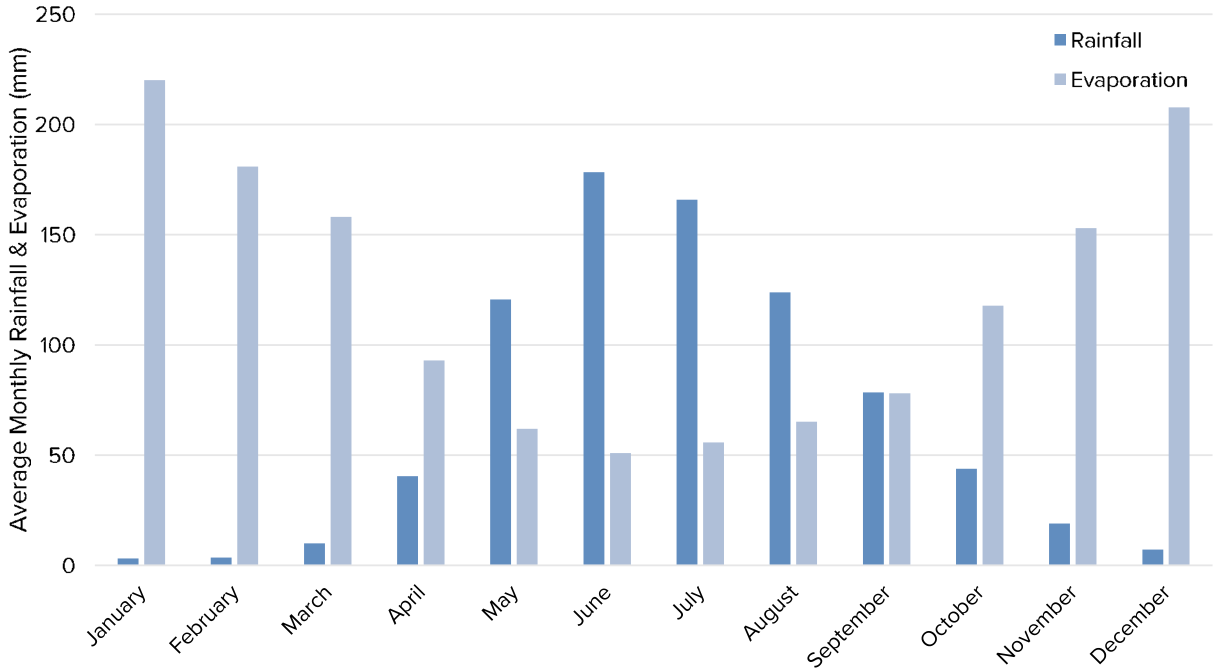


Figure 12: Average monthly rainfall (Halls Head) and evaporation (Dwellingup) (1971 – 2000; Bureau of Meteorology)

3.4.2 Geomorphology

Geomorphic setting is another key driver of wetland ecology. Geomorphology (formation and configuration of landforms) exerts a strong influence on surface and groundwater connections in aquatic and adjacent terrestrial ecosystems. Geomorphic setting influences wetland morphology and soils, and characteristics of the hydrological regime such as flooding depth, as well as frequency and duration of inundation.

The Peel-Yalgorup Ramsar Site is located on the Swan Coastal Plain, bordered by the Indian Ocean to the west and the Darling Escarpment to the east. The Swan Coastal Plain is an area of low topographical relief extending 20 to 30 kilometres inland of the ocean and is mostly less than 20 metres above sea level. The underlying geology is characterised by a series of linear, parallel dune systems, bordered by the loamy soils of the Pinjarra Plain and further inland the igneous and metamorphic rocks of the Darling Scarp (Figure 13).

The Peel-Harvey Estuary comprises two large, shallow basins (mostly less than two metres deep); the circular Peel Inlet and the elongate Harvey Estuary. The Peel Inlet is roughly 10 kilometres in diameter, the Serpentine and Murray Rivers flow into the basin from the east and there is a narrow, natural (but artificially augmented) connection to the sea to the north (Mandurah Channel). The Harvey Estuary receives inflows from the Harvey River to the south and is connected to the Peel Inlet by a narrow navigation channel at its northern end (Figure 13). The Dawesville Channel also connects Peel-Harvey Estuary to the Indian Ocean.

Yalgorup Lakes comprise a chain of wetlands (ten of which are within the Ramsar site boundary) in the Yalgorup National Park, situated in the depression between the Quindalup and Spearwood dune systems. The lakes are all shallow (less than five metres 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 kilometres long and 0.5 to 1.5 kilometres wide, running parallel to the coastline. An artificial causeway separates the northern section of Lake Preston from the remainder of the waterbody. A natural causeway forms a separate water body within the southern portion of Lake Preston known locally as Myalup Lagoon. Lake Clifton is the second largest and is the furthest inland lake. It is approximately 20 kilometres long, and 0.2 to 1.5 kilometres wide. The remaining wetlands are small by comparison and form a disconnected chain between Lake Preston and Lake Clifton (Figure 13).

The two major lakes of the Lake McLarty System, Lakes McLarty and Mealup are part of the "Bibra" suite, a linear wetland system along the Swan Coastal Plain located near the interface of the Bassendean and Spearwood dune systems. The lakes are approximately 600 metres 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 kilometres long and 1.25 kilometres wide and covers approximately 200 hectares. 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 metres to the north, has a similar morphology, but is approximately one third the size at 78 hectares. Lake Mealup has a lake bed of sandy peat The land surrounding the Lake to the west undulates gently towards the lake with a limestone mound to the northwest. Land to the east (of both lakes) is predominately low lying paluspIain (seasonally waterlogged flats).

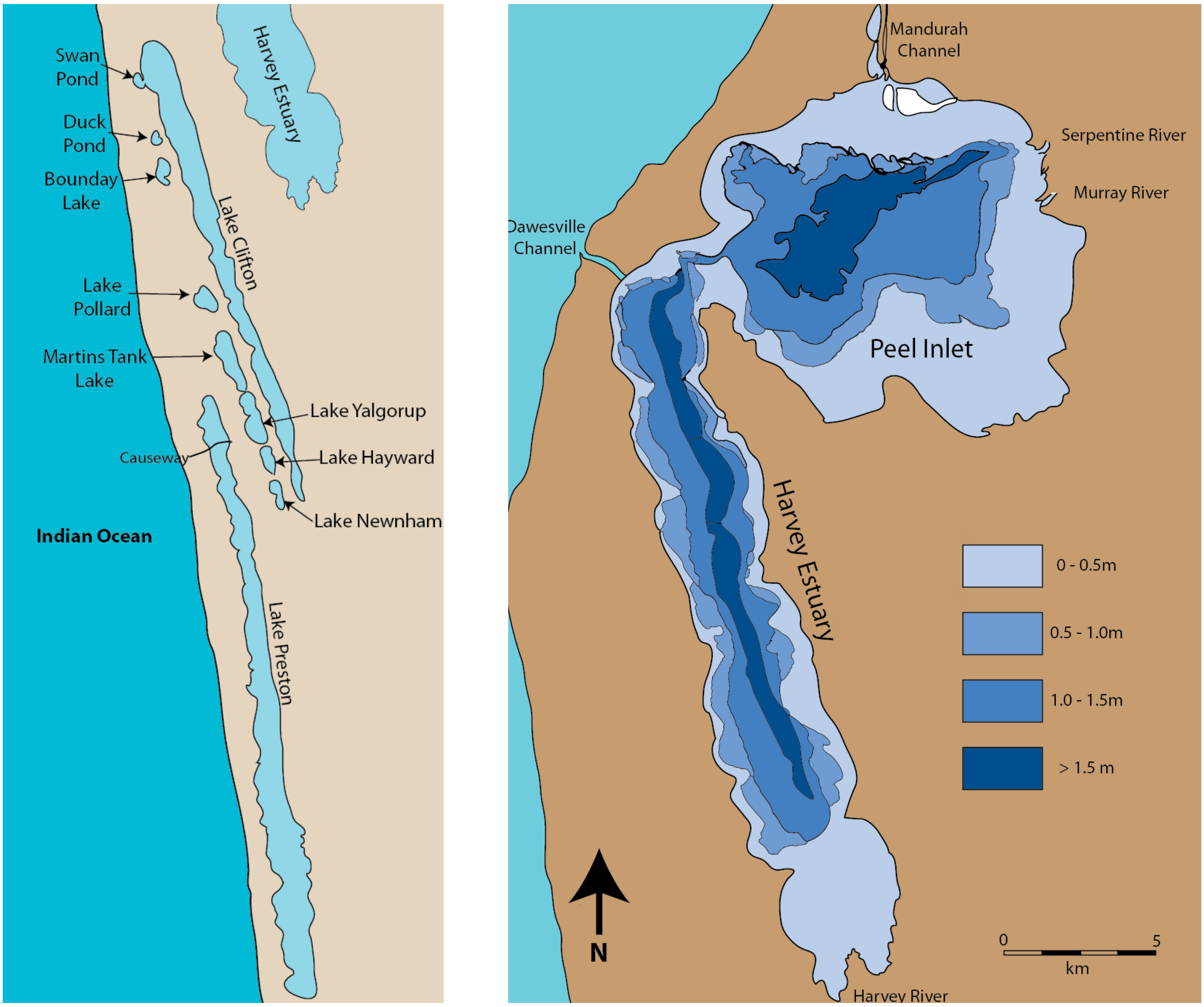


Figure 13: Geomorphology of the Peel-Yalgorup Ramsar Site; top - Swan Coastal Plain (Semeniuk and Semeniuk 2009); left - locations of the Yalgorup Lakes; right - Peel-Harvey Estuary

3.4.3 Hydrology

Hydrology is a fundamental driver of wetland ecology and exerts a strong influence on the ecological character of any wetland. Although all wetlands to some extent are affected by both surface and groundwater, both are not necessarily equal in their influence. In the Peel-Yalgorup Ramsar Site the characteristics that are fundamental to wetland ecology vary according to location. In the Peel-Harvey Estuary it is the balance between freshwater inflows and tidal exchange that largely drive the system, while in the Yalgorup Lakes and at Lake Mealup groundwater is a more important feature.

Peel-Harvey Estuary[9]

The hydrology of the Peel-Harvey Estuary is a complex interaction of river inflows from three main systems (Murray, Serpentine and Harvey Rivers); tidal exchange and wind forces across the large shallow expanse of water (Valesini et al. 2019b). Inflow from these three rivers is rainfall driven and 95 percent of river flow occurs between May and October (Figure 14). Average annual inflow from the rivers (1995 to 2010) was around 380 gigalitres, although interannual variability is high (standard deviation 150 gigalitres). Around 65 percent of total river inflows to the Peel-Harvey Estuary come from the Murray River (including tributaries) with 30 percent of the total river flow from the Harvey River and just five percent from the Serpentine River.

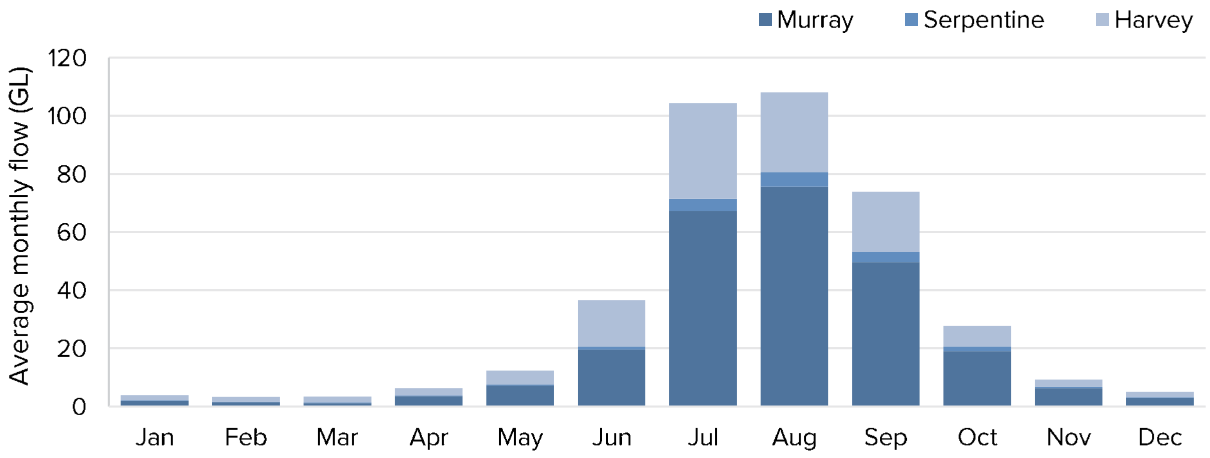


Figure 14: Average monthly flows from lowest gauging stations on the Murray, Serpentine and Harvey Rivers (1995 to 2010). Data from Department of Water and Environmental Regulation (DWER)

The Dawesville Channel dominates tidal exchange in the waterbody. Tidal range is about 45 percent of ocean tides in the Peel Inlet and 55 percent in the Harvey Estuary. Astronomical tidal amplitudes in these coastal waters, however, is relatively low; in the order of just 30 centimetres; with water level changes due to ocean currents and barometric pressure operating over longer time cycles (Ruibal-Conti 2014). As a consequence, tidal ranges in the Peel-Harvey Estuary are also small (often less than 10 centimetres) and the system is classified as micro-tidal. The interaction between river flows and tidal exchange results in greater water exchanged in winter (when river flows are high) and winter retention times are around 22 days. In summer, when water inflows from rivers is very low, retention times increase to an average of 55 days (Valesini et al. 2019b).

Yalgorup Lakes

The hydrology of the Yalgorup Lakes is dominated by direct rainfall and groundwater. There are no surface water inflows or outflows from the system and direct rainfall on the surface of the lakes and groundwater are the only substantive water sources (Moore 1987, Rosen et al. 1996, Noble 2010). There is an unconfined freshwater aquifer extending several kilometres to the east of the lakes, sitting on top of a deeper saline groundwater layer (Figure 15). This surficial aquifer is recharged via winter rainfall and water moves from the east into Lake Clifton, raising water levels during spring (Moore 1987). There is evidence that at the time of listing, Lake Clifton acted as a flow-through wetland with groundwater moving through the lake into those that are further west including Swan Pond, Martins Tank, Yalgorup, Hayward and Newnham (Noble 2010). At the time of listing there were also seasonally charged localised groundwater pockets to the west of each lake where rainfall was held for short periods in the sand dunes (Moore 1987). This may have resulted in localised movement of freshwater into lakes from the west.

The seasonal nature of rainfall and groundwater recharge means that there is an annual cycle of water levels in each of the lakes, with higher water levels in spring and drawdown over summer and autumn months (Moore 1987, Rosen et al. 1996, Noble 2010). Water level in Lake Clifton (1985 to 2000) shows seasonal changes in water level of around 30 to 40 centimetres, but with depths remaining largely around four metres (Figure 16).

9 Reminder that the benchmark for ecological character of this part of the Ramsar site has been established as post Dawesville Channel.

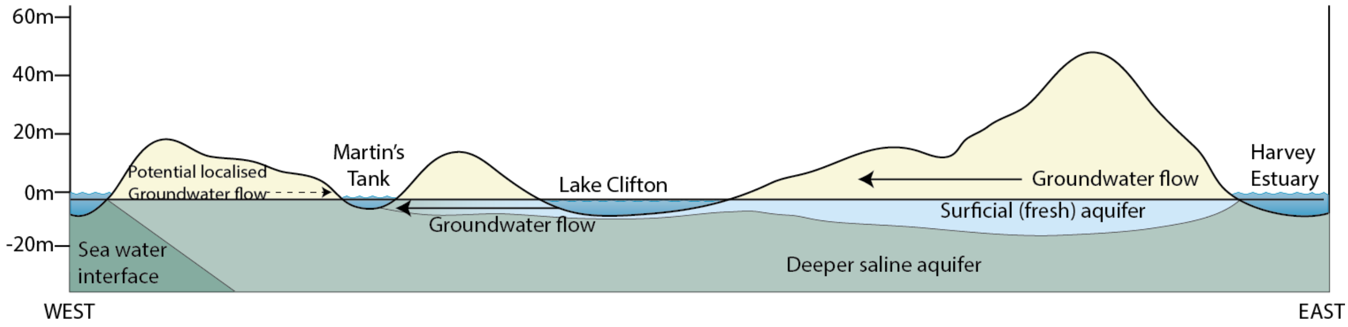


Figure 15: **Stylised cross section of the Yalgorup Lakes showing the upper fresh layer and lower saline groundwater (adapted from Noble 2010, Forbes and Vogwill 2016)**

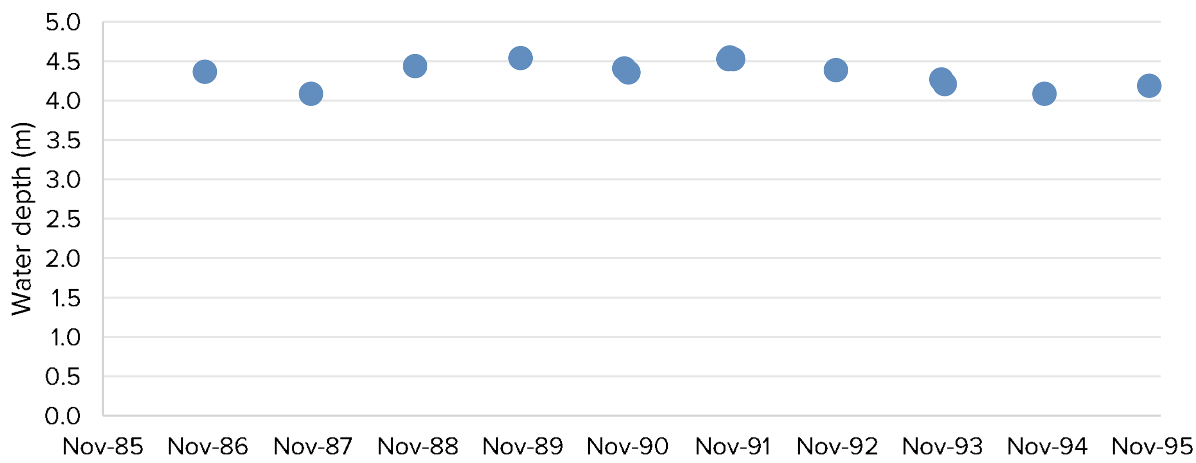


Figure 16: **Water depth (metres) during spring (November) in Lake Clifton from 1985 to 1995 (data provided by Jim Lane, DCBA)**

Lake McLarty

Lake McLarty has no natural surface water channels (although there is a drainage channel to the south that has the potential to overbank into the wetland). The dominant water source is direct rainfall and surface water inflows from a small local catchment. Groundwater plays a role in extending duration of inundation into the early summer. As a consequence, water levels are highest in spring after winter rains and groundwater seepage reach their maximum. At the time of listing, Lake McLarty was typically dry for one to three 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 metres, however, this is greatly variable depending on annual variability in rainfall and temperature.

Lake Mealup

The hydrology of Lake Mealup is complex. At the time of listing there was a surface drainage connection from the lake to the Mealup Main Drain which resulted in most water bypassing Lake Mealup except in periods of extreme rainfall events and in an uncontrolled manner. 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.). Drainage into Lake Mealup was altered in June 2012 with the construction of a weir on the Mealup Main Drain in order to divert water into Lake Mealup and more closely mimic natural drainage patterns. Lake Mealup has water depths of less than 1.5 metres and is 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 data).

Water quality

Water quality is important for supporting ecological character for several reasons. It is a source of nutrients, driving primary production, and variables such as pH, water clarity and temperature have a strong influence over the presence and distribution of aquatic species.

Salinity

At the time of listing there was a gradient of salinity from the hypersaline Lakes Preston, Heyward and Yalgorup, to the estuarine conditions of the Peel-Harvey Estuary, the saline Lake Clifton and the freshwater to brackish wetlands of Lakes McLarty and Mealup. All areas of the Ramsar site experienced an increase in salinity in the summer / autumn months as freshwater levels decrease and a reduction in salinity in winter / spring following rainfall and groundwater recharge (Figure 17).

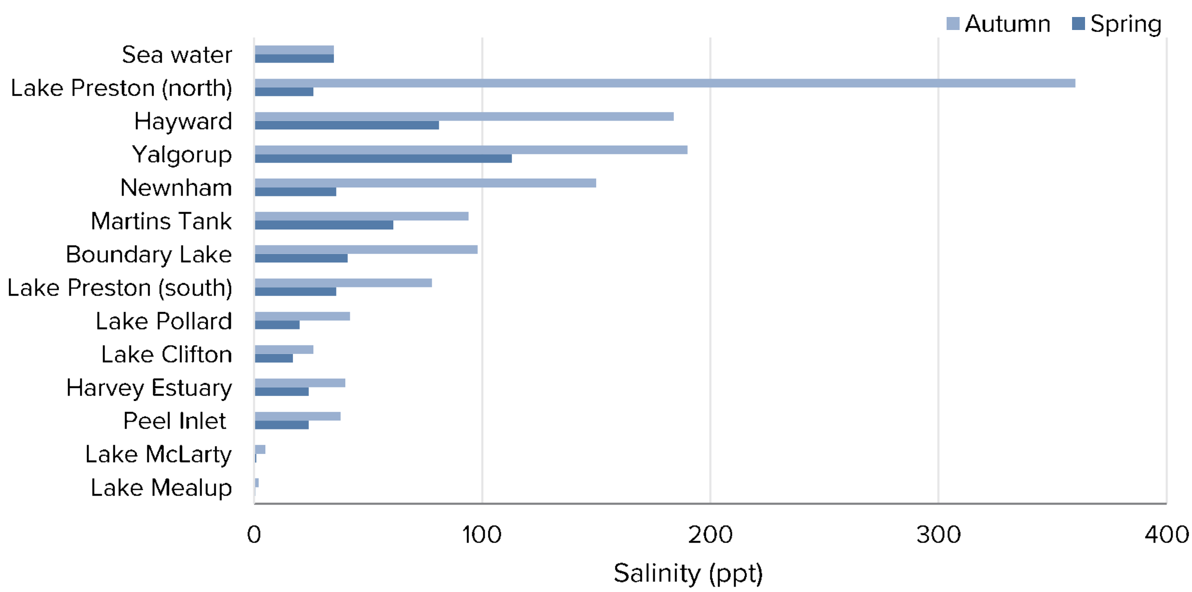


Figure 17: Average autumn and spring salinities in the major aquatic ecosystems of the Peel-Yalgorup Ramsar Site. Patchy data availability limited timeframes for capturing baseline conditions: Yalgorup Lakes 1984 salinity from Moore at al. (1987); Lake McLarty (2000 – 2004) from Bucktin (2004); Lake Mealup (1987-1989) data from Lake Mealup Preservation Society; Peel-Harvey Estuary (2000 – 2010) data from DWER

Salinity in the Peel-Harvey Estuary increased following the opening of the Dawesville Channel (see Appendix A) and the baseline is now of estuarine / marine conditions. Average salinity (2000 to 2010) was approximately 35 parts per thousand (ppt), with seasonal trends in salinity as a result of freshwater inflows from the rivers. During winter months when freshwater inflows are highest, there is a gradient in salinity from the areas of the estuary near the river mouths to areas near the channel connections to the ocean (Figure 18). The system experiences short periods of salinity stratification during these winter months with freshwater flows sitting over saltier, bottom water layers. As freshwater inflows decrease after winter, salinity rapidly returns to marine levels of around 35 ppt, although hyper-saline concentrations of greater than 45 ppt are regularly recorded in the summer in parts of the estuary.

Lake Clifton is the first of the Yalgorup 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 (less than 1 ppt) and high in calcium and bicarbonate. As a consequence, at the time of listing, Lake Clifton remained brackish throughout the year despite the high evaporation and reduction in lake levels during summer. In 1984 salinity in Lake Clifton ranged from 15 – 20 ppt during winter and spring to 26 to 35 ppt during summer and autumn (Moore 1987). As the groundwater moves through Yalgorup Lakes System in an easterly direction, salinity increases. At the time of listing the majority of the remainder of the lakes in the Yalgorup system were hypersaline, particularly in the autumn months (Figure 17). The Yalgorup Lakes also experience periods of stratification ranging from weeks or months at Lake Clifton (Moore 1987), to permanent or near permanent stratification at Lakes Hayward, Newnham and Yalgorup (Turner et al. 2018).

The earliest quantitative water quality data for Lake McLarty that could be sourced was from 2000 (Bucktin 2004). Over the period May 2000 to April 2004, salinity ranged from fresh (around 1 ppt; 2000 µS/cm[10]) in spring to saline (around 5 ppt; 10,000 µS/cm) in autumn as water dried to residual pools. Lake Mealup has a similar seasonal cycle, but at the time of listing (late 1980s to mid 1990s) remained fresh to brackish year-round ranging from less than 0.5ppt (1300 µS/cm) in spring to 2 ppt (2000 µS/cm) in summer (Lake Mealup Preservation society unpublished data).

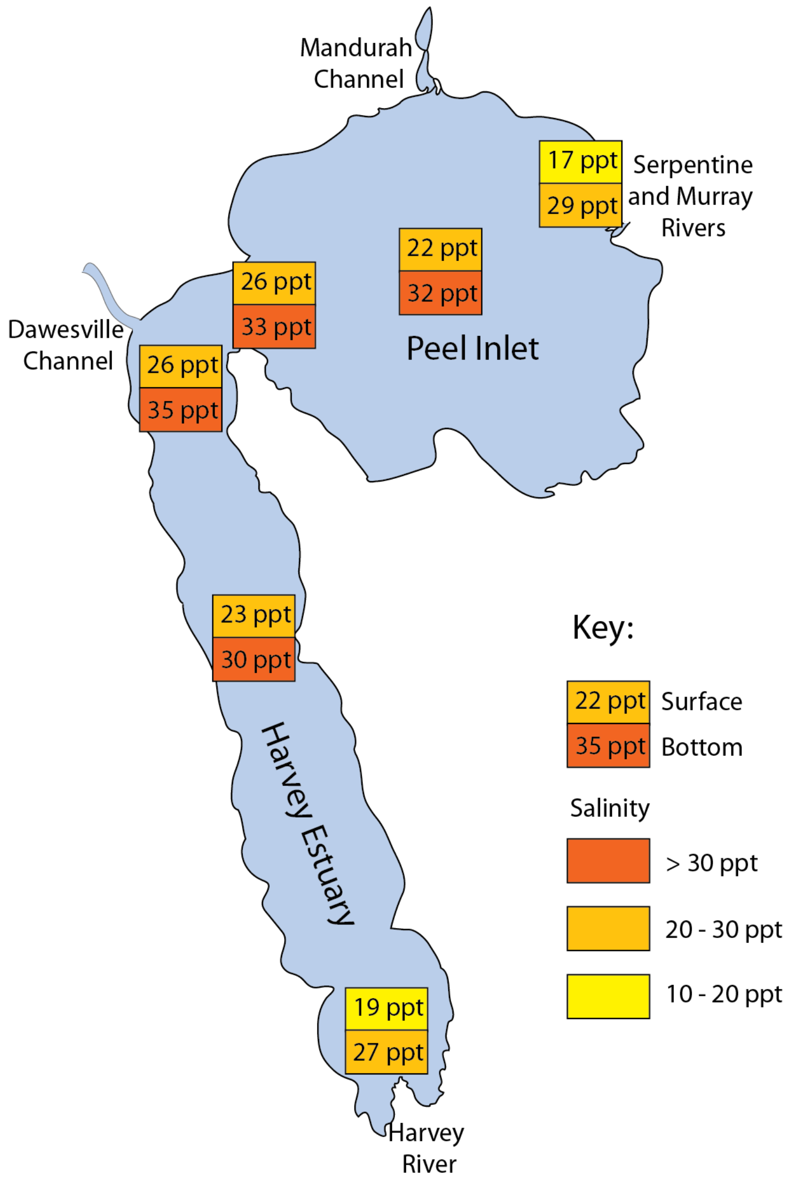


Figure 18: Spatial variability in average salinity across the Peel-Harvey during late winter 2000 - 2010, data from DWER)

10 Converted from conductivity (µS/cm) to salinity (ppt) using formula of Weyl (1964).

Water clarity

High water clarity is a feature of the baseline condition in the estuarine, saline and hypersaline systems within the Ramsar site. The high salinity of the Yalgorup Lakes largely acts to maintain clear water columns although there are observations of wind and waterfowl (swans) disturbing bottom sediments resulting in periods of increased turbidity (Burke and Knott 1989). The increased salinity in the Peel-Harvey Estuary since the opening of the Dawesville Channel has resulted in light penetration through the water column to the bottom. The Peel-Harvey Estuary experiences clear water (less than 5 NTU[11]) during most of the year across both basins. The exception to this in the Harvey Estuary near to river inflows where winter turbidity can be higher (15 to 20 NTU) as a result of turbid water inflows (data from DWER).

Turbidity in the freshwater ecosystems of Lakes McLarty and Mealup is generally higher than the more saline aquatic ecosystems. In Lake McLarty (2000 to 2004), turbidity was moderate (10 to 40 NTU) (Bucktin 2004). The water in Lake Mealup around the time of listing was tannin stained and periodically turbid (Lake Mealup Preservation Society unpublished data).

pH

The aquatic ecosystems of the Ramsar site exhibit a range of pH values. The waters of the Yalgorup Lakes are alkaline with pH values in the range of 7.5 to 10 as a result of alkaline groundwater inflows high in calcium and bicarbonate (Moore 1987, Burke and Knott 1989). Similarly, the pH of Lake McLarty is neutral to slightly alkaline (pH 7 to 8.8), reflecting the limestone aquifer contributions to this wetland (Bucktin 2004). The increasing marine influence on the waters of the Peel-Harvey Estuary since the opening of the Dawesville Channel acts as a buffer and pH values vary from around 7.5 to 8.5 (DWER unpublished data). By contrast, at the time of listing, Lake Mealup was generally slightly acidic to neutral (pH typically 6.7 to 7.5). However, in the periods following drying, pH levels can be very low (pH approximately 3 to 4) indicating oxidation of acid sulfate soils (Lake Mealup Preservation Society unpublished data).

Nutrients

One of the primary reasons for the construction of the Dawesville Channel was to reduce eutrophication in the Peel-Harvey Estuary. The benchmark for the estuary (post-Channel) is one of increased flushing and decreased residence time resulting in a decline in nutrient concentrations in the system. Peak nutrient concentrations occur during winter months when river flow influences are greatest, with much lower concentrations of bioavailable nutrients in summer (Table 14). The reduction in nutrients resulted in a decline in chlorophyll-a with the post-Channel baseline for chlorophyll-a now less than 10 µg /L.

Table 14: Average dissolved inorganic nutrient and chlorophyll-a concentrations (µg/L) in the central sites of the Peel-Harvey Estuary 2000 - 2010 (DWER unpublished data)

LOCATION	NITRATE-NITRITE		AMMONIUM12		PHOSPHATE12		CHLOROPHYLL-A	
	WINTER	SUMMER	WINTER	SUMMER	WINTER	SUMMER	WINTER	SUMMER
Peel Inlet	130	less than 10	110	37	24	9.1	2.8	1.7
Harvey Estuary	85	less than 10	93	38	19	11	10	3.0

Nutrient data from the Yalgorup Lakes are limited. At the time of listing there was a general pattern of higher nutrient concentrations in autumn and lower in spring and winter in Lake Clifton. Rosen et al. (1996) suggested that the lower concentrations in winter / spring were due to the uptake of nutrients by primary producers during favourable growing conditions and that increased temperature and salinity in autumn months led to the death of biota in the lakes and the release of nutrients into the water column. 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 micrograms per litre (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

11 Nephelometric Turbidity Unit measured as scattered light through the water.

within the lake with highest concentrations in autumn and lowest in winter (Table 15), which probably reflects dilution effects due to seasonal increasing and decreasing water volumes, as well as the cycling of nutrients through biota as hypothesised by Rosen (1996). Based on this limited information; Lake Clifton would be classified as mesotrophic (Davies and Lane 1996). There is insufficient data to classify the trophic status of other lakes in the Yalgorup system.

Table 15: Dissolved inorganic nutrient concentrations (µg/L) in Lake Clifton 1993 (Davies and Lane 1996). Note concentrations are the result of single samples collected monthly

MONTH	NITRATE-NITRITE[12]	AMMONIUM[12]	PHOSPHATE[12]
May	100	180	less than 10
June	20	100	less than 10
July	20	20	less than 10
August	40	50	less than 10
September	70	20	less than 10
October	40	30	less than 10

There is a small amount of data for nutrient concentrations in Lake McLarty (2000 to 2004), which suggest that concentrations of bioavailable nutrients are highly variable. Phosphate (as phosphorus) ranged from 50 to over 3000 µg/L and nitrate-nitrite from 20 to over 3000 µg/L Bucktin 2004). This perhaps reflects the natural cycles of nutrient concentrations observed in seasonal wetlands during wetting and drying phases.

Data from Lake Mealup (1987 to 1994) indicate generally moderate levels of total nitrogen and phosphorus and low concentrations of ammonium. In the periods following drying, however, when pH levels drop, correspondingly 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 and release of ammonium from sediments (Bucktin 2004).

3.5 Critical components and processes

The attributes and characteristics of each of the identified critical components of Peel-Yalgorup Ramsar Site are described below (sections 3.5.1 to 3.5.6). Where possible, quantitative information is included, however, as with many Ramsar sites in Australia, there are a number of knowledge gaps (see section 7). A summary of the benchmark condition of critical components within the Peel-Yalgorup Ramsar Site is provided in Table 16.

12 Expressed as µg/L of nitrogen; or phosphorus.

Table 16: Summary of critical components and processes within the Peel-Yalgorup Ramsar Site

COMPONENT / PROCESS	DESCRIPTION
Vegetation type and extent	*Seagrass and macroalgae* – the sediment of the Peel-Harvey Estuary is covered with a mixture of seagrass and macroalgae. In 2009 the estuary contained an estimated 8500 tonnes of macroalgae and 3700 tonnes of seagrass. The highest density of seagrass occurred adjacent to marine water influences, while macroalgal growth was greatest closer to river inflows. *Saltmarsh* – there was an estimated 684 hectares of saltmarsh in the Ramsar site in 2007. Community composition varied with location: beaded glasswort being common in the Peel Inlet and Lake Preston, while sea rush dominated at Lake Clifton and parts of the Harvey Estuary. *Paperbark* – there was an estimated 646 hectares of paperbark in the Ramsar Site in 2007. Saltwater paperbark being the dominant canopy species at the Yalgorup Lakes, with freshwater paperbark prevalent at Lakes McLarty and Mealup. The tree communities in the Peel-Harvey Estuary vary considerably with location. *Freshwater wetland vegetation* – at the time of listing both Lakes McLarty and Mealup supported extensive stands of emergent rushes and sedges. In 2007, there was 40 hectares of emergent wetland vegetation in the inner margins of Lake McLarty and 51 hectares at Lake Mealup.
Thrombolites	At the time of listing, Lake Clifton supported an expanse of living thrombolite communities extending 14 kilometres along the eastern shoreline, including a "reef" 6.5 kilometres long and 120 to 30 metres wide comprised mainly of cyanobacteria.
Estuarine invertebrates	At the time of listing the Peel-Harvey Estuary supported three commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. Estimates from commercial catch data are for 40 to 100 tonnes of blue swimmer crab annually.
Fish diversity and abundance	Over 80 species of native fish have been recorded in the Peel-Harvey Estuary. Abundance estimates are highly variable, with mean densities (2005 – 2007) of 360 fish / 100 metres squared. The most common species are banded blowfish, sandy sprat and elongate hardyhead. The estuary also supports important commercial and recreational fisheries.
Waterbird diversity and abundance	A total of 104 wetland dependent bird species have been recorded within the Ramsar site. Average annual abundance across the site (1995 to 2010) was around 45,000. The site regularly supports greater than 1 percent of the population of eight species.
Waterbird breeding	Evidence of breeding (juveniles, nests, eggs) has been recorded for 34 species of wetland dependent bird in the Peel-Yalgorup Ramsar site. Different areas of the Ramsar site are important for breeding of different types of waterbird. The Yalgorup Lakes supports breeding of several species of Australian resident shorebird including the hooded plover. The Peel-Harvey Estuary is important for breeding of colonial fish-eating species such as cormorants and Australian pelicans, while, Lake McLarty supports a wide diversity of breeding waterbirds.
Marine mammals	The Peel-Harvey Estuary supports Indo-Pacific bottlenose dolphin, with the resident community estimated at around 90 individuals. The estuary is an important feeding, breeding and nursing ground for the species. The year-round resident community uses the estuary to complete their lifecycle. Coastal dolphin communities appear to use the estuary seasonally for feeding and breeding opportunities (pers.comm. Krista Nicholson).

3.5.1 Vegetation type and extent

Four broad vegetation types are critical to the ecological character of the Peel-Yalgorup Ramsar Site: seagrass and macroalgae, saltmarsh, paperbark and freshwater wetland vegetation.

Seagrass and macroalgae

The opening of the Dawesville Channel resulted in a decrease in macroalgae in the Peel-Harvey Estuary (see Appendix A). The benchmark for ecological character for the estuary is one where macroalgae dominate the benthic plant community in areas adjacent to river inflow and seagrass dominates in the areas closer to marine influences (Figure 19). In 2009 macroalgae comprised the greatest biomass in the Peel-Harvey Estuary, estimated at 8500 tonnes. Seagrass biomass in 2009 was less than half that of macroalgae at 3700 tonnes (Pedretti et al. 2011).

In 2009, 14 species of macroalgae were recorded in the Peel-Harvey Estuary, with the vast majority of the biomass comprising green algae (Chlorophyta; 83 percent of total biomass). The dominant macroalgal species in both the Peel Inlet and Harvey Estuary was *Chaetomorpha linum*. Other common species included *Ulva* spp., *Caulerpa* spp. and *Rhizoclonium* sp. Around 13 percent of the macroalgal biomass comprised red algae (Rhodophyta) with *Spyridia filamentosa* the most common species. Small amounts of brown algae (Phaeophyta) and charophytes were also present (Pedretti et al. 2011).

Three species of seagrass were recorded in the Peel-Harvey Estuary in 2009: *Zostera* spp., *Ruppia megacarpa* and *Halophila ovalis*. While *Halophila ovalis* had the greatest distribution across the Peel-Harvey Estuary, the greatest biomass in the Harvey Estuary was of *Zostera* spp. and in the Peel Inlet *Ruppia megacarpa* had the greatest biomass (Pedretti et al. 2011).

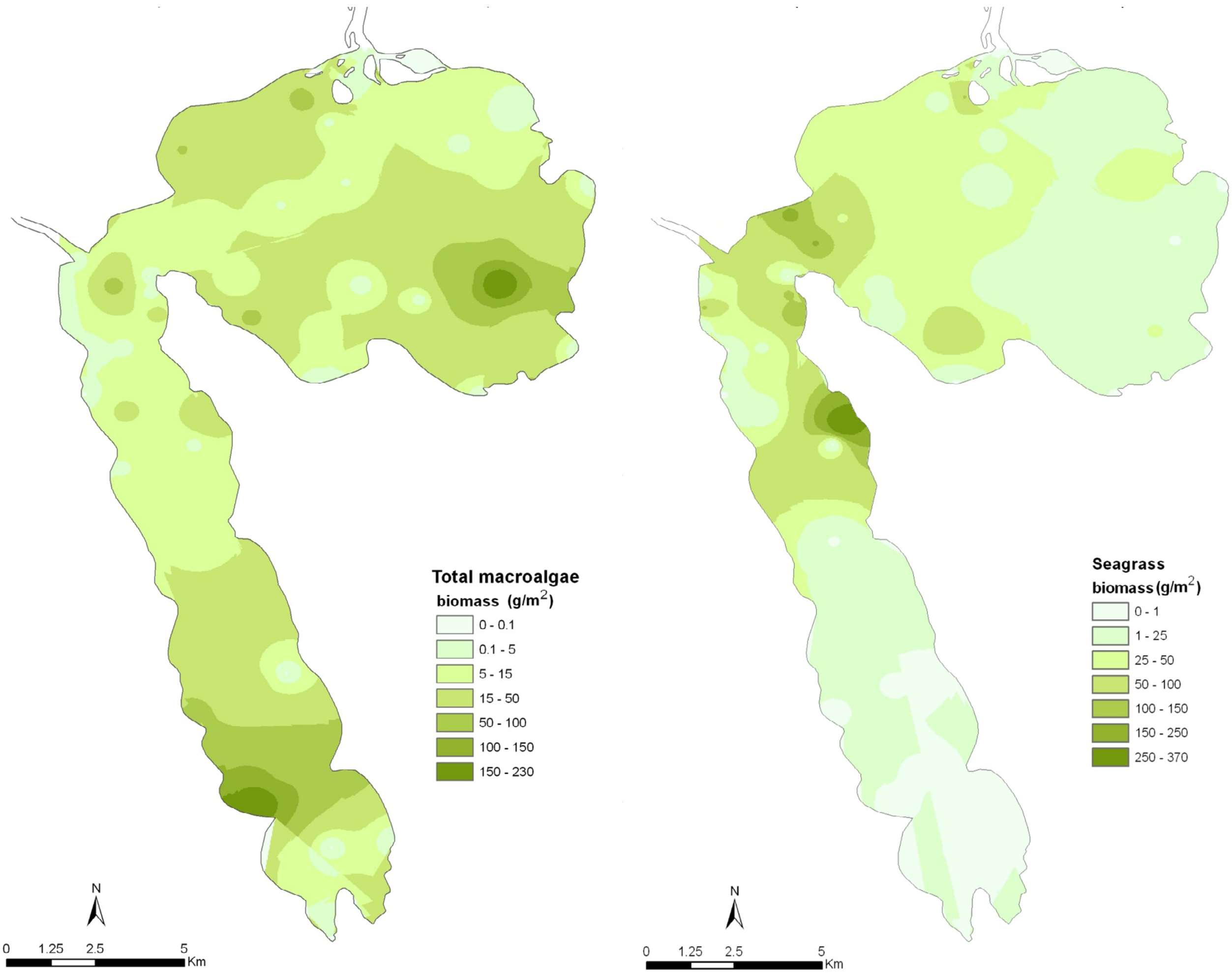


Figure 19: Benthic plant distribution in the Peel-Harvey Estuary in 2009, seagrass (left) and macroalgae (right). Note the different scales on the two images (Pedretti et al. 2011).

At the time of listing there was a benthic plant community in Lake Clifton that consisted predominantly of the charophyte *Lamprothamnium papulosum*. There was also evidence of the macroalgae *Cladophora vagabunda* growing in Lake Clifton, particularly on the thrombolites (Burke and Knott 1989, Rosen et al. 1996). Charophytes were also a feature at Lake Pollard where it formed extensive beds (Burke and Knott 1989). There is no evidence of submerged macrophytes in the other Yalgorup Lakes and salinity may be too high to support anything other than benthic microbial mats (Burke and Knott 1989, Turner et al. 2018).

Saltmarsh

In 2007 there was 684 hectares of saltmarsh within the Peel-Yalgorup Ramsar Site (Hale and Kobryn 2009). This was the first estimate of mapped extent of saltmarsh for the Ramsar site and while it represents the post-Dawesville baseline for the Peel-Harvey Estuary, it is not known if there had been changes in saltmarsh extent prior to 2007 at the Yalgorup Lakes.

Saltmarsh occurs in a narrow band around the Peel-Harvey Estuary as well as Lakes Clifton and Preston in the Yalgorup Lakes. There are smaller areas of saltmarsh near the other lakes that comprise the Yalgorup Lakes system and near Lake McLarty (Figure 20). In 2007, a little over half (387 hectares) of the saltmarsh in the Ramsar site was within the Yalgorup Lakes, with 42 percent (287 hectares) along the shoreline of the Peel-Harvey Estuary.

In 2007, community composition of saltmarsh within the Ramsar site varied with location. At several locations in the Peel-Harvey Estuary, including Samphire Cove and Len Howard Reserve, beaded glasswort *(Sarcocornia quinqueflora)* was the dominant species. In the north of the Harvey Estuary, sea rush *(Juncus kraussii)* was more prevalent and at Carrabungup and Creery wetlands, sea heath *(Frankenia pauciflora)* comprised a significant proportion of the community (Hale and Kobryn 2010). In the Yalgorup Lakes, beaded glasswort dominated the saltmarsh community at Lake Preston, while at Lake Clifton, sea rush was the most common saltmarsh species (Hale and Kobryn 2017).

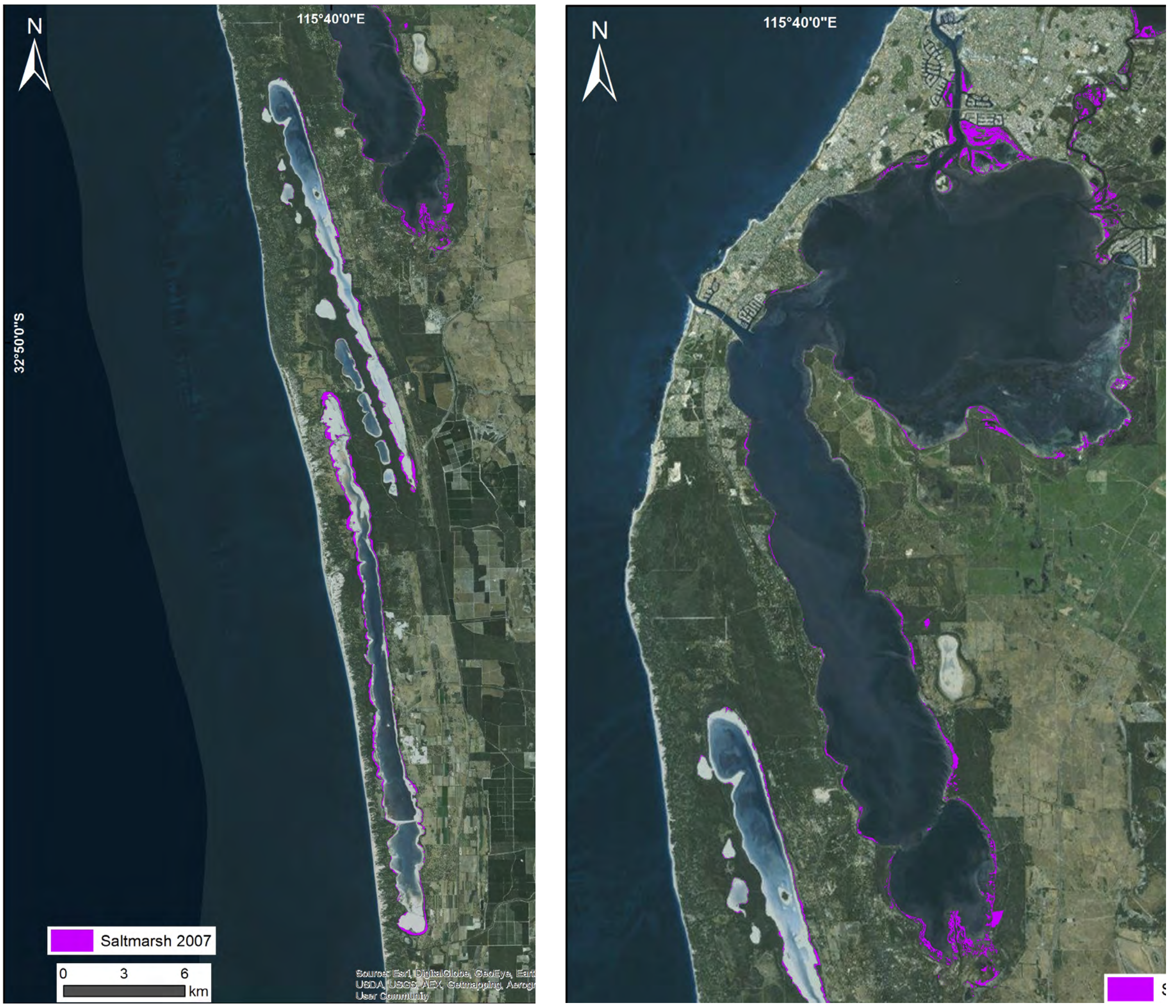


Figure 20: Mapped saltmarsh extent in the Peel-Yalgorup Ramsar site in 2007 (Hale and Kobryn 2009)

Wetland trees

In 2007 there were 646 hectares of wetland tree vegetation communities within the Peel-Yalgorup Ramsar Site (Hale and Kobryn 2009). As with saltmarsh, this was the first estimate of mapped extent of wetland trees for the Ramsar site and while it represents the post-Dawesville baseline for the Peel-Harvey Estuary, it is not known if there had been changes in paperbark extent prior to 2007 at the Yalgorup Lakes.

Paperbark communities in the Peel-Yalgorup Ramsar Site typically occur inland of saltmarsh (in the Peel-Harvey Estuary and Yalgorup Lakes) and in the littoral zone of Lakes McLarty and Mealup. Almost 80 percent (509 hectares) of the paperbark extent in the Ramsar site in 2007 occurred around the Yalgorup Lakes. Around 80 hectares was recorded around the Peel-Harvey Estuary and approximatley 30 hectares at each of Lakes Mealup and McLarty (Figure 21) (Hale and Kobryn 2009).

Saltwater paperbark *(Melaleuca cuticularis)* is the dominant tree species fringing the Yalgorup Lakes, it typically has an understory of salt tolerant plants such as sea rush and coastal saw-sedge *(Gahnia trifida)*. The wetland tree communities at Lakes McLarty and Mealup are dominated by freshwater species such as freshwater paperbark *(M. rhaphiophylla)* and the endemic marsh honey-myrtle *(M. teretifolia)*. Swamp gum *(Eucalyptus rudis)* also occurs on higher ground at Lake Mealup (Ekologica 2009, Hale and Kobryn 2017). The littoral tree communities around the Peel-Harvey Estuary are highly varied. In 2007, at Creery Wetland and Samphire Cove the dominant tree species was swamp she-oak *(Casuarina obesa)*, while in the Harvey Estuary paperbark communities with the endemic mohan *(M. viminea)* was more common (Ekologica 2009, Hale and Kobryn 2017).

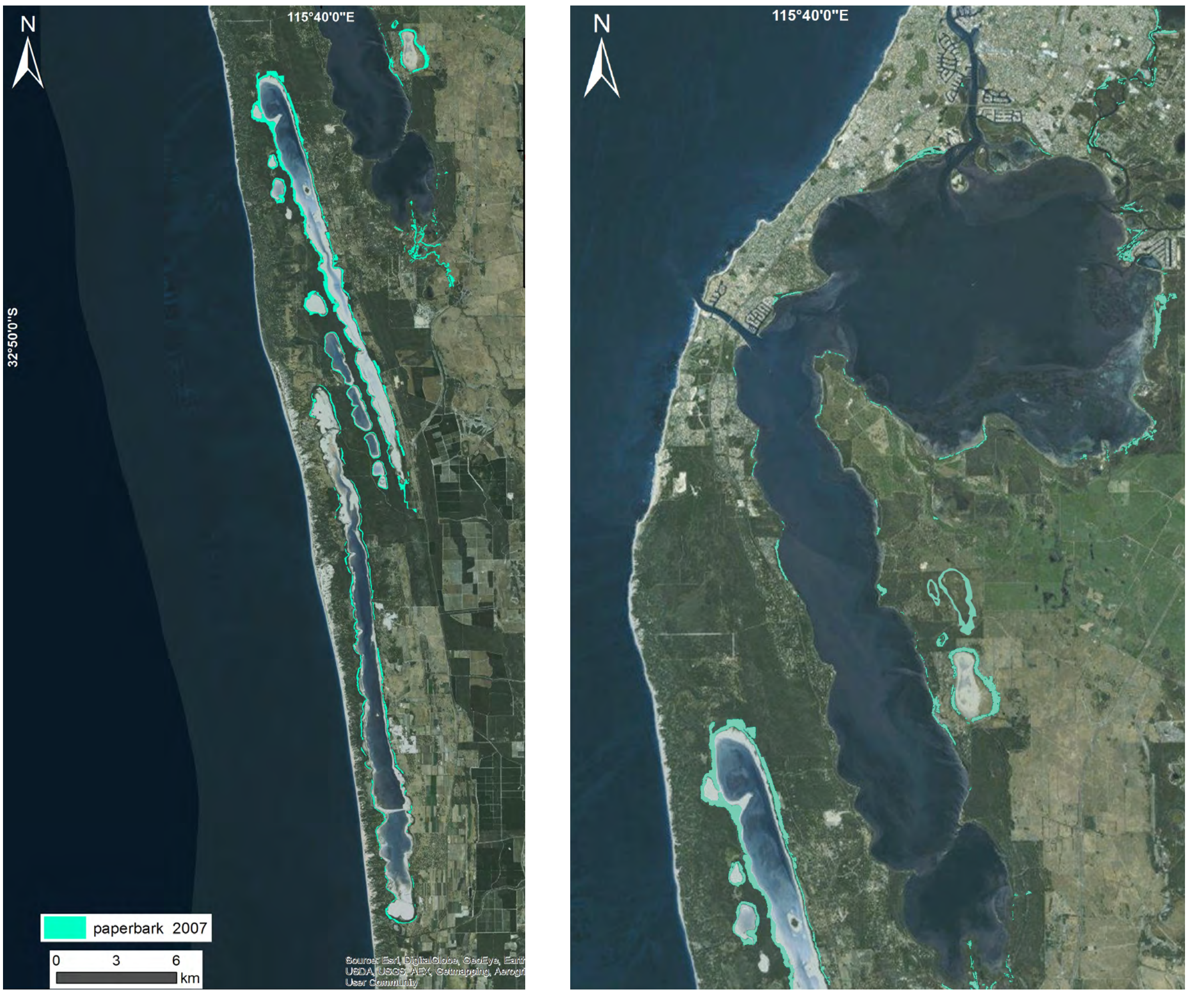


Figure 21: Mapped paperbark (including other wetland trees) extent in the Peel-Yalgorup Ramsar site in 2007 (Hale and Kobryn 2009)

Freshwater emergent vegetation

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. Similarly, the body of Lake Mealup was dominated by sedges and rushes, largely *Typha spp*. (Jaensch et al. 1988). In 2007 Hale and Kobryn (2009) mapped a total of approximately 40 hectares of emergent wetland vegetation in the margins of Lake McLarty (although the bed was largely bare) and 51 hectares at Lake Mealup (Figure 22).

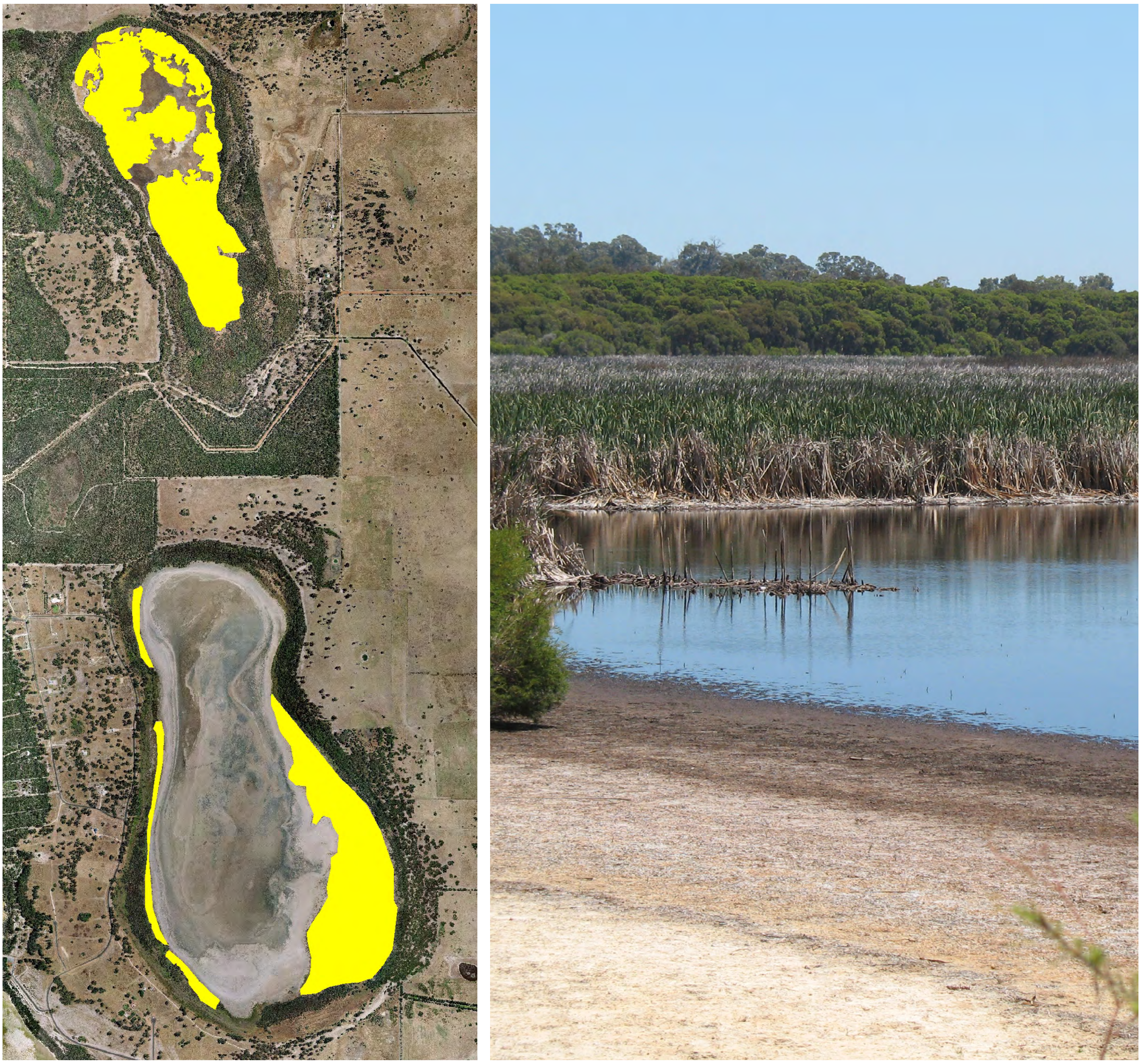


Figure 22: Freshwater emergent vegetation; left - mapped 2007 extent in Lakes Mealup and McLarty (Hale and Kobryn 2009); right – emergent vegetation at Lake Mealup in 2008 (photo N. Thorning).

3.5.2 Thrombolites

The thrombolites are arguably the most significant ecological component of the Yalgorup 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 1993). The thrombolites at Lake Clifton are considered to be 2000 years old and are one of only two examples of living thrombolites in Western Australia and a handful in the world (Moore 1993). Moore (1993) indicated that the thrombolites extended along 14 kilometres of the eastern shore of Lake Clifton, but that they were most prevalent at the north eastern end where they formed a "reef" 6.5 kilometres long and 120 to 30 metres wide. Luu et al. (2004) indicated four square kilometres of thrombolites at Lake Clifton, but it is not clear if this relates to the whole lake, or the north-eastern reef.

Thrombolites are rock-like structures that are formed by the activities of benthic microbial communities (Smith et al. 2010). These communities are diverse and typically comprise cyanobacteria, diatoms and "true" bacteria. At the time of listing, the cyanobacterium most commonly associated with the thrombolites at Lake Clifton was the filamentous *Scytonema*. Other genera included: *Oscillatoria, Dichothrix, Chroococcus, Gloeocapsa, Johannesbaptista, Gomphosphaeria* and *Spirulina* (Moore and Burne 1994). 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 1993).

Figure 23: Image of Thrombolites

3.5.3 Estuarine invertebrates

Post-Dawesville Channel sampling of benthic invertebrates in the Peel-Harvey Estuary indicated a diverse community comprised of a wide range of species (Wildsmith et al. 2009). While the majority of the invertebrates in the system are important for the role they play in food webs and supporting fish and waterbirds, several commercially and recreationally important species are critical to the ecological character of the Ramsar site.

The blue swimmer crab (*Portunus armatus*[13]) is a widespread tropical species of the Indo-West Pacific. In Western Australia it inhabits embayments, estuaries and coastal waters. In the Peel-Harvey Estuary juvenile blue swimmer crabs enter the system from the Indian Ocean early in life. They live and grow in the sheltered waters of the embayment. Females reach sexual maturity at around one year of age and leave the estuary to release their zoea in the marine environment (de Lestang et al. 2003).

Commercial catch data is used as an indicator of the population of blue swimmer crab in the Peel-Harvey Estuary. Total catch between the years 2000 and 2010 ranged from approximately 45 to 100 tonnes, with an annualised catch per unit effort (CPUE) of around 1 kg per traplift (Figure 24). During summer months, blue swimmer crabs are distributed throughout the Peel-Harvey Estuary, but that distribution varies seasonally. In winter blue-swimmer crabs are largely restricted to the areas of the Peel-Harvey Estuary close to marine water influences (Dawesville Channel and Mandurah Channel), while in summer, when salinity is high across the system, the species is distributed throughout the system (Figure 25).

Two other significant crustaceans in the Peel-Harvey Estuary are western king prawns *(Penaeus latisulcatus)* and western school prawns *(Metapeneus dalli)*. Western king prawns spawn in the marine environment, with juveniles entering the Peel-Harvey Estuary during summer and autumn, using the system as a nursery (Potter et al. 1991). By contrast, western school prawns inhabit the Peel-Harvey Estuary for their entire lifecycle. No quantitative data on populations for either of these species post-Dawesville Channel could be sourced.

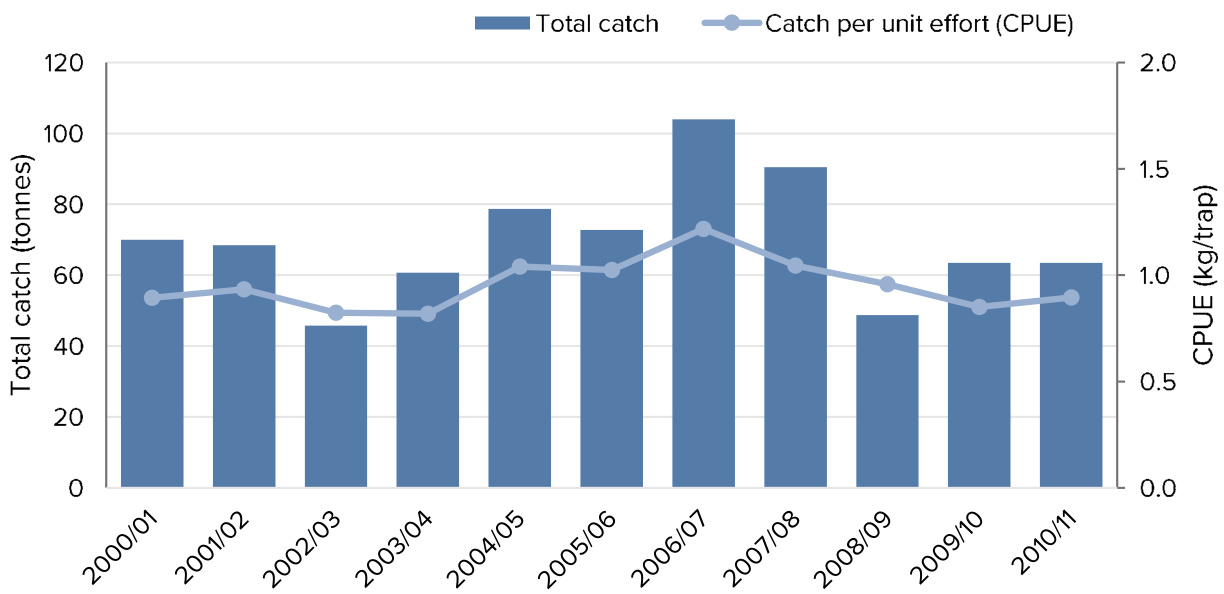


Figure 24: Total catch (tonnes) and CPUE (kg/trap) of blue swimmer crabs in the Peel-Harvey Estuary from commercial fisheries (data from Johnston et al. 2014)

13 Formerly Portunus pelagicus

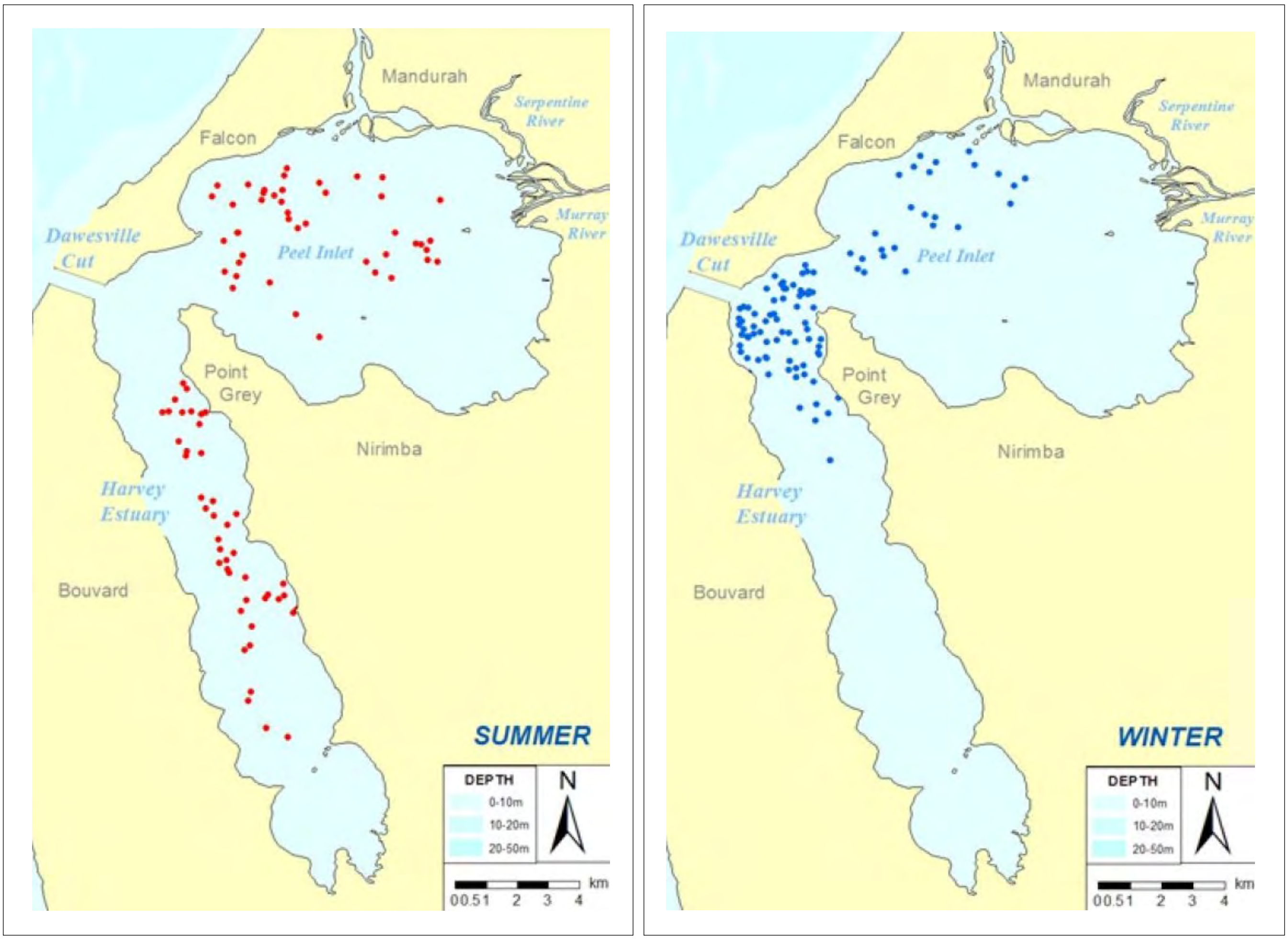


Figure 25: Seasonal differences in blue-swimmer crab distribution in the Peel-Harvey Estuary (Johnston et al. 2014)

3.5.4 Fish diversity and abundance

The Peel-Harvey Estuary supports a diverse fish community, with over 80 species recorded from 2005 to 2010 (Valesini et al. 2009, Potter et al. 2016). The most common species recorded were banded blowfish *(Torquigener pleurogramma)*, sandy sprat *(Hyperlophus vittatus)* and several species of hardyhead including elongate hardyhead *(Atherinosoma elongata)*, spotted hardyhead *(Craterocephalus mugiloides)* and Swan River hardyhead *(Leptatherina presbyteroides).* Valesini et al. (2009) found that mean density of fish varied by an order of magnitude with location and habitat, ranging from 96 fish per 100 m2 in dense submerged aquatic vegetation on the north western shoreline of the Harvey Estuary to 946 fish per 100 m2 in the Murray River Delta. The latter comprised large numbers of the schooling sandy sprat. Average mean fish density across all habitats was around 360 fish per 100 m2. The variability, however, was very high, with the average standard deviation more than three times of mean[14]. In addition, Potter et al. (2016) found that density was highly dependent on sampling equipment, with average density from small mesh seine nets more than six times that from larger mesh nets.

Species richness of fish ranged from over 50 species on the shorelines around Austin Bay in the Peel Inlet to just over 20 on the western shoreline of the Harvey Estuary (Valesini et al. 2009). In all locations and habitats, however, abundance was dominated by a small number of species with elongate hardyhead and / or sandy sprat comprising a large proportion of the total catch.

The Peel-Harvey Estuary provides a range of habitats for species that prefer unvegetated sandy substrates such as banded blowfish and long-headed goby *(Favonigobius lateralis)*; as well as species associated with seagrass and macroalgae such as western striped grunter *(Pelates octolineatus)* and blue weed whiting *(Haletta semifasciata)*.

14 Data in Valesini et al. (2009) was presented as standard deviation of individual species only. Average standard deviation was estimated by calculating the average variance and taking the square root.

The Peel-Harvey Estuary supports resident species (that complete their entire life-cycle within the system) as well as acting as a nursery ground for fish that spend the majority of their lives in the open coasts and oceans (Potter et al. 2016).

The Peel-Harvey Estuary supports a number of fish species that are important for commercial and / or recreational fisheries. This includes: sea mullet (Mugil cephalus), yellow-eye mullet (Aldrichetta forsteri), yellowfin whiting *(Sillago schomburgkii)*, Australian herring *(Arripis georgianus)*, tailor *(Pomatomus saltatrix)* and cobbler *(Cnidoglanis macrocephalus)* (Johnston et al. 2015). Commercial catch data can be used as an indicator of the population of commercially important fish species. While straight total catch data is available for several species, the more robust measure of CPUE was only reported for two species: sea mullet and cobbler. Total catch for sea mullet between 2000 and 2010 ranged from approximately 50 to 70 tonnes, with a CPUE of between 100 and 180 kg / fishing day (Figure 26). Over the same period total catch of cobbler was highly variable ranging from less than one tonne to over nine tonnes, with CPUE similarly variable ranging from less than 10 to greater than 50 kg / fishing day (Figure 26).

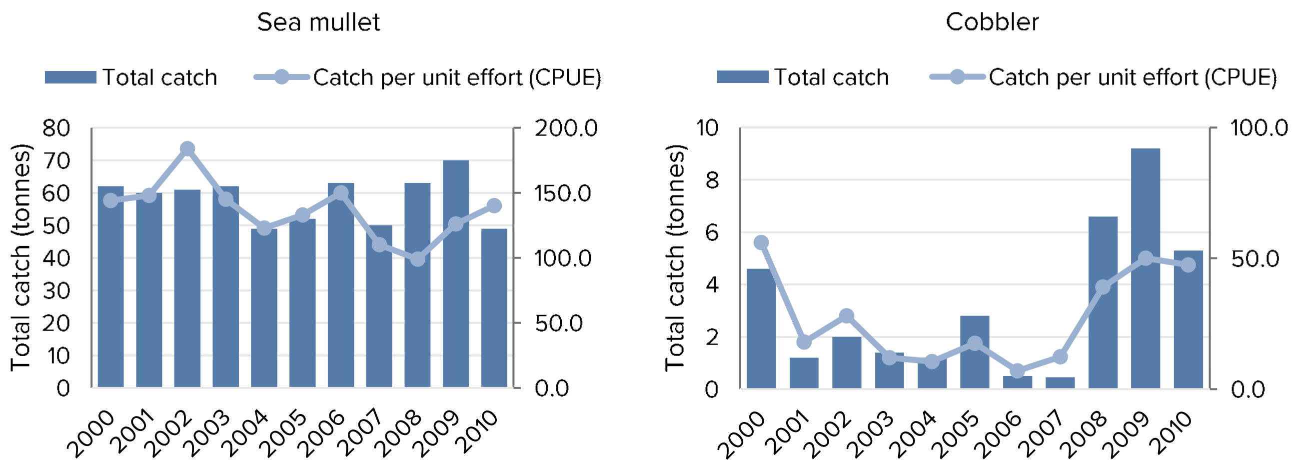


Figure 26: Total catch (tonnes) and CPUE (kg/fishing day) of sea mullet (left) and cobbler (right) in the Peel-Harvey Estuary from commercial fisheries (data from Johnston et al. 2015)

3.5.5 Waterbird diversity and abundance

A total of 104 species of wetland dependent birds have been recorded within the Ramsar site (Table 17), noting that this list excludes vagrants and species for which the site does not provide core habitat (e.g. pelagic seabirds). Resident and common visitors to the site are listed in Table 17 and include 38[15] species listed under international migratory agreements CMS (28), CAMBA (33), JAMBA (34) and ROKAMBA (31) as well as an additional 35 Australian species that are listed as marine under the *Environmental Biodiversity and Conservation Act 1999* (EPBC Act). A full list of waterbirds recorded at the site is presented in Appendix C.

15 Note that while the site "regularly supports" (i.e. in more than two thirds of years) 30 species, there are semi-regular records for an addition eight international migratory species.

Table 17: Number of waterbird species recorded within the Peel-Yalgorup Ramsar Site.

FUNCTIONAL GROUP	DESCRIPTION	NUMBER OF SPECIES
Ducks and small grebes	Ducks and small grebes that typically are omnivorous and shallow or open water foragers.	14
Herbivores	Black swans, swamphens and coots that have a vegetation diet.	6
Fish eating species	Gulls, terns, cormorants, pelicans and grebes with a diet mainly of fish.	20
Australian shorebirds	Australian resident shorebird species that feed in shallow inland waters or mud and sand flats mainly on invertebrates.	12
International shorebirds	Palaearctic shorebird species that breed in the northern hemisphere and migrate to the southern hemisphere to feed.	31
Large wading birds	Long-legged wading birds with large bills, feeding mainly in shallow water and mudflats.	14
Other	Other birds that are wetland dependent such as birds of prey (white-bellied sea eagle, swamp harrier), reed warblers and grassbirds.	7
Total		**104**

Comprehensive counts of waterbirds across the site began sometime after the time of listing. Total waterbird abundance (1995 to 2010; Figure 27) is the best available data representing the time of listing for the site, noting that coordinated counts across the Ramsar site commenced in 2008. Despite some years of very low monitoring effort, more than 20,000 waterbirds were counted in every year (with the exception of 2001) and an average annual maximum abundance (1995 to 2010) of over 45,000 waterbirds.

In terms of abundance, the site supports large numbers of both Australian and international shorebirds as well as ducks. While most sections of the Ramsar site support a diversity of wetland dependent birds, the abundance of different guilds supported at each location is different. Data collected by Dr Michael Craig from Lake McLarty illustrate the importance of this site in terms of both diversity and abundance. Over 90 species of wetland dependent bird have been recorded and this, relatively small lake, regularly supports greater than 20,000 waterbirds annually The average annual maximum abundance (1995 to 2010) for Lake McLarty was over 35,000 (Figure 28). The most abundant species included ducks such as Australian shelduck, grey teal and Pacific black duck, as well as a range of shorebirds including periodically supporting significant numbers of red-necked avocet, red-necked stint and sharp-tailed sandpiper.

Data collected from the Yalgorup Lakes by Mr Bill Russell provides a similar depth of knowledge for this part of the system. The Yalgorup Lakes also occasionally support greater than 20,000 waterbirds, with an average annual maximum abundance from 1995 to 2010 of around 15,000 (Figure 28). This part of the Ramsar site supports significant numbers of hooded plover, fairy tern, red-necked stints and banded stilts. At the time of listing, it also regularly supported thousands of ducks (most notably Australian shelduck) and the herbivorous black swan.

There is less regular counting from the Peel-Harvey Estuary and the data presented in Figure 28 represents just six years of counts (1996 to 1998 and 2008 to 2010). This part of the Ramsar site supports significant numbers of birds and a diversity across all functional groups. In terms of abundance, the Peel-Harvey Estuary supports a greater number of fish-eating species most notably little black and little pied cormorants and Australian pelicans.

Data from Lake Mealup from around the time of listing is sparse, although it is known that this wetland supported modest numbers and diversity of waterbirds compared with other locations in the Ramsar site.

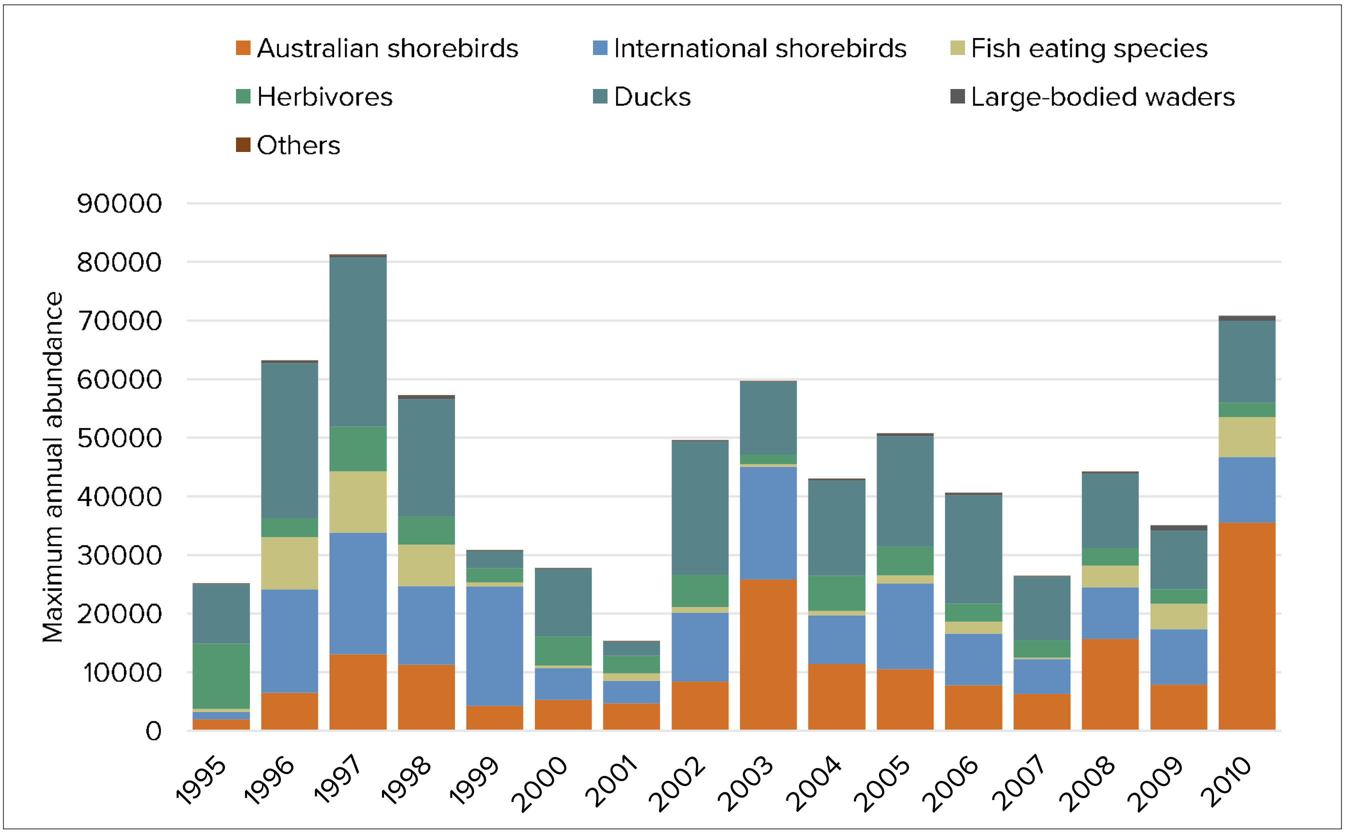
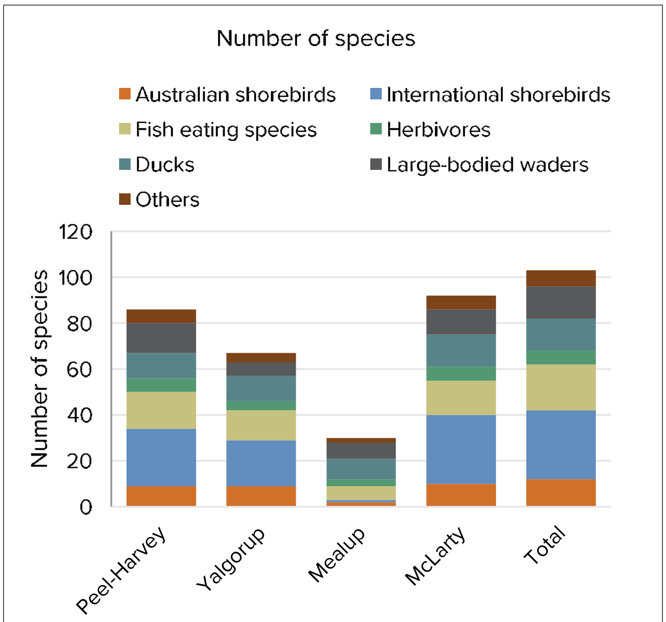


Figure 27: **Maximum annual abundance of waterbirds across the Ramsar site from 1995 to 2010 (data from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002a, b; Mr. B. Russell and Mr. D. Rule)[16]**



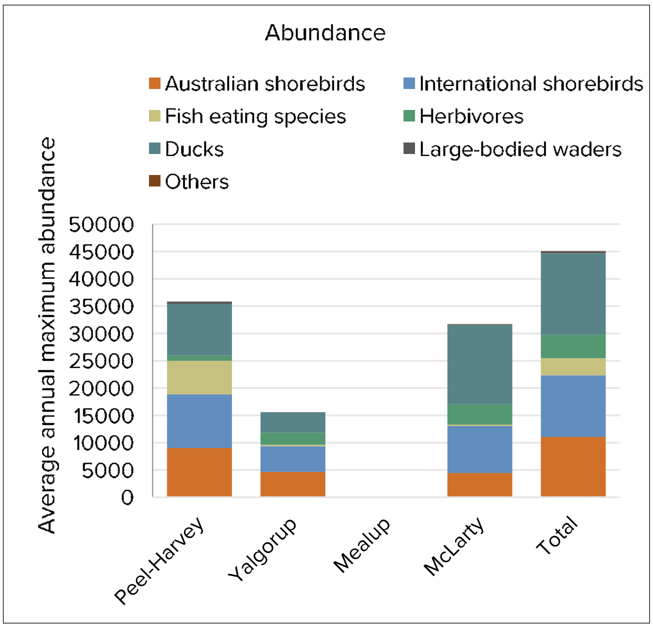


Figure 28: **Total wetland dependent bird species richness (left) and maximum annual abundance of waterbirds from general locations within the Ramsar site (right). Lake McLarty (1995 to 2010) data from Dr M. Craig; Yalgorup Lakes (1995 to 2010) data provided by Mr B Russell; Peel-Harvey Estuary (1996 to 1998) from Lane et al. (2002a, 2002b) (2008 to 2010) from BirdLife Australia/PHCC. Note that there was insufficient data available from Lake Mealup to show abundance**

16 Note that total maximum annual abundance is the sum of individual species maximum abundances. These are summed across locations at the site if counted at the same time (e.g. Shorebirds 2020) or taken as the single maximum abundance at a location, whichever is the greater.

Data from 1995 to 2010 indicate that the Ramsar site supported greater than one percent of the relevant populations[17] of eight species of waterbird (Figure 29). While several of these species are supported at multiple locations (e.g. red-necked stints occur in significant numbers at Lake McLarty, the Yalgorup Lakes and the Peel-Harvey Estuary) others are primarily supported at a single location. The hooded plover population occurs at the Yalgorup Lakes (primarily lakes Pollard, Martin's Tank, Preston and Lake Clifton) while fairy terns occur in the greatest number at Creery Wetlands in the Peel Inlet (Lane et al. 2002a, 2002b, Bamford and Bamford 2003).

The Peel-Yalgorup Ramsar Site supports seven threatened species of wetland dependent bird. These are described in section 3.7.3 below.

17 As defined by the Wetlands International Waterbird Population Estimates and Clements et al. (2016).

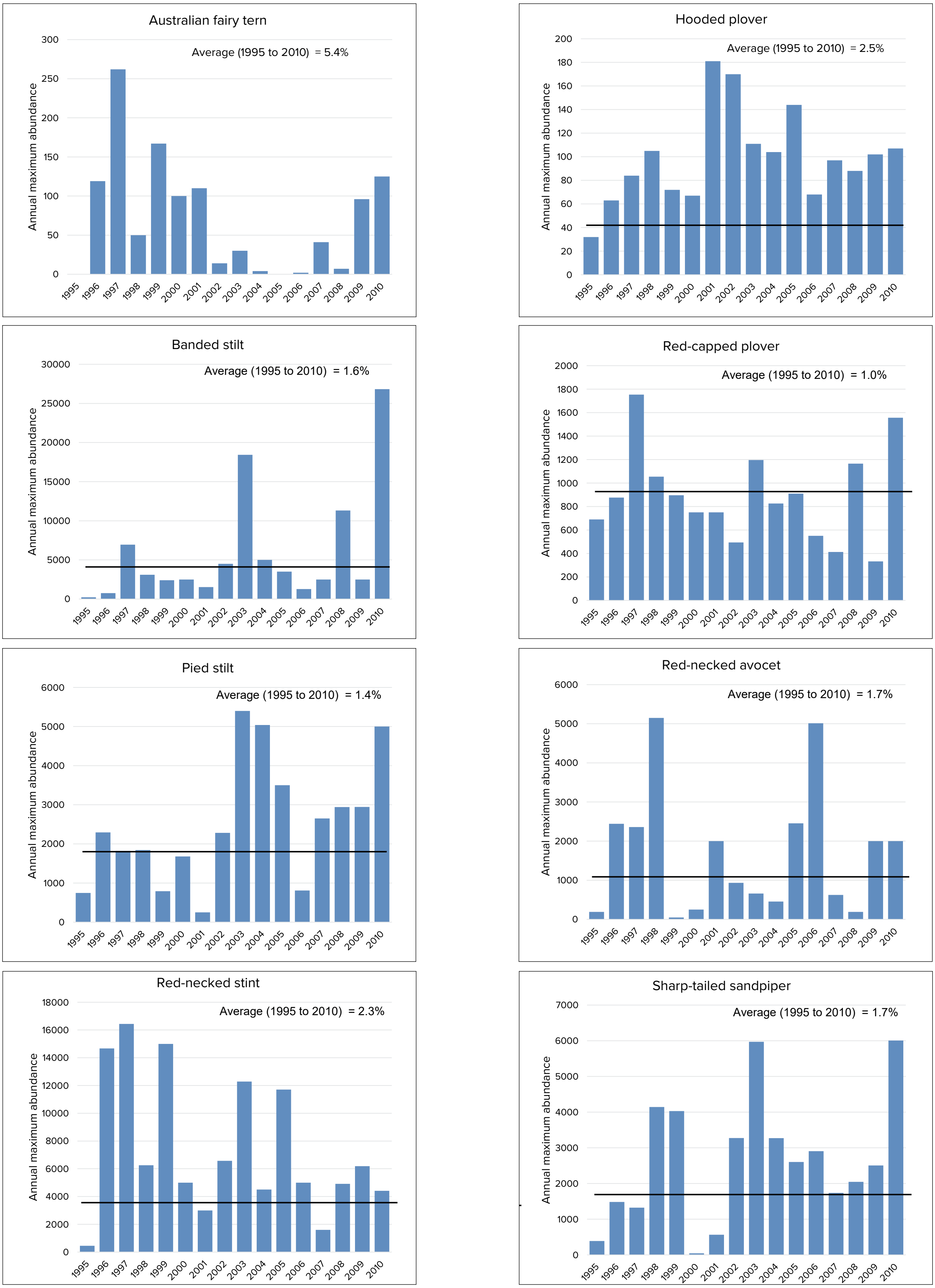


Figure 29: Maximum annual abundance of waterbirds for which the site supported greater than one percent of the population at the time of listing (data from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002a, b; Mr. B. Russell and Mr. D. Rule). Horizontal black line represents the one percent population estimate (Wetlands International 2012; Clements et al. 2016)

3.5.6 Waterbird breeding

Evidence of breeding (e.g. observations of juveniles, nests, eggs) has been recorded for 36 species of wetland dependent bird in the Peel-Yalgorup Ramsar site (See Appendix C). This includes a small number of ducks and Australasian darter at Lake Mealup, and 20 species recorded breeding at Lake McLarty (Figure 30). The Yalgorup Lakes supports nesting of several Australian shorebird species including hooded plover and red-capped plover. While the Peel-Harvey supports several colonial nesting fish eating species such as Australian pelicans, little black cormorants and little pied cormorants. Of note is the lack of breeding records for large-bodied waders, with the exception of recent observations of nesting Australian while ibis (Figure 30).

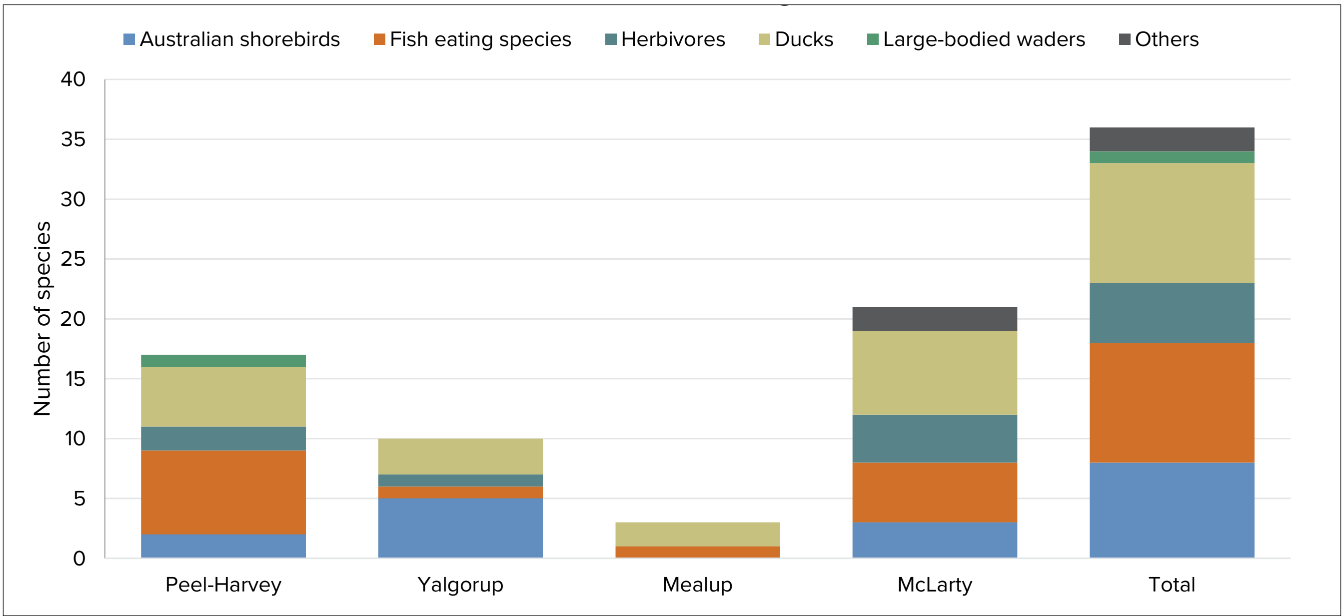


Figure 30: Species for which evidence of breeding has been recorded within the Ramsar site (Atlas of Living Australia, Lane et al. 2002a, b; Craig et al. 2018; OTS 2010; Mr. B. Russell and Mr. D. Rule).

Quantitative data on nesting rates and breeding success is sparse. It is known, however, that at the time of listing, hooded plover bred annually at the Yalgorup Lakes, which contained the largest known aggregation of breeding efforts documented for the species in Western Australia (Singor 1999).

In the late 1990s, nest and fledging estimates were made for Australian pelicans breeding on Boundary Island in the Peel Inlet (Table 18). The Peel-Harvey Estuary also supported breeding of colonial nesting cormorants. In the 1980s, hundreds of little black and little pied cormorants were observed nesting at Carrabungup Nature Reserve (Jaensch et al. 1988); more recently nesting counts have been made at several Peel-Harvey locations including a major nesting site at Len Howard Nature Reserve (Table 19).

Table 18: Breeding of Australian Pelican at Boundary Island in the Peel Inlet (Lane et al. 1997).

YEAR	ADULTS ON NESTS	ESTIMATED FLEDGLINGS
1994	65	35-45
1995	unknown	150-200
1996	100	200-250
1997	80	150-200

Table 19: Breeding of cormorants at Len Howard Reserve (OTS 2016).

YEAR	2010	2016
Active nests	115	161
Little pied cormorant eggs	71	22
Little black cormorant eggs	248	516

3.5.7 Marine mammals

The Peel-Harvey Estuary supports a distinct community of Indo-Pacific bottlenose dolphins *(Tursiops aduncus)*. Recent research suggests a year-round resident community of around 90 individuals which swells up to several hundred, due to seasonal visitation by individuals outside the system. These coastal visitors appear to use the system for feeding and breeding opportunities (pers. comm. Krista Nicholson). The Peel-Harvey Estuary is used by the resident dolphin community members to complete their lifecycle. As such the estuary is an important birthing ground and nursery area for the resident community comprising juveniles / sub-adults (30 percent) and dependent calves (20 percent) (Nicholson et al. 2017).

3.6 Cultural services

3.6.1 Noongar connection to the wetlands of the site[18]

The Peel-Yalgorup Ramsar Site is important to the Bindjareb Noongar people, the Traditional Owners and custodians of the land and waters of the Bindjareb Boodja which includes the Ramsar Site. All waterways are sacred to Noongar Creation Beliefs. For over 50,000 years the Bindjareb language group of the Noongar Nation have dwelt within the Peel-Yalgorup System, tended the land and been sustained by its natural resources. Their ongoing spiritual, cultural and intellectual connections to the land are strong and provide opportunities to enhance management of the Ramsar Site.

Noongar and other Aboriginal[19] cultural heritage and values are unique and irreplaceable; they are kept alive through knowledge sharing, arts, rituals and performances, by speaking and teaching language, and also by protecting sacred and significant sites, materials and objects.

Bindjareb Noongar people have a life commitment and cultural responsibility to the preservation of waterways. The management of the waterways is based on the six seasons, to identify and associate the changing seasons with the food resources and interconnectedness of all life. This is based on spiritual beliefs and ongoing usage of foods from the waterways. Bindjareb Noongar people continue to gather bush tucker (native plants) for food and medicinal purposes. Hunting and gathering food at special places brings about co-benefits for Bindjareb Noongar people, preserving culture, keeping spirit strong, improved health and wellbeing, and is of economic benefit to families.

The Bindjareb Noongar people know the Peel-Harvey estuary by its ancient name Djilba; this name, Djilba, was recorded on early European maps. The Bindjareb Noongar people have looked after the Djilba for 50,000 years based on governance and Lore. Elders are responsible for looking after country. This responsibility is deep and manifests in the health and wellbeing of Elders, who are also responsible and accountable to other Bindjareb Noongar people for the care of our waterways.

18 This section has been provided by our Noongar community; it was finalised at a meeting with Elder Harry Nannup and George Walley TO, along with PHCC Officers Thelma Crook and Kim Wilson, held on 19 November 2019.

19 "Aboriginal" rather than "Indigenous" is used in this document in alignment with the expressed preference of the Noongar people.

'Looking after our waterways makes our spirit strong', explains Elder Harry Nannup. "I have grown up on the rivers, lakes, swamps, estuary and ocean so I want these waterways and land near the waterways to be protected. I looked at the swamps as a survival kit because they kept us alive. Turtles use the land nearby to go and lay their eggs. The rivers' name is Bilya and bilya also means umbilical cord. The Bilya sustains life for humans, marine life, land animals, water birds and plant ecosystems; the healthier the river [and umbilical cord] is, the healthier all life is. Noongar people have always seen the importance of looking after the waterways and land, and then we will be looked after. If the umbilical cord is sick then we will be sick."[20]

"Bindjareb Noongar people maintain a very important relationship with the waterways today, as our ancestors have done in times past. When families visit the rivers it is with the same reasoning, to sit, look for foods, relax, swim, and to experience what their parent's generation have experienced. Every generation has maintained links in some form to what the waterways have kept that is sacred. The sacredness is the same today as it has been since the Woggaal created all waterways".[21]

"Before moving on with the change of seasons, old people camped at the top end of Lake Preston to take (soak in) the mineral water there and gain strength," recalls Elder Harry Nannup.

"Take your shoes off and feel country," invites Elder Franklyn Nannup.

"Noongar Creation Beliefs and cultural knowledge is ingrained into our everyday language, culture, rituals, ceremonies and way of life", recalls George Walley.

Families would look for cobbler, marron, tortoise and gilgi in the freshwater, and mullet, bream, kingfish, crabs, prawns and yellow tail in the sections of water that had more salt content in. Most of the time spears would be used but there were fish traps built to take advantage of the tidal movement. Birds were also hunted. People could swim underwater and pull the bird underwater and later cooked it. The waterways gave people the opportunity to stay in the same place for months.

The name for the paperbark tree is bibol. Bibol comes from the base word and name, bibi which means breast. The paperbark tree is very important in its association with language, culture and practical usage.

"Our families camped in the paperbark groves in summer where it was cool. You could use the bark to make ground covers to sit on, and to sleep on at night. Firewood was readily available, and shade was constant throughout the day, and it made life much more relaxing. A plant called dodder grows on the paperbark tree and it can get so thick that children could climb on the plant and sit on it up in the tree and eat the small edible fruit."

Some larger paper bark trees can carry water inside its trunk. The bark could be used to make water carrying and storage vessels. These water vessels could be carried whilst walking from camp to camp, and on hunting and food gathering trips. Bark was also used to wrap fish in to cook on the coals. The bark would be dampened, fish wrapped inside and placed in the coals for slow cooking.

Bark was also used to place on the top of winter shelters. Long sections of bark were cut from much larger paperbark trees and would be used as a roof to stop rain from entering the shelter. The bark was also used on the bottom of shelters to stop moisture from coming up from the ground into the bedding".[22]

"Nature has a system in place that works at optimum to maintain an environmental balance. In ancient times Bindjareb Noongar people worked with that understanding to respect the environment. This is the same understanding we work with today as Traditional Owners".

The simple approach has been and should be, "when we look after the land, the land will look after us," Elder Harry Nannup, Elder Franklyn Nannup and George Walley Traditional Owner.

20 Elder: Harry Nannup; written by nephew: George Walley adapted from "Welcome to Country", Peel-Harvey Catchment Council (2015), BIndjareb Boodja Landscapes 2025, A Strategy for Natural Resource Management in the Peel-Harvey Region, A Report to the Peel-Harvey Catchment Council, Jane O'Malley & Andrew Del Marco (eds.) Mandurah, Western Australia.

21 George Walley and Franklyn Nannup (2012), BIndjareb Noongar Perspective, Report for Water Quality improvement plans for selected subcatchments in Peel-Harvey as part of filtering the nutrient storm project.

22 Bindjareb Traditional Owner George Walley's knowledge and perceptions of the Ramsar site, excerpts edited from Noongar Boodja, Bindjareb Boodja, Yoordjanggaap Boodja, Ancient Connections to Country project, Shire of Waroona & Harvey River Restoration Taskforce.

The Aboriginal Story of the Waterways and Lake Clifton

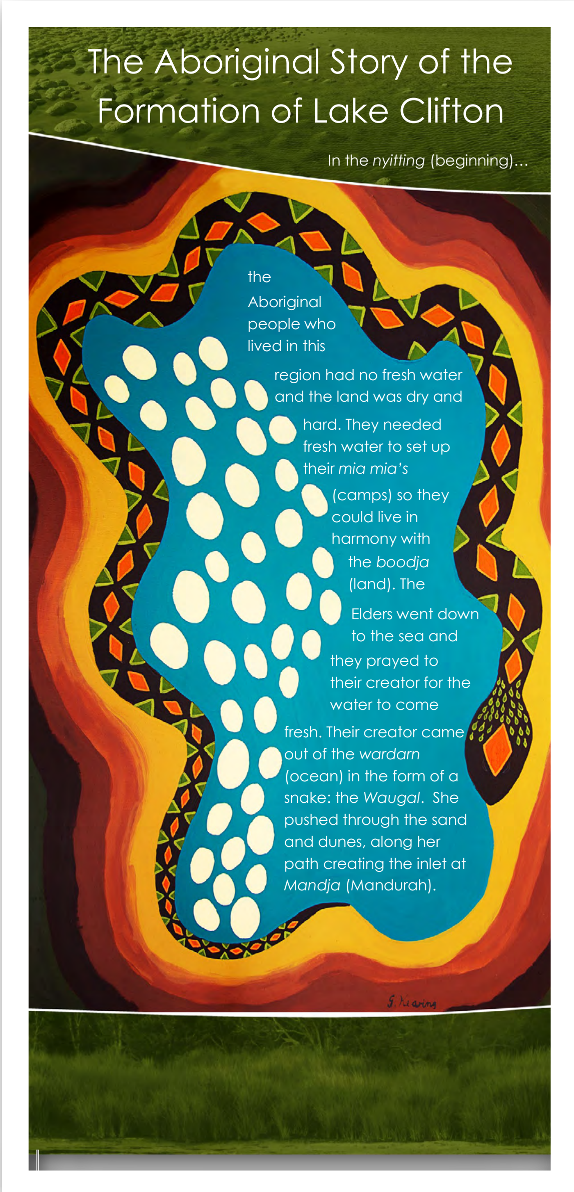
To the Aboriginal people of this region, Lake Clifton is a very special place. It is significance in culture and history, with stories passed from generation to generation. It is a place for the yorga (women) as it tells of the creation of the Lake and Thrombolites by Wagyl.

From the local Elders and families, we learn how the rivers and estuaries were formed, how the inlet and lakes were made and how it all came together for their people. They called on the Wagyl to save them, in pray and song, and she answered them. This is their story.

In the beginning the Aboriginal people who live in this region had no fresh water and all the land was dry and hard. They needed the fresh water to set up their mia mia's (camps) so they could live in harmony with the budjar (land). The Elders went down to the sea and they prayed to their creator for water to come fresh. Their creator came out of the wardarn (ocean) in the form of a snake as she was the Wagyl. She pushed through the sand and dunes, along her path creating the inlet.

Wagyl slithered back and forth and carved out a hollow which formed the derbal (estuary) and here she laid her eggs. She curled her body around her eggs and protected them. In time some of the eggs hatched and young began to appear. Then they scattered carving out the major bilya (rivers), the Harvey, Murray and Serpentine.

The little ones, they were fat and they kept going east, up the hills, forming rivers and swamps. They came to be tired and starved as they didn't stop to eat. The grooves they cut became thinner as they were further from their birthplace. When their end came they died and went underground, back into their heaven, the wardarn, left behind them were water supplies, fresh and plentiful and water was restored to the land once more.



But the Wagyl, she went in search of her young, she went underground and came up at Lake Clifton and Lake Preston. She kept going, looking for them, all the way to the estuary at Australind. She never found her babies, instead she burrowed down in the derbal and where her mouth was, a spring of fresh water comes and it is a place where fish gather and Nyungars can catch them and Wagyl, she is still there waiting for her young to return.

The Aboriginal people always live by the rules of the Wagyl and hold them in highest reverence for they gave their lives to the people and created the waterways.

Text box 2: The Aboriginal story of the formation of Lake Clifton. Interpretation based on Myth as recorded by Senior Elder Joseph Walley (RIP) in display at the Mandurah Museum and interviews with Woman Elder Mrs Gloria Kearing and her daughter Karrie-Anne Kearing recorded in early 2013. Story adapted by Christine Comer, Peel-Harvey Catchment Council; Reviewed by Dr. Amanda Yates, Archaeologist.

3.6.2 Recreation and tourism

The Peel-Yalgorup Ramsar Site is regionally significant in terms of recreational and tourism values. In 2015, the Peel region attracted over three million visitors, with an estimated total spend of over $500 million (Marketrade 2016). A significant proportion of visitors include trips to parts of the Ramsar site, including the Yalgorup National Park, where the boardwalk into Lake Clifton to view the thrombolites is popular. Boating, fishing, sightseeing, dolphin tours and nature observation are all activities supported by the ecological character of the Peel-Yalgorup Ramsar Site. The recreation values are important to locals as well as visitors, perhaps more so. The Ramsar Site's importance to the local economy is strongly recognised (Peel Development Commission 2016).

The Peel-Harvey Estuary supports an important recreational fishery and the recreational and commercial blue swimmer crab and commercial sea mullet fishery has been certified as sustainable by the Marine Stewardship Council.

3.7 Critical benefits and services

Critical ecological services, such as water cycling, nutrient cycling and habitat for biota, are those which are considered essential for the production of all other ecosystem services. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time. A summary of the critical benfits and services of the site is provided in Table 20.

Table 20: Summary of critical benefits and services within the Peel-Yalgorup Ramsar Site.

CRITICAL ECOLOGICAL SERVICES	DESCRIPTION
Provides physical habitat for waterbirds	The site provides a network of habitats for waterbird feeding, roosting, moulting and breeding. Species that are supported by the site represent a wide range of functional groups (e.g. shorebirds, ducks, fish-eaters, large-bodied waders) each with different habitat requirements
Threatened wetland species and communities	The site provides important habitat for seven species of threatened fauna, including: six international migratory shorebirds and Australian fairy tern, as well as three ecological communities: Clay pans of the Swan Coastal Plain Ecological Community, coastal saltmarsh and the thrombolites
Ecological connectivity	The Ramsar site has a range of distinct wetland types which are ecologically connected. The connection between the marine, estuarine and freshwater components is significant for fish migration and reproduction. The site also supports significant numbers of international migratory shorebird species
Supports a diversity of wetland types	The site comprises a network of wetland types including intermittent freshwater wetlands, permanent saline coastal lagoons and estuarine waters

3.7.1 Provides physical habitat for waterbirds

The Peel-Yalgorup Ramsar Site provides a high diversity of habitats for waterbirds across the different areas. The mobile nature of birds means that individuals can use different parts of the site for different needs. For example, the colonial nesting little black and little pied cormorants that nest in paperbark at Len Howard Reserve travel to open water habitats in the Peel-Harvey Estuary to feed (OTS 2010). The Ramsar Site provides important habitat for foraging, roosting, moulting and breeding of wetland dependent birds.

Moulting

Waterfowl undergo an annual moult of their primary flight feathers, during which individuals are flightless for a period of two to five weeks, which makes them more vulnerable to predators. In addition, protein comprises greater than 80 percent of flight feathers and during moult birds have a high requirement for protein in their diets. This includes green fodder for herbivores and invertebrates for carnivorous waterfowl (Ringelman 1990).

The permanent waters of the Yalgorup Lakes and Lake Preston in particular are important for Australian shelduck during their moulting phase. The birds arrive in late spring and congregate on open water where there is little fringing vegetation and which provides good visibility of approaching predators. Australian shelduck have also been observed using Lake McLarty for moulting when water levels are sufficient (Craig et al. 2011). The combination of reliable permanent open water and high productivity supplying adequate food resources provides ideal habitat for moulting waterfowl.

Foraging and roosting

The foraging and roosting habitat requirements of waterbirds can be considered in terms of feeding functional groups. The habitat requirements of select species known to occur within the Ramsar site are described in Table 21.

Table 21: Feeding and roosting habitat requirements of select waterbird species from the Peel-Yalgorup Ramsar Site

FUNCTIONAL GROUP	SPECIES	HABITAT CHARACTERISTICS	KEY LOCATIONS IN THE RAMSAR SITE
Fish eating waterbirds	Great pied cormorant	• Mainly marine in Australia, but also on inland wetlands • Roost in trees near water or on cliffs, offshore rocks • Diet consists mainly of fish, which they catch by pursuit diving	Peel-Harvey Estuary
	Caspian tern	• Mainly coastal on beaches, bays, estuaries and lagoons • Roost on bare flat sand areas • Diet mainly fish caught from the surface or shallow waters mainly in inshore areas	Peel-Harvey Estuary
	Australian pelican	• Diet consists mainly of fish, which are caught by plunge diving in coastal and inland wetlands	Peel-Harvey Estuary
Ducks	Australian shelduck	• Generally sedentary, but post breeding migration over short distances for moulting • Grazes on land or in shallow water where it feeds on algae, insects and molluscs	Yalgorup Lakes, Lake McLarty, Peel-Harvey Estuary
	Grey teal	• Mainly nomadic wandering large distances across the continent • Occur in most wetland types commonly in intertidal areas in estuaries • Seeds of aquatic plants are an important food source as are invertebrates	Yalgorup Lakes, Lake McLarty, Peel-Harvey Estuary
Herbivores	Black swan	• Inland and estuarine shallow waters where floating, submerged or emergent vegetation is plentiful • Roost – mostly over water, but occasionally on shore • Diet – herbivorous feeding on the shoots and leaves of aquatic plants including filamentous algae and seagrass	Yalgorup Lakes, Peel-Harvey Estuary
Shorebirds	Banded stilt	• Nomad, breeding in the inland, but parts of the population may be sedentary and has been recorded in the estuary year round • Prefers shallow, saline waters • Feeds mainly on crustaceans and insects by foraging in shallow water	Yalgorup Lakes, Peel-Harvey Estuary
	Red-necked stint	• International migrant, breeds in Siberia. Present in the site between late August and early April • Uses intertidal habitat feeding in mudflats and in saltmarsh on invertebrates and plants such as seagrass and seeds	Yalgorup Lakes, Lake McLarty, Peel-Harvey Estuary
	Red-capped plover	• Australian nomad, but parts of the population may be sedentary and has been recorded in the site year round. Breeds in coastal wetlands • Prefers shallow, saline waters • Feeds mainly on gastropods and insects by foraging on mudflats and shores	Yalgorup Lakes

Large bodied waders	White-faced heron	• Very diverse array of habitats from arid inland to temperate coasts • Feeds on a diversity of prey including aquatic insects, molluscs, crustaceans, frogs and fish • Foraging – variety of techniques, wading and disturbing prey, ambush hunting and probing crevices and mud	Yalgorup Lakes, Lake McLarty, Peel-Harvey Estuary

Breeding

The species recorded breeding at the site utilise a range of different habitats within the system (Table 22). Lake McLarty supports the greatest number of breeding species. The Yalgorup Lakes are important for Australian resident shorebirds and parts of the Peel-Harvey Estuary are important for colonial nesting species. Breeding of several species has been recorded at Lake Mealup including Australian darter.

Table 22: Breeding habitat requirements of select waterbird species from the Peel-Yalgorup Ramsar Site

FUNCTIONAL GROUP	SPECIES	BREEDING REQUIREMENTS	KEY LOCATIONS IN THE RAMSAR SITE
Fish eating waterbirds	Great 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	Peel-Harvey Estuary: Len Howard Reserve. Carrabungup. Occasionally at Lake McLarty
	Little black cormorant	• Nests in forks and branches of Melaleuca trees in or over water. • Colonial breeder with up to 10s of nests in a tree • Young remain in nests until mature	Peel-Harvey Estuary: Len Howard Reserve, the Peninsula
	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 three to four weeks • First flight at three months	Peel-Harvey Estuary: Boundary Island
Ducks	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	Peel-Harvey: Creery wetlands. Chicks often observed at Yalgorup Lakes
	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 eight weeks	Peel-Harvey Estuary; Peel Inlet Nature Reserve
Herbivores	Black swan	• Nest mound built in open water or in aquatic vegetation • Requires minimum water depth of 30 to 50 centimetres until cygnets are independent • First flight 20 to 25 weeks	Peel-Harvey Estuary, Lake Preston; Lake McLarty
	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	Lake McLarty
Shorebirds	Hooded plover	• Nest between August and February on hard limestone or sand near the waterline • Nesting success is thought to be low (less than 30 percent)	Yalgorup Lakes
	Red-capped plover	• Nests in scrape made in sand or mud • Young leave nest within one day and self-feed, require vegetation for cover	Yalgorup Lakes; Peel-Harvey Estuary: Soldiers Cove
Other	White-bellied sea eagle	• Build a large nest of sticks that is used for multiple seasons. • Generally nest in a tree and at Lake McLarty nests are in tuart *(Eucalyptus gomphocephala)*. Fledged after 60 to70 days, but dependent on parents for food for a further four months	Two sites on the western side of Lake McLarty

3.7.2 Supports threatened species and communities

Species and communities which are listed at the national or international level and which are regularly found within the site are considered as contributing to this critical service. The habitat preferences and general characteristics of the listed communities and key threatened taxa are summarised in Table 23.

Table 23: Summary of listed species and communities regularly supported by the Peel-Yalgorup Ramsar Site.

LISTED SPECIES OR COMMUNITY
Subtropical and temperate coastal saltmarsh
Vegetation community consisting mainly of salt-tolerant vegetation including grasses, sedges, rushes and shrubs. Typically in Australia (and the Peel-Yalgorup Ramsar Site) the community is characterised by low species richness and dominance by a small number of species (Adam 1990). Community composition is a factor of both inundation and salinity (Boon et al. 2011). Within the Ramsar site, the dominant species are largely beaded glasswort in more saline locations and sea rush where salinity is brackish to saline (Hale and Kobryn 2017). The conservation listing advice for subtropical and temperate coastal saltmarsh under the EPBC Act indicates that only saltmarsh that is subject to tidal inundation is included in the listed vulnerable community and that saltmarshes of coastal lagoons "would not be considered as part of the ecological community if the disconnection [to the sea] were permanent" http://www.environment.gov.au/biodiversity/threatened/communities/pubs/118-conservation-advice.pdf. By this standard, the listed community would include the saltmarsh around the microtidal Peel-Harvey Estuary, but exclude that within the Yalgorup Lakes.
Thrombolites
At the time of listing the thrombolites at Lake Clifton were actively growing and reliant on the inflow of fresh groundwater rich in calcium and bicarbonate. Groundwater maintained lake levels to prevent desiccation of the thrombolites and kept salinity in the system hyposaline (1 to 10 ppt) throughout 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. It was hypothesised that if nutrients in the groundwater source increased, the growth of this and other macroalgae (or phytoplankton) could inhibit the thrombolites (Rosen et al. 1996). The main processes for the formation of the thrombolites in Lake Clifton is thought to be the precipitation of calcium carbonate through photosynthesis of the blue-green algae *Scytonema* (Moore and Burn 1994). It is the combination of low salinity, high alkalinity, calcium rich water that supplies the necessary ingredients for the growth of the Thrombolites. There are fossil thrombolites in several other lakes in the Yalgorup Lake system and it has been suggested that increasing salinity in these sites eventually led to their demise (Moore and Burne 1994).
Clay Pans of the Swan Coastal Plain
The critically endangered ecological community "Clay Pans of the Swan Coastal Plain" is characterised by clay pan basins where clay soils form an impermeable layer close to the surface. They are rainfall reliant and contain a diversity of annual vegetation species. The threatened ecological community comprises four distinct floristic community types, of which two are presented within the Peel-Yalgorup Ramsar Site: herb rich saline shrublands in clay pans occurs in Austin Bay Nature Reserve and shrublands on dry clay flats occurs within Kooljerrenup Nature Reserve. Herb rich saline shrublands in clay pans is a community characterised by early flowering aquatic species such as *Centrolepis spp*. and *Stylidium spp*. flower. Shrublands on dry clay flats occurs on skeletal soils which are infrequently wet. Shrubs in the community include *Hakea sulcata, Hakea varia, Pericalymma ellipticum* and *Verticordia densiflora* (Department of Parks and Wildlife 2015).
Migratory shorebirds
The Ramsar site regularly supports six threatened species from the East Asian-Australasian Flyway: • Bar-tailed godwit *(Limosa lapponica menzbieri)* – Critically endangered (EPBC) • Curlew sandpiper *(Calidris ferruginea)* – Critically endangered (EPBC) • Eastern curlew *(Numenius madagascariensis)* – Critically endangered (EPBC); endangered (IUCN) • Great knot *(Calidris tenuirostris)* – Critically endangered (EPBC); endangered (IUCN) • Greater sand plover *(Charadrius leschenaultii)* – Vulnerable (EPBC) • Red knot *(Calidris canutus)* – Endangered (EPBC)

These international migratory species spend the non-breeding season in the southern hemisphere. They arrive in late spring, spend the summer feeding on invertebrates in intertidal mudflats and depart for the northern hemisphere in February to March. Juveniles of all species who arrive in the Ramsar site spend their first one or two winters before heading to the northern hemisphere to breed. Although the species have similar life histories, they are physically very different. The eastern curlew is the largest of the shorebirds with a wingspan of over one metre and a weight of nearly one kilogram. The red knot and bar-tailed godwits are smaller, but still large shorebirds. In contrast the curlew sandpiper is a small bird, with a weight of just 60 grams (Higgins and Davies 1996).

Fairy tern (Sterna nereis nereis)

The Australian fairy tern is a small bird that feeds on small fish and occasionally invertebrates (Higgins and Davis 1996). The species is long lived, with individuals over 20 years old observed still breeding (Greenwell et al. 2019). While Australian fairy terns have been recorded at Yalgorup Lakes (in increasing numbers in recent years), they are in the greatest abundance in the Peel-Harvey Estuary in Samphire Cove and Austin Bay. The Ramsar site regularly supports greater than one percent of the population of this species (see Figure 29). Prior to development of the Mandurah Marina the species regularly nested at the mouth of the Peel Inlet in Mandurah due to suitable vegetation free sandy habitat and the close proximity to small schooling fish in the Mandurah Channel (Greenwell et al. 2019). In 2017, the Mandurah Fairy Tern Sanctuary was established to secure breeding of the species, where small numbers of terns bred. There was a large colony recorded in 2019 (40 nests) at the nearby Town Beach (Greenwell et al. 2019).

3.7.3 Ecological connectivity

Ecological connectivity can relate to water mediated movement of biota, energy and materials through the landscape and is a well-established principle in the maintenance of spatially structured populations. Aspects of ecological connectivity considered critical to the character of the Peel-Yalgorup Ramsar Site include pathways for migratory fish, particularly for diadromous fish, and interconnected habitat for waterbirds.

Fish

The Peel-Harvey Estuary supports a range of fish with different life history strategies (Figure 31). The majority of the fish species in the estuary (2005 to 2010) were marine stragglers which spawn at sea and typically enter estuaries in low numbers staying in areas where salinity doesn't drop below 35 ppt (Potter et al. 2016). Species in this category include leatherjackets, wrasse, flathead and anchovies. In terms of abundance, however, the majority of the individuals caught in surveys were in the solely estuarine category (i.e. species that live their entire lives within estuarine waters), which accounted for 30 to 40 percent of the total catch, dominated by the elongate hardyhead (Valesini et al. 2009, Potter et al. 2016). Marine and estuarine opportunists, which breed in the ocean, but move into the estuary as juveniles to take advantage of sheltered and productive waters, are also common in terms of abundance. This group includes the sandy sprat which schools in large numbers in the shallow waters of the Peel-Harvey Estuary and is an important food source for several fish eating bird species (Finn and Calver 2008, Greenwell et al. 2019).

The semi-anadromous category is represented by a single species in the Peel-Harvey Estuary, the Perth Herring *(Nematalosa vlaminghi),* which lives the majority of its life along the Western Australian coast but enters estuaries to spawn, with juvenile fish migrating back out into the Indian Ocean (Potter and Hyndes 1999).

The site also supports a single species that is wholly catadromous, the pouched lamprey *(Geotria australis)*, which has been recorded in the Serpentine River (Klunzinger et al. 2011). This species lives its juvenile lifecycle (three to four 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 following spawning.

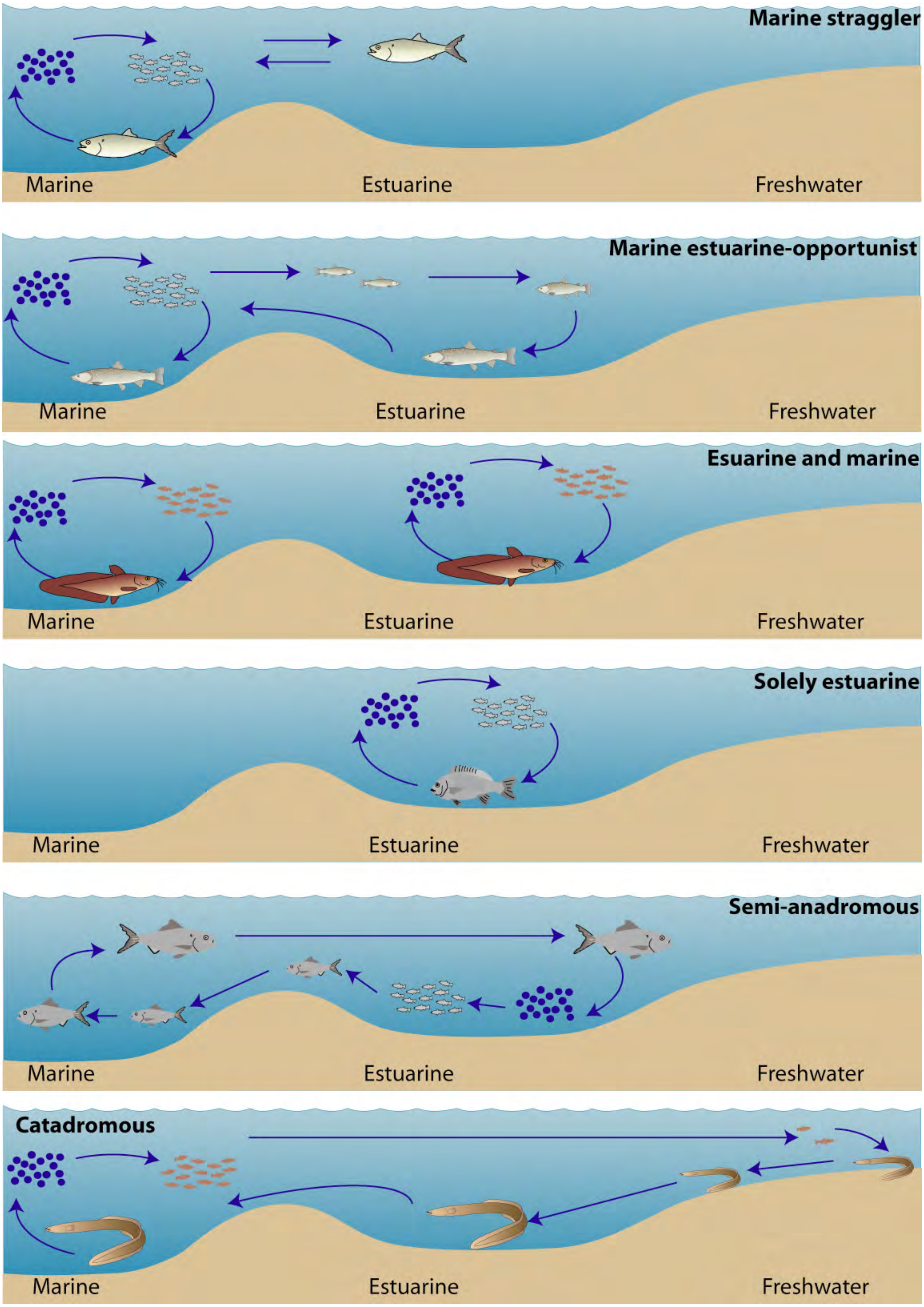


Figure 31: Fish use of the Peel-Harvey Estuary (adapted from Potter and Hyndes 1999)

Waterbirds

Ecological connectivity with respect to waterbirds at the site is provided at a local scale by the diversity of wetlands and habitat types provided for breeding, feeding and roosting. In addition, the site supports a number of migratory shorebirds from the East Asian-Australasian Flyway. The majority of these birds migrate from breeding grounds in North-east Asia and Alaska to non-breeding grounds in Australia and New Zealand, covering the journey of over 10,000 kilometres twice in a single year (Figure 32).

The lifecycle of most international migratory shorebirds involves (Bamford et al. 2008):

- breeding in May to August (northern hemisphere);
- southward migration to the southern hemisphere (August to November);
- feeding and foraging in the southern hemisphere (August to April); and
- northward migration to breeding grounds (February to May).

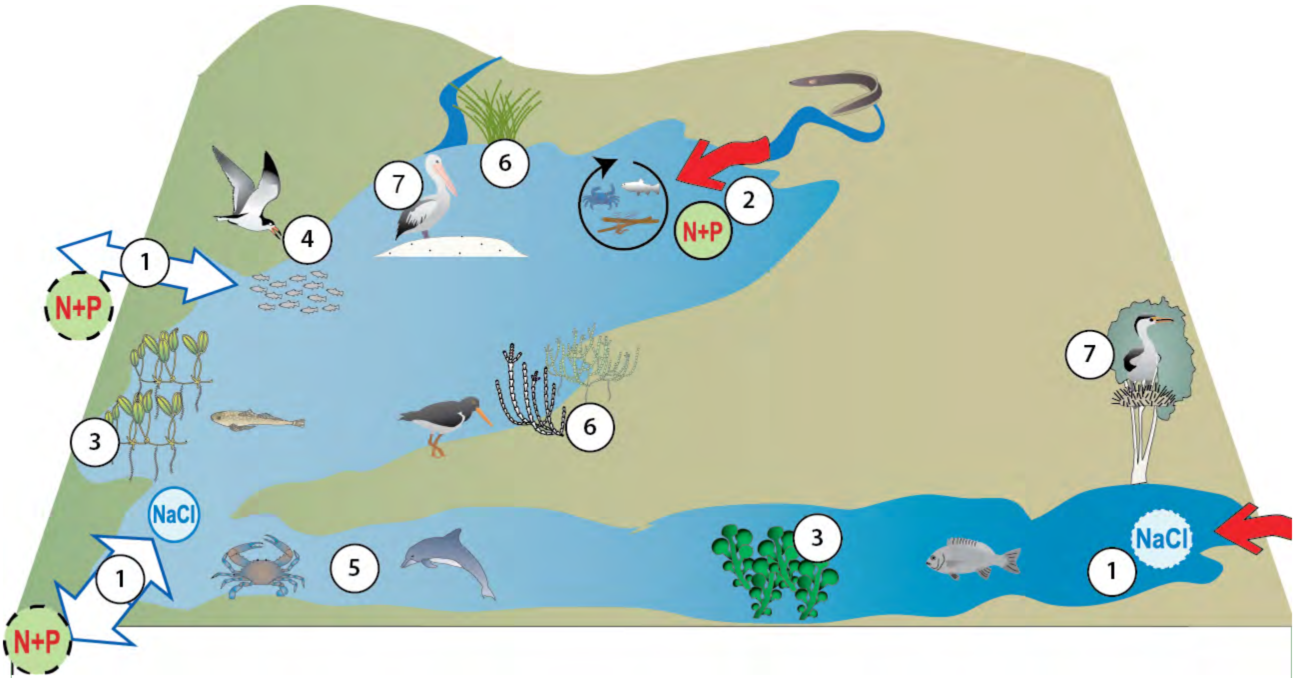
During both northward and southward migration, birds may stop at areas on route to rest and feed. These stopovers are referred to as "staging" areas and are important for the birds' survival. In addition, birds on their first southward migration have not yet reached breeding maturity and may remain in Australia over the southern winter period.

Figure 32: East Asian-Australasian Flyway (adapted from Bamford et al. 2008).

3.7.4 Supports a diversity of wetland types

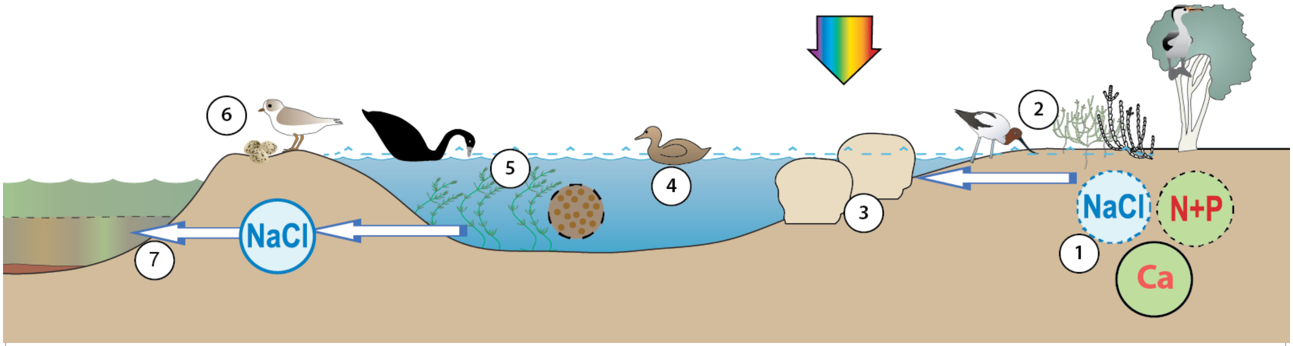
As described in section 2.3, the Peel-Yalgorup Ramsar Site contains seven wetland types, some of which can be considered significant in a bioregional context. This diversity of habitat is brought about by the interactions between geomorphology, hydrology and vegetation. Water regime and salinity are the most significant determinant of wetland vegetation, with different groups of species having different morphological adaptations to patterns of inundation (Roberts and Marston 2011). Hydrological processes including groundwater recharge and discharge are key drivers of the character of the site and underpin all other services supported at the site.

The diversity of wetlands and habitats, and how they support the critical components and processes of the site is illustrated in the conceptual models in Figures 30 to 33.



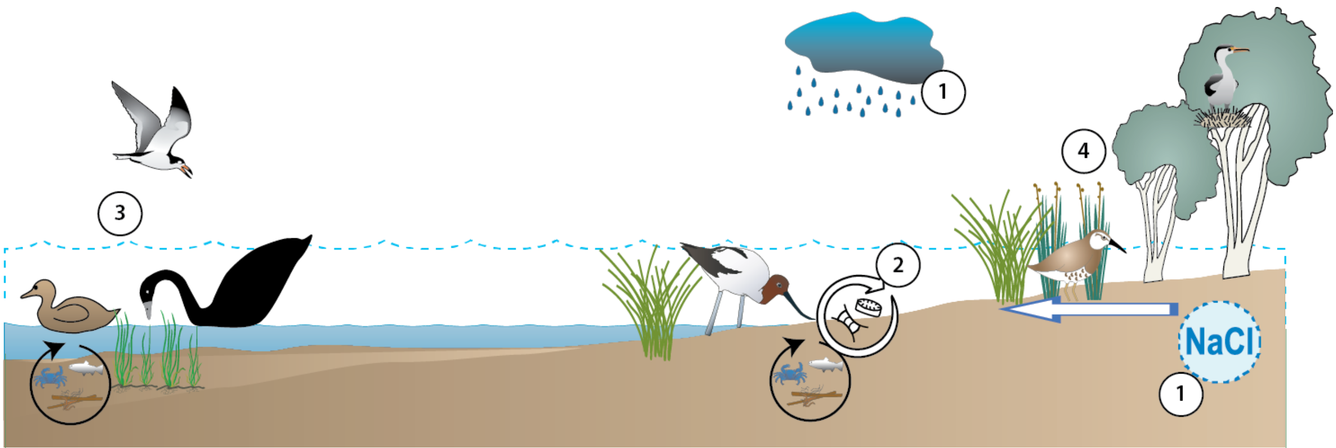
1. Seasonal freshwater inflows act with tidal exchange to create a gradient of salinity from rivers to areas adjacent to the Dawesville Channel and Mandurah Channel.
2. River inflows bring loads of nutrients and sediments driving productivity and food webs. Nutrients are exported through the connections to the Indian Ocean.
3. The gradient of nutrients and salinity promotes growth of macroalgae closer to river outlets and seagrass closer to ocean connections.
4. The gradient of salinity and variety of habitats supports different fish species in different regions. The high abundance of fish (particularly schooling fish) supports fish eating waterbirds.
5. Sheltered habitats support a variety of biota including a range of fish, blue swimmer crabs and bottlenose dolphins.
6. The micro-tidal exchange and salinity gradient supports a variety of fringing vegetation with saltmarsh closest to the water grading to paperbark and swamp sheoak on higher ground. Saltmarch and mudflats provide foraging grounds for shorebirds.
7. A variety of habitats support nesting birds including Australian pelicans on islands, colonial nesters in trees and fairy terns on beaches.

Figure 33: Stylised conceptual model of the Peel-Harvey Estuary portion of the Ramsar site showing the interactions between components, processes and services



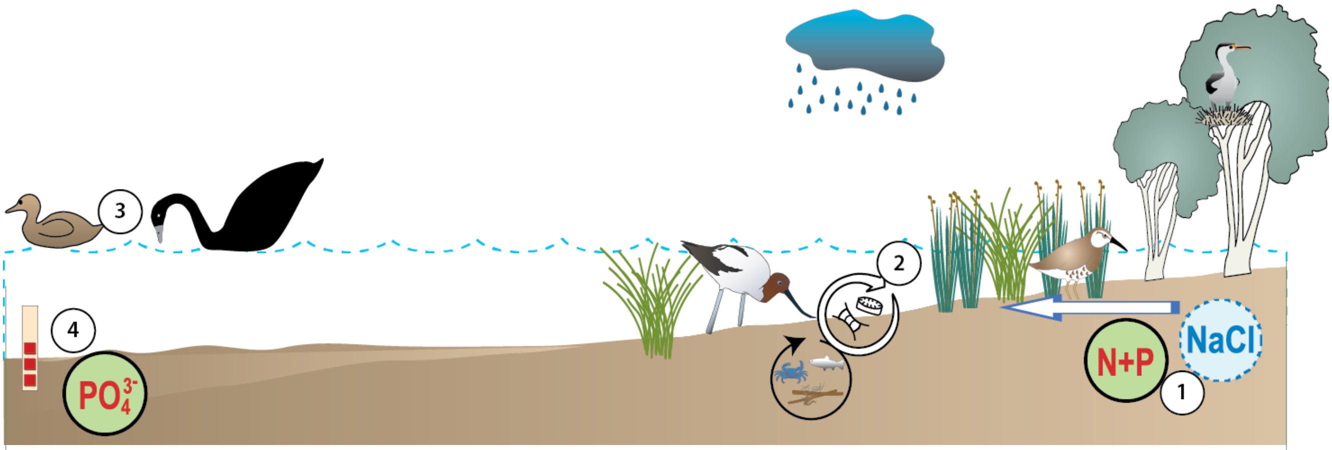
1. Low salinity, low nutrient, calcium rich groundwater flows into Lake Clifton, supporting the growth of the Thrombolites.
2. Seasonal inflows of water raise water levels inundating shorelines and saltmarsh vegetation communities and providing foraging habitat for shorebirds. Saltwater paperbark provides roosting habitat for waterbirds.
3. Seasonal inflows of groundwater maintain salinity within the tolerance of Thrombolites. Good water clarity facilitates photosynthesis of the cyanobacteria responsible for driving the growth of the Thrombolites.
4. Open water provides habitat for moulting waterfowl, particularly Australian Shelduck.
5. Moderate salinity, low nutrients and high water clarity promotes the growth of benthic plants such as Ruppia and charophytes. This is turn provides food for grazing waterfowl such as black swans.
6. Limestone substrate adjacent to shallow water feeding areas providing nesting habitat for hooded plovers, red-capped plovers and other shore-nesting species.
7. Groundwater flows through Lake Clifton into other lakes, increasing salinity and contributing to prolonged stratification.

Figure 34: Stylised conceptual model of the Yalgorup Lakes portion of the Ramsar site at the time of listing showing the interactions between components, processes and services.



1. Direct rainfall, surface flows from a small catchment and some low salinity groundwater inundate the wetland seasonally.
2. As water levels recede over summer, productivity in exposed mudflats provides extensive foraging areaas for waders.
3. When inundated, the site provides habitat for different feeding guilds of waterbirds and supports annual moult of waterfowl, particularly Australian shelduck.
4. The variability in inundation supports healthy littoral vegetation of reeds and sedges with an overstorey of freshwater paperbark. This provides habitat for roosting, foraging and nesting waterbirds.

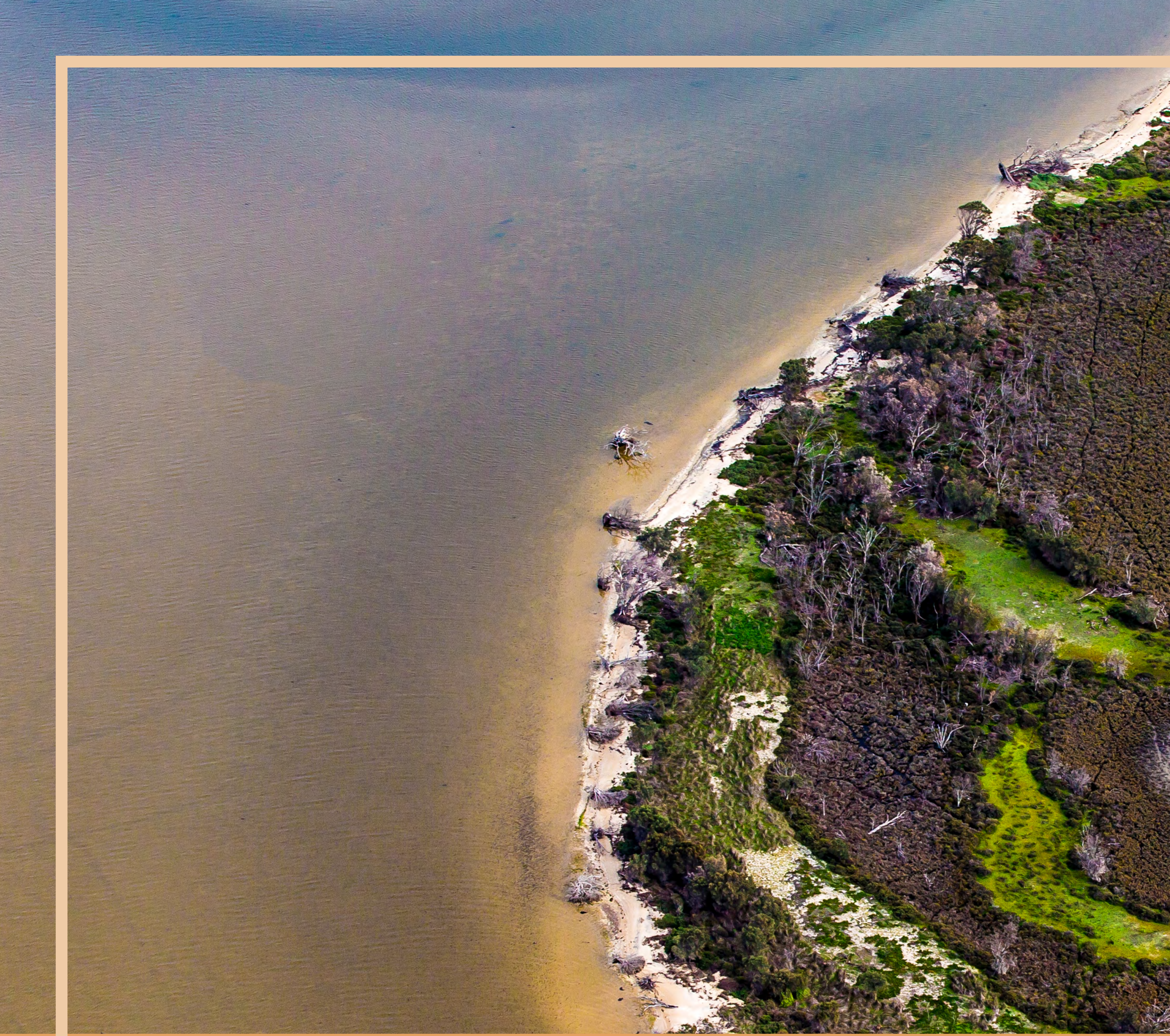
Figure 35: Stylised conceptual model of Lake McLarty at the time of listing, showing the interactions between components, processes and services



1. Water sources include direct rainfall, groundwater from surficial and deeper aquifers as well as nutrient rich water from the Mealup Main Drain. This leads to seasonal inundation of the wetland in spring and summer.
2. As water levels recede over summer, productivity in exposed mudflats provides foraging areas for waders and allows for the growth of emergent reeds such as Typha.
3. When inundated, the site provides habitat for different feeding guilds of waterbirds.
4. Exposure of acid sulphate soils leads to decreases in pH upon rewetting, leading to the release of phosphorus from the sediments.

Figure 36: Stylised conceptual model of Lake Mealup at the time of listing, showing the interactions between components, processes and services

Fish and Invertebrates



4 LIMITS OF ACCEPTABLE CHANGE

4.1 Process for setting Limits of Acceptable Change

Limits of Acceptable Change (LAC) are defined as the variation that is considered acceptable in a particular component or process, without indicating change in ecological character that may lead to a reduction or loss of the criteria for which the site was Ramsar listed (modified from definition adopted by Phillips 2006).

Natural variability needs to be considered when setting LAC, but this is rarely a simple process. For example, change from natural variability can occur in a number of ways, not just exceeding maximum and minimum values (Figure 37). The pattern of change and degree of change should both be considered when setting limits that indicate a distinct shift from natural variability. This could include 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 (Hale and Butcher 2008; Butcher 2011; Butcher and Hale 2011). In reality however, patterns of natural variability are rarely fully understood and even with long time series data it can be difficult to resolve whether shifts in patterns of variability are natural cycles occurring over longer time scales than the data available, natural shifts between different stable states, or change in response to some external pressure (Ramsar Convention Secretariat 2011). Defining LAC is therefore rarely a purely statistical procedure, and commonly they are arrived at by consensus of experts in a workshop, informed by available data sets and current statistical interpretation.

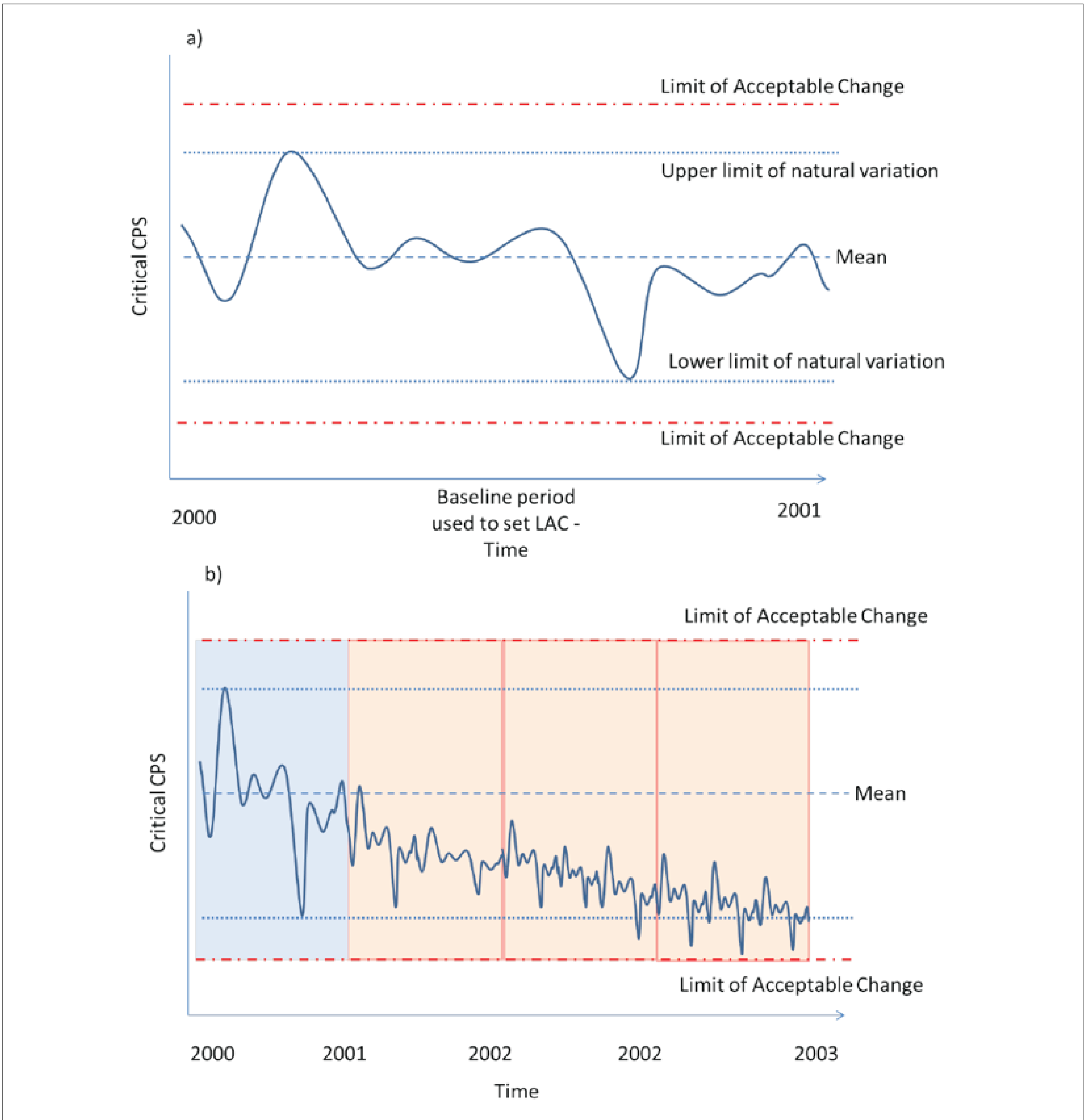


Figure 37: Issue of setting LAC only on upper and lower limit of natural variability. A) represents upper and lower limit of natural variation and b) which shows a changed temporal pattern as well as a declining trend, which would not be detected as it would not trigger the LAC.

The following should be considered when developing and assessing LAC:

- Limits of Acceptable Change are a tool by which ecological change can be measured. However, Ecological Character Descriptions are not management plans and Limits of Acceptable Change do not constitute a management regime for the Ramsar site.
- Exceeding or not meeting Limits of Acceptable Change does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting Limits of Acceptable Change may require investigation to determine whether there has been a change in ecological character.

- While the best available information has been used to prepare this Ecological Character Description and define Limits of Acceptable Change for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The Limits of Acceptable Change may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.
- Users should exercise their own skill and care with respect to their use of the information in this Ecological Character Description and carefully evaluate the suitability of the information for their own purposes.
- Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

4.2 Limits of Acceptable Change (LAC) for the Peel-Yalgorup Ramsar Site

The original LAC in the 2007 ECD for the Peel-Yalgorup Ramsar Site (Hale and Butcher 2007) were established prior to the development of advice from the Australian Government on LAC and what they should represent. The LAC in Hale and Butcher (2007) were set at levels designed to trigger management action, consistent with the approach to setting national trigger values for water quality under the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000). The new LAC, established here, better reflect the Australian Government's current approach to LAC and should not be considered as a management tool (or aim) but rather as an indication of potential change in character (Department of Sustainability, Environment, Water, Population and Communities 2012).

The original (2007) LAC for waterbirds were derived from small amounts of data and without consideration of the Ramsar concept of "regularly supports" (see Text Box 1). As a consequence, there were LAC in the original ECD for supporting greater than 1 percent of the population of several waterbird species on the basis of isolated count data. For example, there is insufficient evidence to suggest that the site regularly supported greater than 1 percent of the population of musk duck, Australasian shoveler, Eurasian coot or grey teal. In addition, the LAC established in 2007 for individual wetlands within the system have been determined to better represent management triggers due to the ability of waterbirds to utilise habitat values from multiple wetlands and not meeting population counts in one particular wetland does not indicate that waterbirds are not using other wetlands within the Peel-Yalgorup system. The LAC provided in Table 24 are based on more robust data, collected over multiple years.

The level of confidence for each LAC is also provided, and has been assigned as follows:

- High – Quantitative site-specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measurable
- Medium – Some site-specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measurable
- Low – no site-specific data or reliable evidence from the scientific literature or expert opinion, LAC may not be objectively measurable and/or the importance of the indicator to the ecological character of the site is unknown

Table 24: Limits of Acceptable Change for the Peel-Yalgorup Ramsar Site

CRITICAL COMPONENTS, PROCESSES AND SERVICES	BASELINE / SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE	CONFIDENCE
Vegetation: seagrass and macroalgae	In 2009, macroalgae and seagrass covered the majority of the Peel-Harvey Estuary. There was an estimated 8500 tonnes of macroalgae comprising 14 species and 3700 tonnes of seagrass comprising thee species (Pedretti et al. 2011). Seagrass can be highly variable over short timeframes (Wood and Lavery 2000), so a LAC that accounts for longer cycles is proposed.	Seagrass biomass will not decline below 1500 tonnes for a period of greater than 10 continuous years. Benthic habitat will be comprised of a habitat mosaic of both seagrass and macroalgae with no group comprising more than 80 percent of total biomass for more than three continuous years.	Medium
Vegetation: saltmarsh	The extent of saltmarsh in the Ramsar site has been established in 2007 (Hale and Kobryn 2009) at 684 hectares: • Peel-Harvey Estuary – 287 ha • Yalgorup Lakes – 387 ha • Lakes Mealup and McLarty – 8 ha As natural variability of saltmarsh extent is low and the recovery of saltmarsh from disturbance is known to be slow (Saintilan 2009). The LAC has been set based on a moderate loss across the Ramsar site. Also, given the very small extent of saltmarsh around Lakes McLarty and Mealup, a LAC for change in extent was not deemed warranted.	Extent of saltmarsh will not decline by more than 20 percent from the 2007 benchmark. That is, saltmarsh will not decline below: • Peel-Harvey Estuary – 230 ha • Yalgorup Lakes – 300 ha	High
Vegetation: wetland trees	The extent of wetland trees (paperbark, swamp gum and swamp sheoak) in the Ramsar site has been established in 2007 (Hale and Kobryn 2009) at 646 hectares: • Peel-Harvey Estuary – 80 ha • Yalgorup Lakes – 500 ha • Lake Mealup – 30 ha • McLarty – 30 ha Paperbark communities in the Yalgorup Lakes are dominated by saltwater paperbark, while those at Lake Mealup and McLarty are dominated by freshwater paperbark. Maintaining the two communities in the Ramsar site is critical to ecological character. Wetland tree communities in the Peel-Harvey Estuary are highly variable over small spatial scales and include a variety of species including mohan and swamp sheoak.	Extent of wetland trees will not decline by more than 20 percent from the 2007 benchmark. That is, paperbark extent will not decline below: • Peel-Harvey Estuary – 65 ha • Yalgorup Lakes – 400 ha • Lake McLarty – 24 ha • Lake Mealup – 24 ha The paperbark community at the Yalgorup Lakes will be dominated by saltwater paperbark *(Melaleuca cuticularis)* and the paperbark community at Lakes McLarty and Mealup will continue to be dominated by freshwater paperbark *(M. rhaphiophylla)*	High

CRITICAL COMPONENTS, PROCESSES AND SERVICES	BASELINE / SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE	CONFIDENCE
Vegetation: freshwater emergent	At the time of listing, Lakes McLarty and Mealup were characterised by extensive emergent wetland vegetation (Jaensch et al. 1988). In 2009, the mapped extent of freshwater emergent vegetation was 40 hectares at Lake McLarty and 51 hectares at Lake Mealup (Hale and Kobryn 2009). The emergent vegetation at both wetlands had been increasing since listing and was restricting habitat for a variety of waterbirds, particularly shorebirds. As such, the LAC has been established based on maintaining habitat mosaics important for supporting waterbirds and other fauna.	Freshwater emergent macrophyte vegetation will be present within Lakes McLarty and/or Mealup in no less than two in every 10 year period.	Low
Thrombolites	At the time of listing, Lake Clifton supported up to four square kilometres (400 ha) of thrombolites (Luu et al. 2004) and the "reef" extended for 6.5 kilometres along the north-eastern shore of the lake (Moore 1993). Given that it is not clear whether the estimate of extent refers to active thrombolites or if this is a continuous area, the LAC has been based on the extent of the active thrombolite "reef" that has been well documented and studied (e.g. Moore 1987, 1993, Moore and Burne 1994).	No less than 50 percent of the thrombolites within the "reef" along the north eastern shoreline of Lake Clifton to be active (i.e. accreting and growing).	Medium
Marine invertebrates	Peel-Harvey Estuary supports three commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. Estimates from commercial catch data are for 40 – 100 tonnes of blue swimmer crab annually; with a CPUE of 1 kg/trap (Johnston et al. 2014). CPUE is a measure of population and not related to commercial fishing total catch. In the absence of quantitative data on other marine invertebrates blue swimmer crab CPUE is used as an indicator.	The Peel-Harvey Estuary will continue to support three species of commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. Blue swimmer crab abundance will not fall below limit as set by harvest strategy, for a continuous period of 5 years or more.	Medium
Fish	Over 80 species of native fish have been recorded in the Peel-Harvey Estuary. Mean densities (2005 to 2007) of 360 fish per 100 square metres, but variability is too high to establish a quantitative LAC with the standard deviation more than three times the mean (Valesini et al. 2009). The fish within the Peel-Harvey Estuary represent a broad range of life history strategies (Valesini et al. 2009, Potter et al. 2016).	Native fish within the Peel-Harvey Estuary will represent each of the following life history strategies: estuarine, marine-estuarine opportunists, marine stragglers, diadromous and obligate freshwater species.	Medium

CRITICAL COMPONENTS, PROCESSES AND SERVICES	BASELINE / SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE	CONFIDENCE
Waterbird abundance	Average annual maximum counts from 1995 to 2010, are as follows (mean ± standard deviation): • Total waterbirds – 45,000 ± 18,000 • Migratory shorebirds – 11,000 ± 6000 • Australasian shorebirds – 11000 ± 8500 • Ducks – 15,000 ± 7500 • Fish eating species – 3000 ± 3000 • Herbivores – 4000 ± 2500 There is a high degree of variability in waterbird abundance as evidenced by the high standard deviations in the list above. To account for this variability, a sustained change of approximately 50 percent has been set as the LAC. The group “large-bodied waders” is small in number and high in variability and so has not been included in the LAC. In addition, waterbird counts rarely include wetland birds of prey and passerine reed inhabiting birds in a consistent manner, making the data difficult to interpret. These species have therefore been included in terms of total waterbird abundance and in the LAC for diversity.	Abundance of waterbirds across the entire site will not decline below the following (calculated as a rolling five-year average of maximum annual count): • Total waterbirds – 22,000 • Migratory shorebirds – 5500 • Australasian shorebirds – 5500 • Ducks – 7500 • Fish eating species – 1500 • Herbivores – 2000	Medium
Waterbird diversity	A total of 104 species of wetland dependent bird have been recorded at the site (excluding vagrant observations). The LAC for species richness has also been established for functional groups based on the following averages (1995 to 2010): • Total waterbirds – 64 ± 11 • Migratory shorebirds – 18 ± 4 • Australasian shorebirds – 7 ± 1 • Ducks – 11 ± 2 • Fish eating species – 11 ± 3 • Herbivores – 4 ± 1 • Large bodied waders – 8 ± 2 • Other – 5 ± 2	Diversity of waterbirds will not decline below the following (calculated as a rolling five-year average of number of species): • Total waterbirds – 48 • Migratory shorebirds – 13 • Australasian shorebirds – 5 • Ducks – 8 • Fish eating species – 8 • Herbivores – 3 • Large bodied waders – 6 • Other – 4	Medium
Waterbird breeding	Evidence of breeding (juveniles, nests, eggs) has been recorded for 34 species of wetland dependent bird in the Peel-Yalgorup Ramsar site. Breeding records, however, are insufficient to establish a quantitative LAC. LAC has been established on the continued breeding of important species.	The following species will be recorded breeding no less than one in every two years: Australian darter, Australian fairy tern, Australian pelican, black swan, hooded plover, red-capped plover, little pied cormorant, little black cormorant.	Low

CRITICAL COMPONENTS, PROCESSES AND SERVICES	BASELINE / SUPPORTING EVIDENCE	LIMIT OF ACCEPTABLE CHANGE	CONFIDENCE
Marine mammals	The Peel-Harvey Estuary supports a resident population of bottle-nose dolphins. The species breeds annually within the Estuary, with several calves born annually. LAC is based on advice from experts.	Bottle-nose dolphin calves to be observed within the Peel-Harvey Estuary no less than once every year.	High
Diversity of wetland types	The Peel-Yalgorup Ramsar Site supports seven wetland types using the Ramsar wetland classification system: • F – estuarine waters in the Peel-Harvey Estuary • B – marine subtidal beds represented by seagrass in the Peel-Harvey Estuary • Q – permanent saline/brackish/alkaline lake represented by all 10 lakes in the Yalgorup system. • H – intertidal marshes represented by saltmarsh • P – seasonal /intermittent freshwater lakes at Lake McLarty and Mealup • Xf – freshwater, tree-dominated wetlands represented by paperbark communities • G – intertidal mud, sand flats in the Peel-Harvey Estuary • R – seasonal / intermittent saline/brackish lakes represented by Duck Pond, Swan Pond and Carrabungup.	No loss of wetland type with the following Ramsar wetland types represented within the Ramsar site: • F – estuarine waters • B – marine subtidal beds • Q – permanent saline/brackish/alkaline lake • H – intertidal marshes • P – seasonal /intermittent freshwater lakes • Xf – freshwater, tree-dominated wetlands • G – intertidal mud, sand flats • R – seasonal / intermittent saline/brackish lakes	Medium
Threatened ecological community: Clay Pans of the Swan Coastal Plain	This critical service is covered by the LAC for diversity of wetland types.	See LAC for diversity of wetland types.	
Physical habitat for waterbirds	This critical service is covered by the LAC for waterbirds.	See LAC for waterbird abundance, diversity and breeding.	
Threatened species: waterbirds	The site regularly supports seven threatened waterbird species. Counts of bar-tailed godwit, curlew sandpiper, eastern curlew, great knot, greater sand plover and red knot indicate moderate to low, but persistent numbers within the site. LAC is based on continued presence for these species. At the time of listing, the site regularly supported 5 percent of the population of the Australian fairy tern and a quantitative LAC based on population estimates is established for this species.	Bar-tailed godwit, curlew sandpiper, eastern curlew, great knot, greater sand plover and red knot recorded within the site in three out of five seasons. Abundance of Australian fairy tern will not decline below 2.5 percent of the population (calculated as a rolling five year average of maximum annual count; percentages calculated based on the latest Wetlands International Waterbird Population Estimates).	Moderate
Ecological connectivity	This is related to the supporting of migratory birds and a range of fish life history strategies and covered by the LAC for waterbirds and fish	See LAC for fish and waterbird abundance, diversity and breeding.	Medium

5 THREATS TO ECOLOGICAL CHARACTER

Wetlands are complex systems and an understanding of components and processes and the interactions or linkages between them is necessary to describe ecological character. Similarly, threats to ecological character need to be described not just in terms of their potential direct effects, but also in terms of their interactions. One mechanism for exploring these relationships is the use of stressor models (Gross 2003); the use of stressor models in ecological character descriptions has been suggested by a number of authors to describe ecological character (Hale and Butcher 2008b) and to aid in the determination of limits of acceptable change (Davis and Brock 2008).

Stressors are defined as (Barrett et al. 1976):

> *"physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level"*

When assessing or managing threats, it is useful to separate the threatening process or activity from the stressor(s) through which the threats affect critical components, processes and services that underpin a site's ecological character. In this manner, the cause(s) of impacts to natural assets are made clear, and decisions can then be made as to whether a response is required to address the threat or mitigate its impact.

A number of potential and actual threats may impact on the ecological character of the Ramsar site, as illustrated in Figure 38.

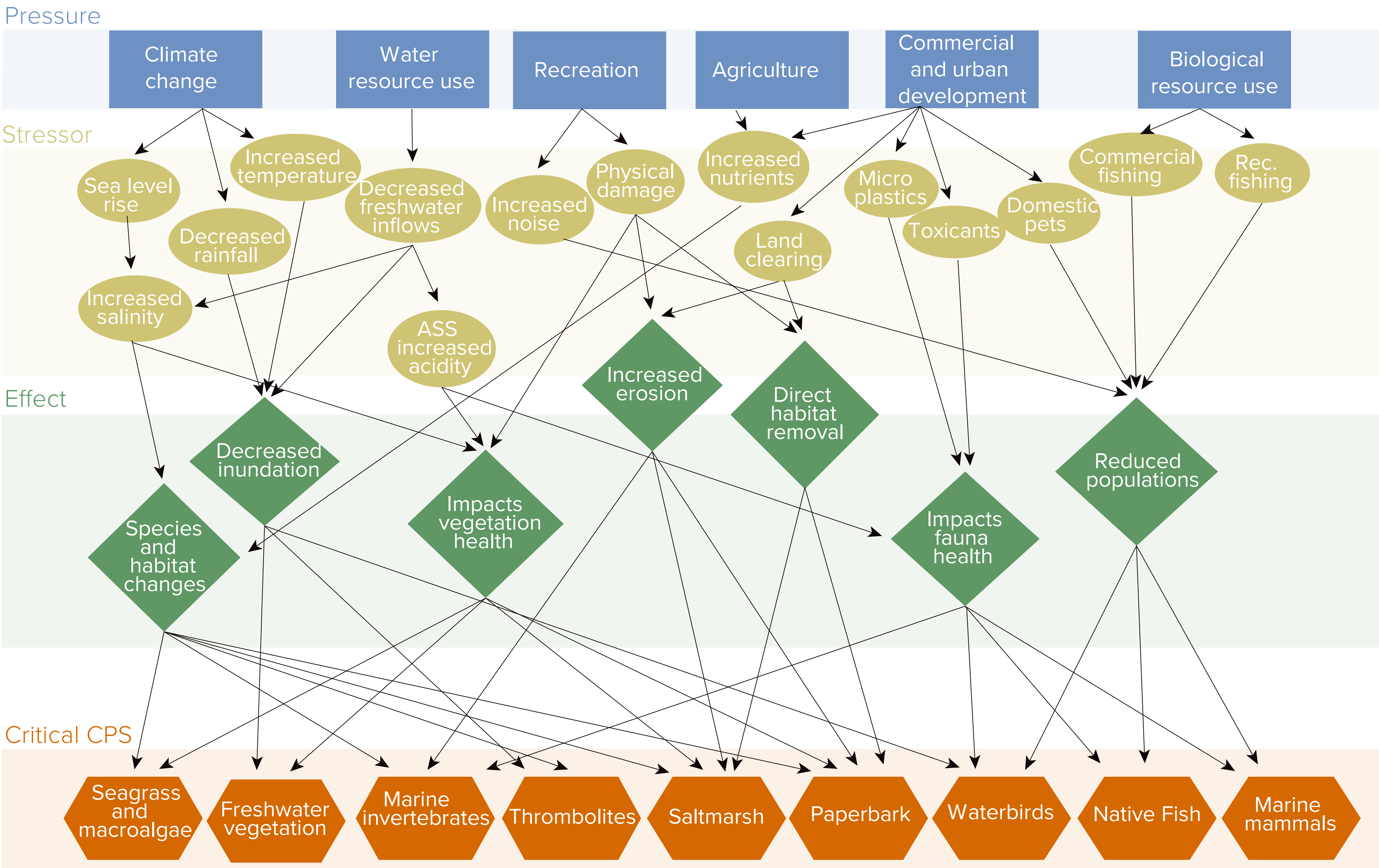


Figure 38: Simple stressor model for the Peel-Yalgorup Ramsar Site

5.1 Commercial and urban development

A large proportion of the Peel-Yalgorup Ramsar site is located within the City of Mandurah, which has experienced rapid population growth in the past two decades. The City of Mandurah has a population of just over 80,000 people (Australian Bureau of Statistics 2019), which is around a 3.5 times increase since the time of listing, when the population was around 23,000[23]. 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. A number of potential threats associated with increased development around the wetlands could impact on the 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 accumulation of mono-sulfidic black ooze (in navigation channels, marinas ad residential canal developments)
- Increased recreational pressure on the wetland sites
- Predation by domestic species (pets)

Clearing

There are no specific statistics available for clearing of native vegetation for residential development in the Peel Region. In the catchment over 75 percent of native vegetation has been cleared (Ruprecht and George 1993). While figures for vegetation clearing for urban development in the region are not available, the increase in population and built environment since the time of listing has resulted in the removal of deep-rooted vegetation. 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. Eco Logical Australia (2015) suggests that there have been instances of unlawful clearing of riparian vegetation within nature reserves surrounding the estuary by adjacent private landowners to improve the view from their property as well as by illegal grazing in nature reserves.

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 kilograms per hectare per year, which is more than twice that for agricultural landuses. More recent studies have suggested that the large areas of urban development adjacent to the Peel-Harvey Estuary may be contributing significant nutrient loads to the estuary (Ruibal-Conti 2014).

There is little information on the non-nutrient contaminant loads entering the system or the loads that could be expected from urban run-off, representing a significant knowledge gap.. For example, there is evidence of bioaccumulation of mercury through the food chain, with Caspian terns that feed in the waters of the Peel-Harvey Estuary having elevated concentrations of mercury in tail feathers (Dunlop and McNeill 2017), however both the source of the mercury and its accumulation and progression through the food chain have not been determined.

In addition, the prevalence of micro-plastics (plastic particles smaller than 5 millimetres in dimeter) in waterways receiving urban and commercial stormwater is a newly emerging field of science. Although there is no data from the Peel-Harvey Estuary, studies from estuaries in Victoria that are adjacent to urban and commercial centres have indicated that concentrations of microplastics from stormwater and litter can be high (Blake and Charko 2014). There is a large body of evidence from studies overseas on the potential effects of microplastics on the marine environment. This includes effects on invertebrates (Wright et al. 2013), fish (Lusher et al. 2013), seabirds (Sutherland et al. 2012) and marine mammals. Impact pathways include release and bioaccumulation of toxicants from ingested micro-plastics in the gut (Eriksson and Burton 2003) and blocking of the digestive tract leading to starvation (Gregory 2009).

Acid Sulfate Soils and mono-sulfidic black ooze

Acid sulfate materials including Acid sulfate Soils (ASS) and Monosulfidic Black Oozes (MBOs) are common in coastal areas of Australia (Sammut and Lines-Kelly 2000). ASS are benign unless disturbed or exposed, for example through the drying and cracking of lake beds. MBOs form and accumulate in channelised areas and

23 Data from the 1991 Census, Australian Bureau of Statistics.

depressions of the Peel-Harvey Estuary under anerobic conditions. In the past, dredging in the Peel Inlet and disposal of the dredge spoil has disturbed these MBOs and ASS resulting in short term deoxygenation of the water column and legacy issues of acid sulfate drainage around the on-land spoil disposal site at Goolongup Island at the mouth of the Murray River (Sullivan et al. 2006). Lake Mealup experienced low pH levels due to the annual drying and then re-wetting of the lakebed.

Exposure of 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 sulfuric acid into the water column. The carbonate concentrations in seawater should be sufficient to buffer this effect (Sullivan et al. 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).

Increased recreational pressure on the wetland sites

Migratory shorebirds arrive in the Peel-Yalgorup after an 11,00 kilometres flight and having lost up to 75 percent of their body weight. It is important that they can rest and feed undisturbed to replenish energy stores for the return flight. Whenever the shorebirds are disturbed and take flight, they use energy and lose feeding time.

Predation

Domestic pets are known to both disturb and prey on wildlife both in the Ramsar site and elsewhere. A recent example of the potentially devastating impact on ecological character by domestic animals was the predation of Australian fairy tern adults, chicks and eggs by a domesticated (de-sexed) cat in Mandurah in 2019. The single cat was responsible for the deaths of multiple individuals of the threatened species and ultimately led to the abandonment of all 11 nests by the colony (Greenwell et al. 2019).

5.2 Climate change

In general, the climate in south-western Australia has exhibited the following trends (CSIRO and Bureau of Meteorology 2017):

- a 30 percent increase in carbon dioxide concentrations since 1956 (316 to 408 parts per million (ppm))
- an increase in mean surface temperature of around 1 degree Celsius since 1910
- an increase in the duration, frequency and intensity of extreme heat events
- a decline in winter rainfall in south western Australia of around 16 percent since 1970, and
- an increase in sea levels exacerbated by high tides and storm surges

The future climate in the Peel region is predicted to continue to be hotter, drier and with more frequent and intense storms. Of note is the predicted decline (by 2030) of winter and spring rainfall by up to 15 percent (https://www.climatechangeinaustralia.gov.au/en/climate-projections). It is estimated that stream flows into the Peel- Harvey Estuary have already declined by up to 50 percent (Silberstein et al. 2012), with predicted future declines as a result of declining winter and spring rainfall.

In terms of sea level rise, there is clear evidence of realised change and projections for continued change into the distant future. The most recent analyses of mean sea level from satellite data extends back to 1992 and indicates that mean sea level has increased at a rate of 3.4 millimetres per year on average since that time (Figure 39). Data for the south west of western Australia are less certain, but since 1970 are estimated at 2.6 mm / year (Valisini et al. 2019), which equates to nearly an eight centimetre rise in sea levels since the site was listed in 1990.

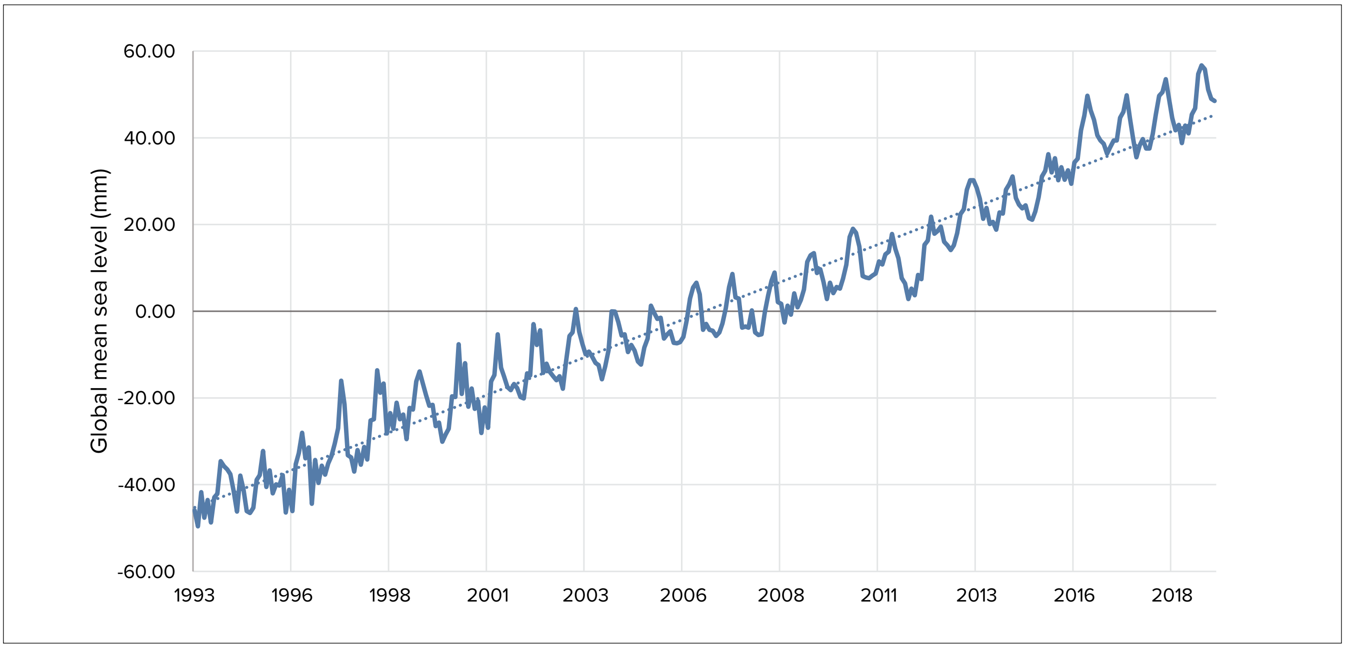


Figure 39: Mean global sea level since 1992 with seasonal signal (blue) and trend line (red). (https://www.cmar.csiro.au/sealevel/sl_hist_last_decades.html)

The combined effects of reduced river inflows and increasing sea levels will be an increase in marine water incursion into the Peel-Harvey Estuary. This is likely to result in a further increase in salinity and extended duration of hypersaline conditions. Modelling of future condition in the Peel-Harvey Estuary suggest that winter salinity could be up to 9 ppt higher and residence time increase by up to 25 days by 2058 (Valesini et al. 2019; Figure 40). Sea-level rise also increases foreshore erosion and causes inundation of tidal mud flats.

Increased temperatures and decreased rainfall will affect inundation and increased salinity in the Lakes of the Yalgorup system as well as Lakes McLarty and Mealup. At Lake McLarty, the effects of prolonged drying have been documented, with an increase in encroachment of terrestrial vegetation and a loss of shorebird foraging habitat (Craig et al. 2018). In addition, recent assessments have indicated that there is a risk associated with the exposure of ASS associated with the sediments at Lake McLarty (D'Alessio 2019). At Lake Mealup drying also brings the risk of exposing acid sulfate ASS and in the past, exposure of wetland sediments has led to periods of very low pH (Lake Mealup Preservation Society unpublished data).

5.3 Water resource use

Hydrology is a key driver of wetland ecology and has an effect 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 suspected 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. The system is an estuary and relies on freshwater inflows into the system to maintain ecosystem function and processes such as reproduction.

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. More recent assessments indicate that the system is more dependent on rainfall (re-charging the aquifer) than on abstraction from the surficial freshwater lens that feeds the Lakes systems (Antao 2015). The exact nature of the impact of water resource use on the Yalgorup Lakes remains unknown and is an identified knowledge gap (see section 7).

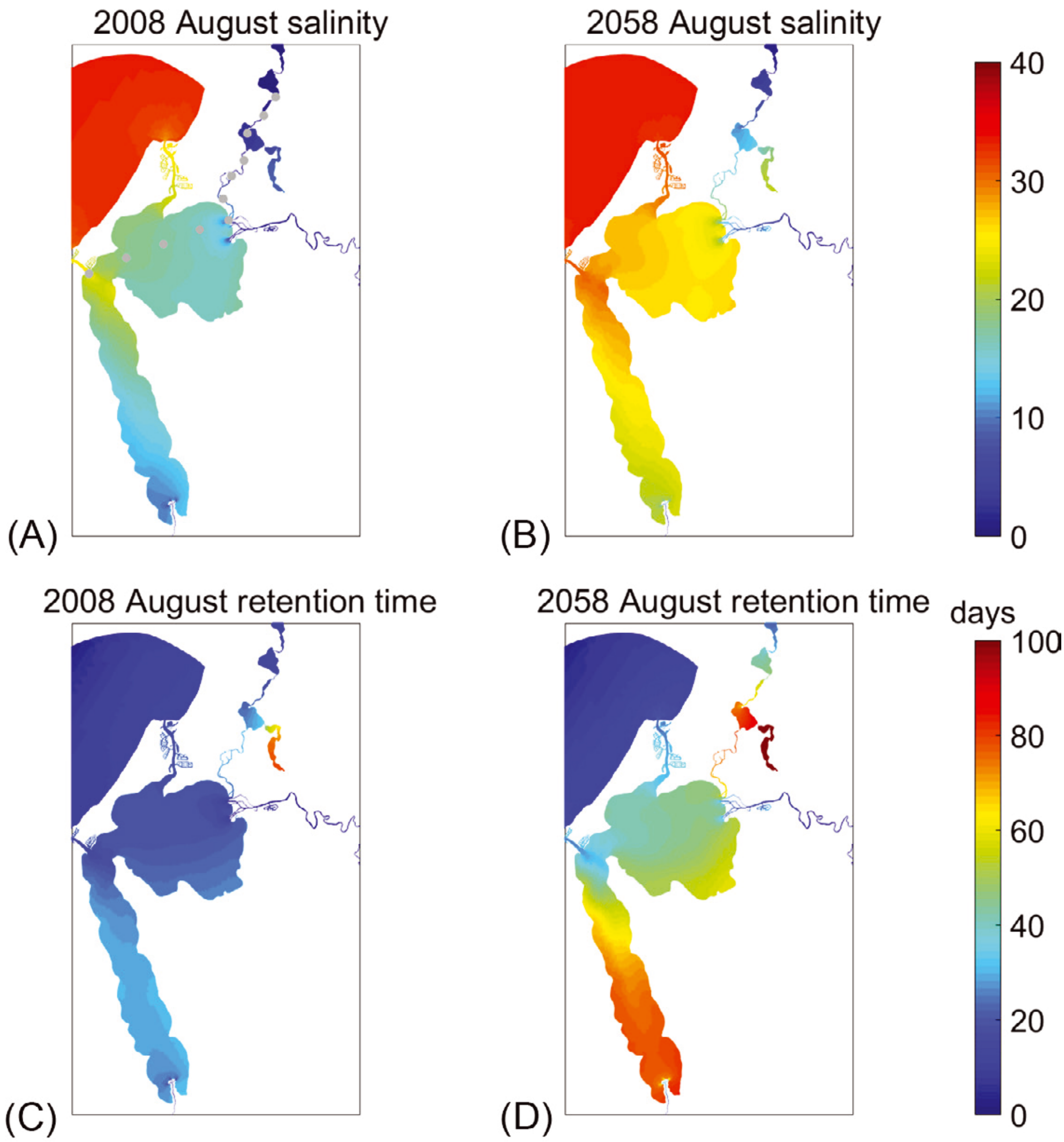


Figure 40: Modelled average salinity (top) and residence time (bottom) from 2008 and 2058 (Valesini et al. 2019b)

5.4 Agriculture

Prior to the construction of the Dawesville Channel, the Peel-Harvey Estuary had suffered the effects of eutrophication largely due to large loads of nutrients entering the system through the rivers from agricultural activities in the highly drained catchment. While there is little evidence of a decline in nutrient loads from the catchment, the system is now effectively flushed through the Dawesville Channel without an accumulation of nutrients in the system (Ruibal-Conti 2014).

5.5 Biological resource use

The Peel-Harvey Estuary supports a commercial fishery and is a popular recreational fishery attracting locals and visitors from elsewhere. The recreational and commercial blue swimmer crab and commercial sea mullet fishery has been certified as sustainable by the Marine Stewardship Council, suggesting that these fisheries do not pose a significant threat to the ecological character of the Ramsar site. There is anecdotal evidence, however that compliance with sustainable takes is an issue for recreational fishing in the Peel-Harvey Estuary. This may be a serious threat to fish populations in the system, especially the blue swimmer crab.

5.6 Recreation

Recreational activities within the wetlands include bird watching, fishing, crabbing, bushwalking, camping, horse riding, boating, jet skiing, water skiing and swimming; illegal off-road activities include motorbike riding and four-wheel driving. 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 major impacts are erosion of the shoreline due to boat wash, and disturbance of the shorelines, fringing vegetation and waterbirds due to illegal recreational vehicle use, trampling of the thrombolites by foot or recreational vehicles 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 increased the problem of shoreline erosion and the resulting negative impacts to fringing vegetation will affect the quality of habitat available for fauna which rely on the fringing vegetation as habitat.

In addition, clay pans surrounding the estuary are favoured locations for illegal four-wheel driving, motor cycles and quad bikes (Eco Logical Australia 2015). This is leading to degradation of wetland habitats and increasing erosion.

Disturbance of waterbirds

Increased noise from shore based or nearshore boating activities (including jet skis, kite surfing, kayaking and other water based activities), fishers walking and wading through shorebirds to scoop for crabs and the presence of domestic dogs on beaches have all been identified as high risks to waterbirds in the Ramsar site. There is growing evidence that disturbance of waterbirds by human activities (walking, boating, vehicles, dogs) can have significant negative impacts on both feeding behaviour and habitat use. A database collated from a large number of scientific studies of flight initiation distances (FID, the distance between the activity and the bird taking flight) indicates that nesting birds can be disturbed by human activities at very short distances (e.g. mean FID for nesting pelicans was only 21 metres and for ducks 32 metres from pedestrians) (Livezey et al. 2016). FIDs for non-nesting species were typically greater (e.g. 60 metres for ducks from pedestrians). Birds are disturbed at closer distances by dogs and watercraft as opposed to pedestrians, but interestingly, non-motorised watercraft such as canoes and paddleboards had equal or smaller FIDs compared to motorised vessels (Glover et al. 2015, Livezey et al. 2016). The consequences for individuals and populations can be significant, with decreased time spent feeding, increased energy spent in flying away from disturbances, nest abandonment and ultimately population declines all cited as potential effects (Glover et al. 2011, Martín et al. 2015).

5.7 Summary of threats

Although a risk assessment is beyond the scope of an ECD, the DEWHA (2008) framework states that an indication of the impacts of threats to ecological character, likelihood and timing of threats should be included. The major threats considered in the previous sections have been summarised for the Ramsar site in accordance with the (DEWHA 2008) framework Table 25.

Table 25: Summary of threats to the Ramsar site

THREAT OR POTENTIAL THREAT	POTENTIAL IMPACTS	LIKELIHOOD[1]	TIMING[1]
Commercial and urban development	• Physical habitat loss • Disturbance of ASS • Increased drainage	Certain	Immediate -Long term
Climate change	• Altered hydrological regimes • Reduced water depth in lakes • Impacts on flora and fauna (e.g. breeding events, vegetation distribution) • Impacts on habitat condition and availability • Increased erosion and habitat destruction • Exposure of ASS	Certain	Immediate -Long term
Water resource use	• Altered hydrological regimes (timing, magnitude and frequency of flows) • Changes to water depth • Increased salinity • Exposure of ASS • Impacts on flora and fauna	Certain	Immediate -Long term
Agriculture	• Nutrient enrichment • Reduced habitat quality	Low	Immediate -Long term
Biological resource use	• Reduced blue swimmer crab populations, reduced food resources, reduced waterbird abundance	Low	Immediate -Long term
Recreation: Human intrusion and disturbance	• Disturbance of waterbirds • Damage to flora and waterbird habitat	Certain	Immediate -Long term

[1] For Likelihood, Certain is defined as known to occur at the site or has occurred in the past; Moderate is defined as not known from the site but occurs at similar sites; Low is defined as theoretically possible, but not recorded at this or similar sites. For Timing, Immediate is 1-5 years, Medium is 5-10 years, Long term is 10+ years.

Vegetation

6 CHANGES SINCE DESIGNATION

The most significant change to the Peel-Yalgorup Ramsar Site since it's designation in 1990, was the construction and opening of the Dawesville Channel. This had such a profound (and positive) impact on the Peel-Harvey Estuary, that a new baseline, post Dawesville Channel, has been established for the Peel-Harvey Estuary in the ECD (2007).

There have, however, been several other changes in the system since listing, and in the Peel-Harvey Estuary in the past decade. This includes altered hydrology, increasing salinity and associated biological responses to these physical changes. These are described below, together with a clear indication if the change has resulted in an exceedence of a LAC (Table 26). Relative confidence levels (based on the extent and type of data available have also been provided based on the following scale:

- High confidence – where there is sufficient data for statistical comparisons;
- Medium confidence – where there is insufficient data for statistical analysis, but sufficient data to allow for considered expert opinion; and
- Low confidence – where there is little or no data, but judgements have been made on observations or opinion.

Table 26: Assessment of current condition against Limits of Acceptable Change

CRITICAL COMPONENTS, PROCESSES AND SERVICES	LIMIT OF ACCEPTABLE CHANGE	2019 ASSESSMENT	CONFIDENCE
Vegetation: seagrass and macroalgae	Seagrass biomass will not decline below 1500 tonnes for a period of greater than 10 continuous years. Benthic habitat will be comprised of a habitat mosaic of both seagrass and macroalgae with no group comprising more than 80 percent of total biomass for more than three continuous years.	Assessments in 2017 and 2018 indicate that seagrass biomass has increased substantially around the estuary since 2009. In spring 2017 seagrass comprised 60% of the total biomass across the Peel-Harvey Estuary, with green macroalgae comprising a further 27% and 3% of other macroalgal species. All three species of seagrass remain, with Ruppia sp. the dominant species (Valesini et al. 2019a). **LAC is met**	High
egetation: saltmarsh	Extent of saltmarsh will not decline by more than 20 percent from the 2007 benchmark. That is, saltmarsh will not decline below: • Peel-Harvey Estuary – 230 hectares • Yalgorup Lakes – 310 hectares	Hale and Kobryn (2017) mapped 640 hectares of saltmarsh in the Ramsar site, with 272 hectares in the Peel-Harvey Estuary and 362 hectares at the Yalgorup Lakes. **LAC is met**	High
Vegetation: Paperbark	Extent wetland trees will not decline by more than 20 percent from the 2007 benchmark. That is, paperbark extent will not decline below: • Peel-Harvey Estuary – 65 hectares • Yalgorup Lakes – 400 hectares • Lake McLarty – 24 hectares • Lake Mealup – 24 hectares. The paperbark community at the Yalgorup Lakes will be dominated by saltwater paperbark (Melaleuca cuticularis) and the paperbark community at Lakes McLarty and Mealup will continue to be dominated by freshwater paperbark (M. rhaphiophylla).	Hale and Kobryn (2017) mapped 594 hectares of wetland trees (paperbark, swamp gum and swamp sheoak) in the Ramsar site: • Peel-Harvey Estuary – 74 hectares • Yalgorup Lakes – 463 hectares • Lake McLarty – 29 hectares • Lake Mealup – 28 hectares. Dominant species recorded in transects were saltwater paperbark at the Yalgorup Lakes and freshwater paperbark at Lakes McLarty and Mealup. **LAC is met**	High
Vegetation: freshwater emergent	Freshwater emergent macrophyte vegetation will be present within Lakes McLarty and / or Mealup in no less than two in every 10 year period.	In 2017, there was no evidence of freshwater emergent vegetation at Lakes McLarty or Mealup (Hale and Kobryn 2017). The removal of dense stands of Typha from Lake Mealup in 2011 to 2013 was the result of a dedicated management program aimed at improving habitat for waterbirds and restoring ecological character. Re-establishing a more diverse emergent vegetation community is currently being considered. Emergent vegetation was present prior to 2013 and so for at least two of the past 10 years. **LAC is met**	Low

CRITICAL COMPONENTS, PROCESSES AND SERVICES	LIMIT OF ACCEPTABLE CHANGE	2019 ASSESSMENT	CONFIDENCE
Thrombolites	No less than 50 percent of the thrombolites within the “reef” along the north eastern shoreline of Lake Clifton to be active (i.e. accreting and growing).	Assessments in 2014, suggest that the former extent of living Thrombolites at Lake Clifton has decline dramatically (Warden 2016). In the 1990s the thrombolite “reef” extended for six kilometres along the north eastern shoreline of Lake Clifton and by 2014 this had been reduced to just two kilometres (Warden 2016). The proportion of the thrombolites that are active is unknown. **Insufficient data to assess the LAC**	Low
Marine invertebrates	The Peel-Harvey Estuary will continue to support three species of commercially and recreationally important marine invertebrate species: blue swimmer crab, western king prawns, western school prawns. Blue swimmer crab abundance will not fall below the lower limit as set by the Harvest Strategy, for a continuous period of five years or more.	The current harvest strategy sets a CPUE limit of < 0.5 kilograms per trap lift (Department of Fisheries 2015). The most recently available commercial fish data is for the 2016/17 and from 2011/12 to 2016/17 the blue swimmer crab harvest has been between 0.9 and 1.4 kilograms per trap lift (Gaughan and Santoro 2019). No data could be sourced on western king prawns and western school prawns. **LAC is met for blue swimmer crab, insufficient data to assess LAC for prawn species**	High (blue swimmer crab)
Fish	Native fish within the Peel-Harvey Estuary will represent each of the following life history strategies: estuarine, marine-estuarine opportunists, marine stragglers, diadromous and obligate freshwater species.	Despite a decline in the occurrence of species in the freshwater group, fish from all life history strategies were recorded in the system in 2016 to 2018 (Hallett et al. 2019). **LAC is met**	High
Waterbird abundance	Abundance of waterbirds across the entire site will not decline below the following (calculated as a rolling five-year average of maximum annual count): • Total waterbirds – 22,000 • Migratory shorebirds – 5500 • Australasian shorebirds – 5500 • Ducks – 7500 • Fish eating species – 1500 • Herbivores – 2000	Average abundance of waterbirds from the past five years (2015 to 2019) indicates the following (data from Shorebirds2020; Dr M. Craig; Mr. B. Russell; OTS 2016, 2019): • Total waterbirds – 42,000 • Migratory shorebirds – 7100 • Australasian shorebirds – 10,000 • Ducks – 11,000 • Fish eating species – 8000 • Herbivores – 4500 **LAC is met**	High

CRITICAL COMPONENTS, PROCESSES AND SERVICES	LIMIT OF ACCEPTABLE CHANGE	2019 ASSESSMENT	CONFIDENCE
Waterbird diversity	Diversity of waterbirds will not decline below the following (calculated as a rolling five-year average of number of species): • Total waterbirds – 55 • Migratory shorebirds – 15 • Australasian shorebirds – 5 • Ducks – 8 • Fish eating species – 10 • Herbivores – 2 • Large bodied waders – 5 • Other – 2	Average species richness of waterbirds from the past five years (2015-2019) indicates the following (data from Shorebirds2020; Dr M. Craig; Mr. B. Russell; OTS 2016, 2019): • Total waterbirds – 77 • Migratory shorebirds – 39 • Australasian shorebirds – 8 • Ducks – 12 • Fish eating species – 15 • Herbivores – 4 • Large bodied waders – 11 • Other – 6 **LAC is met**	High
Waterbird breeding	The following species will be recorded breeding no less than one in every two years: Australasian darter, Australian fairy tern, Australian pelican, black swan, hooded plover, red-capped plover, little pied cormorant, little black cormorant.	Australian fairy tern have been recorded breeding near Mandurah in 2018 and 2019 (Greenwell et al. 2019). Hooded plover breeding at Yalgorup Lakes continued annually through to 2018, albeit in reduced numbers and red-capped plovers still breed regularly at this location (Bill Russell unpublished). Despite some changes in abundance and location (see section 6.4) little pied and little black cormorants breeding in 2019 at Len Howard Reserve (OTS 2019). Australasian darter has been recorded breeding regularly in Lake Mealup since 2013 (Singor 2018). **LAC is met for most species, but data deficient for Australian pelican**	Medium
Marine mammals	Bottle-nose dolphin calves to be observed within the Peel-Harvey Estuary no less than once every year.	Bottle-nose dolphin calves have been observed in the Peel-Harvey Estuary annually for the past five years (citizen science observations; https://www.mandurahcruises.com.au/mandurahs-dolphins/). **LAC is met**	Medium

<table>
<thead>
<tr><th>CRITICAL COMPONENTS, PROCESSES AND SERVICES</th><th>LIMIT OF ACCEPTABLE CHANGE</th><th>2019 ASSESSMENT</th><th>CONFIDENCE</th></tr>
</thead>
<tbody>
<tr><td>Diversity of wetland types</td><td>No loss of wetland type with the following Ramsar wetland types represented within the Ramsar site:
• F – estuarine waters
• B – marine subtidal beds
• Q – permanent saline/brackish/alkaline lake
• H – intertidal marshes
• P – seasonal /intermittent freshwater lakes
• Xf – freshwater, tree-dominated wetlands
• G – intertidal mud, sand flats
• R – seasonal / intermittent saline/brackish lakes</td><td>Despite the changes to vegetation and hydrology at Lakes McLarty and Mealup (see sections 6.2 and 6.3) and the increase in salinity at the Yalgorup Lakes (see section 6.1), there is no indication that there has been a change to wetland type or a loss of any wetland type from within the Ramsar site.

LAC is met</td><td>Medium</td></tr>
<tr><td>Threatened species: waterbirds</td><td>Bar-tailed godwit, curlew sandpiper, eastern curlew, great knot, greater sand plover and red knot recorded within the site in three out of five seasons.

Abundance of Australian fairy tern will not decline below 2.5 percent of the population (calculated as a rolling five year average of maximum annual count; percentages calculated based on the latest Wetlands International Waterbird Population Estimates).</td><td>Data from 2015 to 2019 indicate presence of the six species (BirdLife Australia) in each of the past five years, with the exception of the greater sand plover, which was not recorded in 2019.

Average annual maximum abundance (2015 to 2019) for the Australian fairy tern was over 10 percent of the population (163 individuals)

LAC is met</td><td>High</td></tr>
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6.1 Lake Clifton water quality and thrombolites

There have been a large number of investigations into water quality changes at Lake Clifton and the potential effects on the listed thrombolite ecological community (Knott et al. 2003, Smith et al. 2010, Burne et al. 2014, Forbes and Vogwill 2016, Gleeson et al. 2016, Warden et al. 2016, among others). There is a general agreement that salinity is increasing, water level is decreasing and that this has had, and is continuing to have, a profound effect on the thrombolites in the lake.

Salinity and water quality data collected by the Department of Biodiversity, Conservation and Attractions clearly confirms that salinity in Lake Clifton has increased and water levels decreased since 1985 (Figure 41). It should be noted that since 2012, the data in Figure 41 are from two samples a year collected in September and November. The seasonal nature of freshwater inflows to the system, means that peak salinity is often reached in late autumn / early winter (Forbes and Vogwill 2016) and salinity as high as 180 ppt was recorded in August 2014 (Warden 2016).

There is also some suggestion of increasing nutrients in the system, but historical data on nutrients were too sparse and uncertainty around this as potential change is high (Smith et al. 2010, Warden 2016).

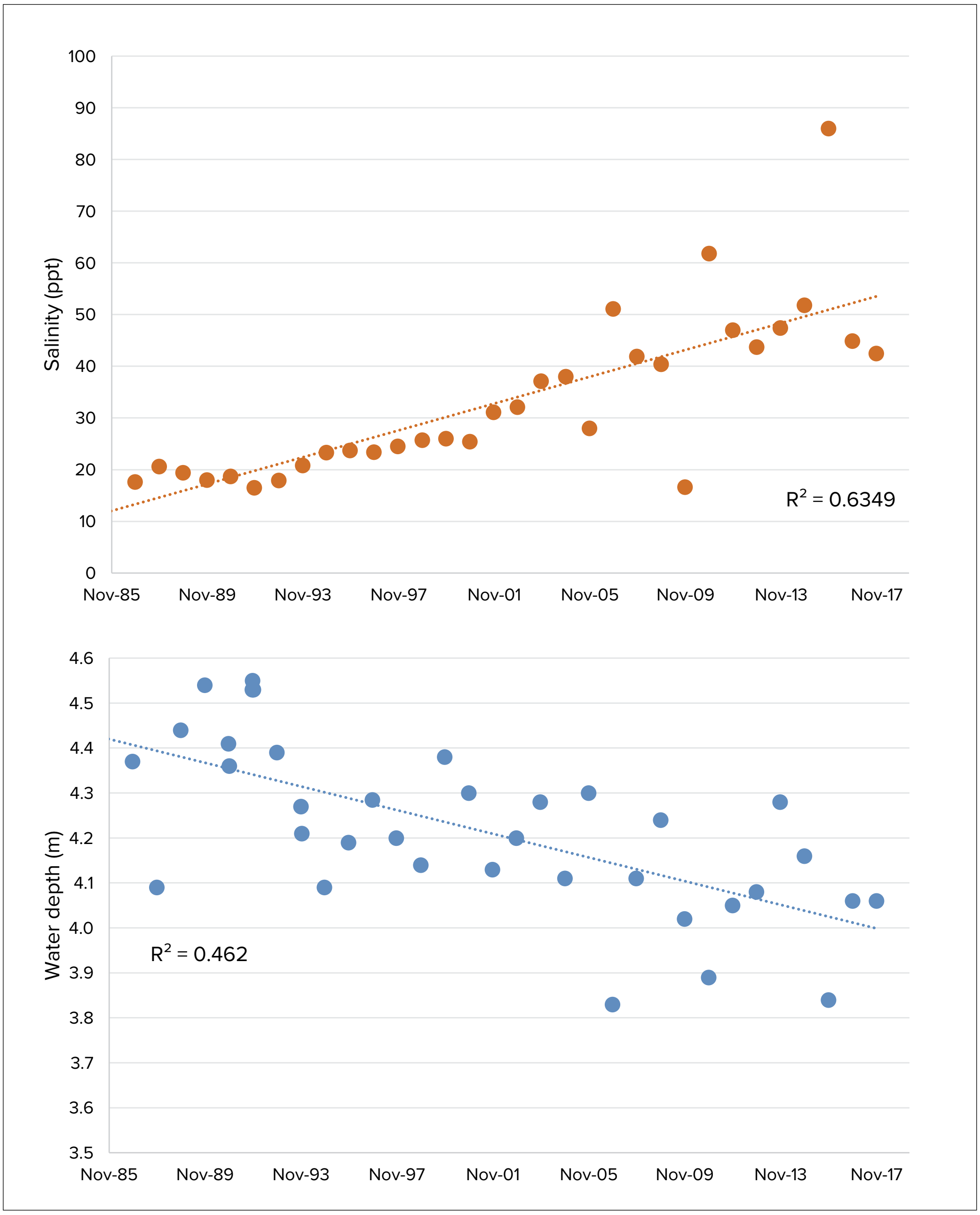


Figure 41: Salinity (top) and water level (bottom) during November at Lake Clifton from 1985 to 2017 (data provided by Jim Lane)

The causes of the changes in Lake Clifton remain uncertain. In particular, decreasing rainfall and increased temperatures are resulting in a reduction in both freshwater inflows to Lake Clifton and sub-surface recharge of the freshwater surficial groundwater aquifer (Knott et al. 2003, Smith et al. 2010, Forbes and Vogwill 2016). It is possible that these changes are also resulting in movement of more saline groundwater into Lake Clifton (Forbes and Vogwill 2016). The effect of groundwater use on the system remains a knowledge gap.

Smith et al. (2010) predicted that the increased salinity would result in a change in the species that comprise the thrombolites. More recent studies have suggested that this may have already occurred with cyanobacteria, the primary driver of thrombolite growth now representing only one to three percent of the microbial community. The microbes of the thrombolites are now dominated by proteobacteria, which may have significant implications for the ongoing health of the threatened ecological community (Gleeson et al. 2016).

There has already been a reduction in the extent of the thrombolites at Lake Clifton and while it is uncertain if the LAC has been exceeded, there is some evidence of a decline in active thrombolites in the lake (Warden 2016). Climate change is undoubtedly a factor and it is likely that this will continue to negatively impact the thrombolites as predictions of hotter and drier conditions are realised.

6.2 Altered hydrology at Lake McLarty

Prior to 2006, Lake McLarty dried for a period of between one and three months annually. Since 2006, however, this period of dry has increased to between four and seven months with a significant reduction in peak water levels (Figure 42). Recent analysis indicates that there has been a "step-change" in rainfall in the area around Lake McLarty, with a reduction of 13 percent from 2000 onwards compared to previous decades (Muirden 2017). Given the small catchment large proportion of the water budget attributed to direct rainfall, this has contributed to increased periods of dry conditions.

The increased duration of dry conditions has resulted in a loss of mudflat habitat as terrestrial plants encroached across the bed of the lake (Figure 43). This in turn has resulted in a loss of valuable feeding habitat for shorebirds and a decline in waterbird numbers at this location (Craig et al. 2018).

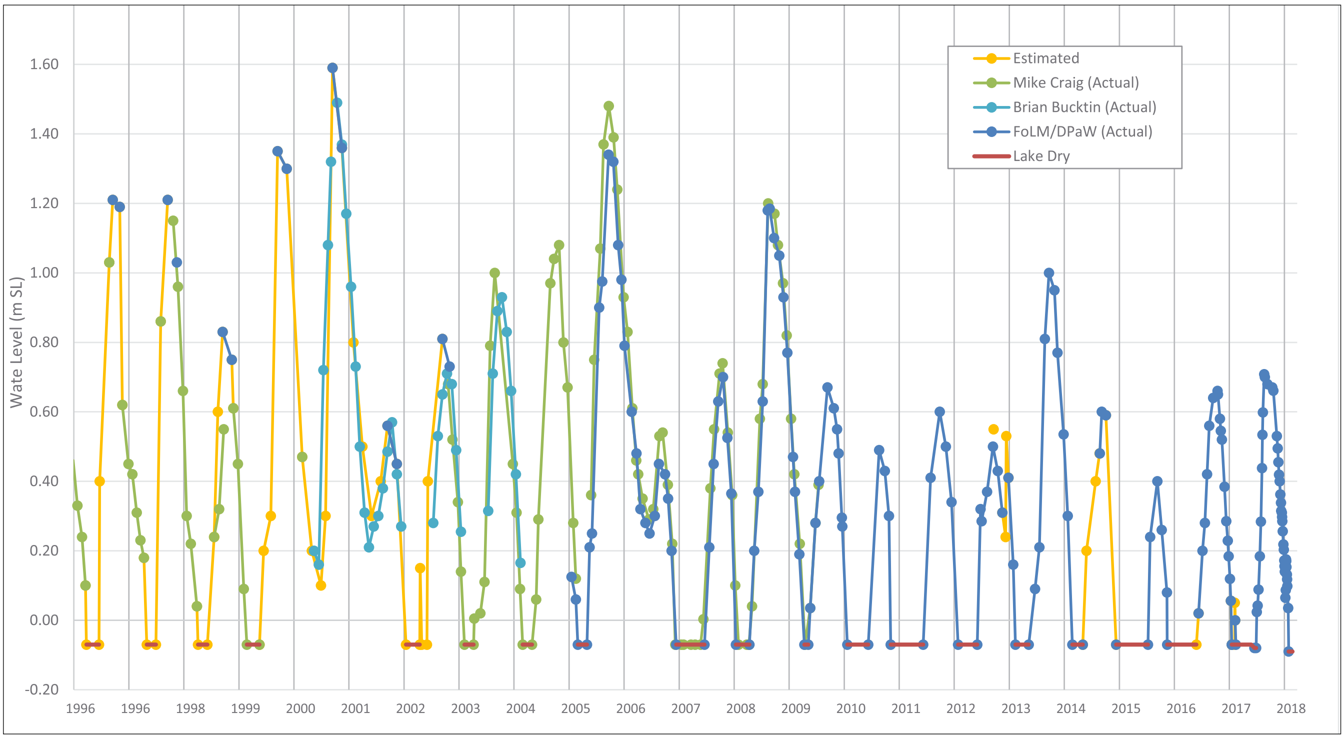


Figure 42: Water levels in Lake McLarty from 1995 to 2017 (Muirden 2017)

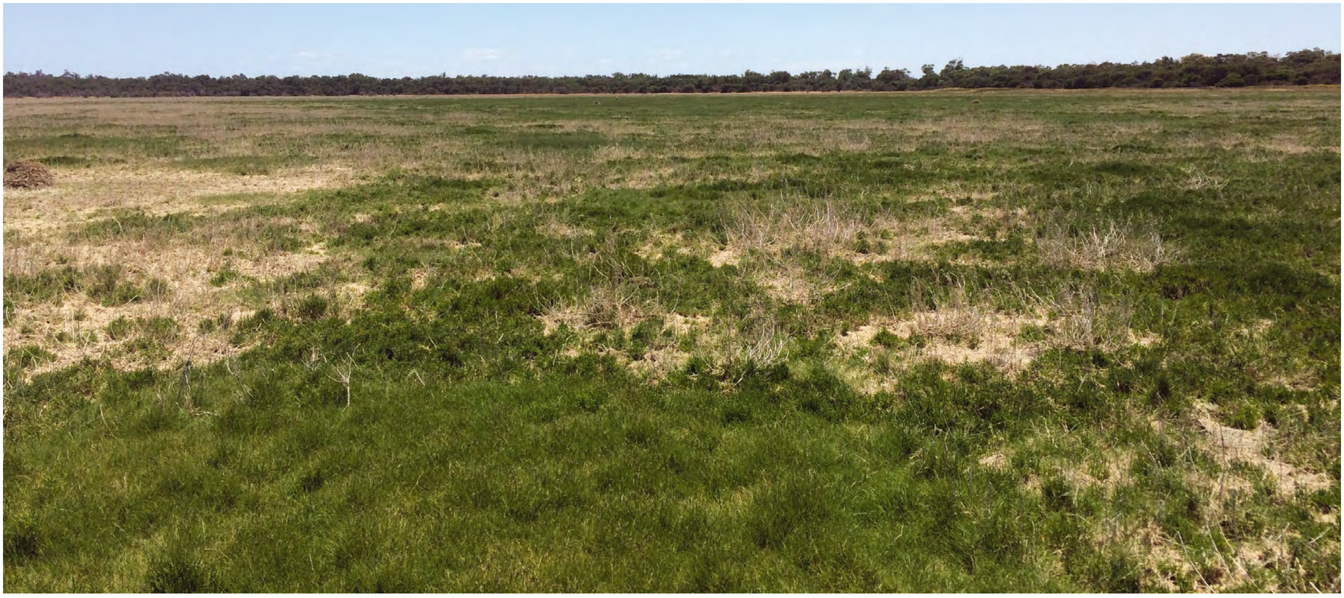


Figure 43: Lake McLarty in February 2012 (top) and February 2018 (bottom) showing increased terrestrial vegetation (Craig et al. 2018)

The decline in shorebird numbers at Lake McLarty has not been reflected in totals for the entire Ramsar site, with average annual abundance (2015 to 2019) of both Australian and international shorebirds across the site within the Limits of Acceptable Change and in the variability of the historical data (Figure 44). The decrease in shorebirds at Lake McLarty has coincided with increases at other locations, most notably the Yalgorup Lakes, but also parts of the Peel-Harvey Estuary such as Austin Bay (data from BirdLife Australia unpublished). For example, while the average number of Australian and international shorebirds at Lake McLarty dropped (2008 to 2019 compared with 1995 to 2006) from 4400 to 1000 and 8600 to 1500 respectively. Over the same period the average number of Australian and international shorebirds in the rest of the site increased from 5000 to 12,000 and 3700 to 6000 respectively. While the conditions at Lake McLarty have changed, the birds are currently supported within the broader Ramsar site.

The loss of shorebird feeding habitat at Lake McLarty may have broader implications over time if not addressed. There is evidence from the international literature that shorebirds are able to more efficiently gain nutrition feeding in freshwater rather than saline habitats, with an energy cost associated with regulating the additional salt load from marine and estuarine feeding (Gutiérrez et al. 2011). Therefore, the freshwater forging habitat provided by Lake McLarty may not be adequately offset by increased shorebird feeding in nearby saline habitats.

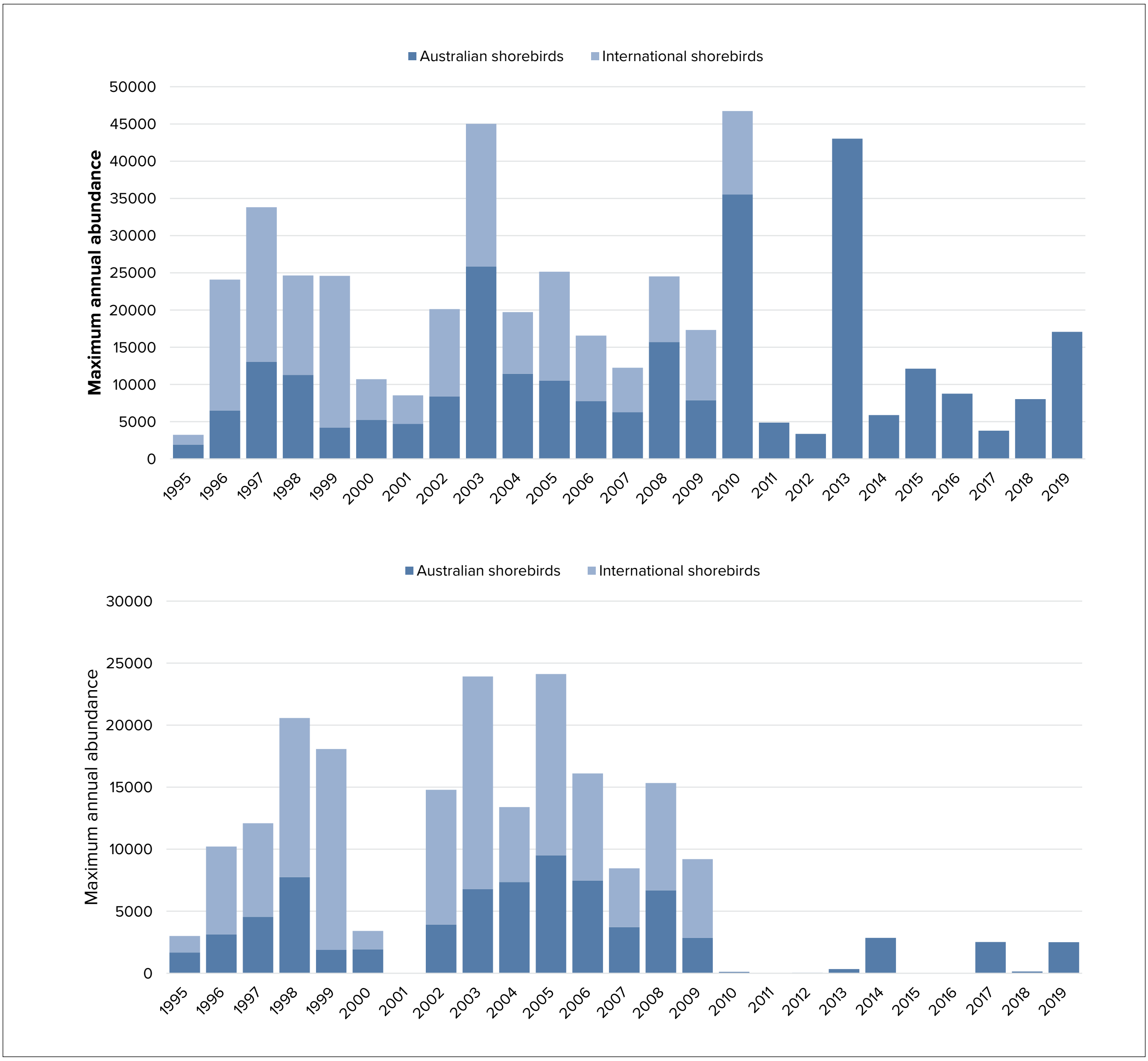


Figure 44: Average maximum abundance- top) Lake McLarty (data from Dr. M. Craig) and bottom) combined records from other locations within the Ramsar site (data from BirdLife, Atlas of Living Australia, Mr Bill Russell; Lane et al. 2002a and b)

6.3 Altered hydrology and vegetation at Lake Mealup

There have been changes in the conditions at Lake Mealup since the time of listing, but these have to a large extent improved ecological character. The two decades from listing in 1990 to 2012 saw Lake Mealup experience frequent periods of wetting and drying, which resulted in poor water quality with periodic high salinity and extended periods of acidity (low pH) due to exposure and rewetting of sediments (Figure 45). This water regime also favoured the growth of the native, but invasive species of rush, *Typha orientalis*, which formed dense monospecific stands across the bed of the wetland reducing habitat for waterbirds.

A diversion weir constructed in the Mealup Main Drain and commissioned in 2012 enabled water levels to be augmented in Lake Mealup, so that the lake is no longer dry in late summer and autumn. Since that time water has remained largely fresh and neutral. Active management from 2011 to 2013 eliminated Typha from the wetland. These changes have improved the outcome for waterbirds with regular counts of over 1000 birds. In autumn 2019 some 4,000 birds were counted. Since 2012 over 35 waterbird species have been recorded (Lake Mealup Preservation Society unpublished data).

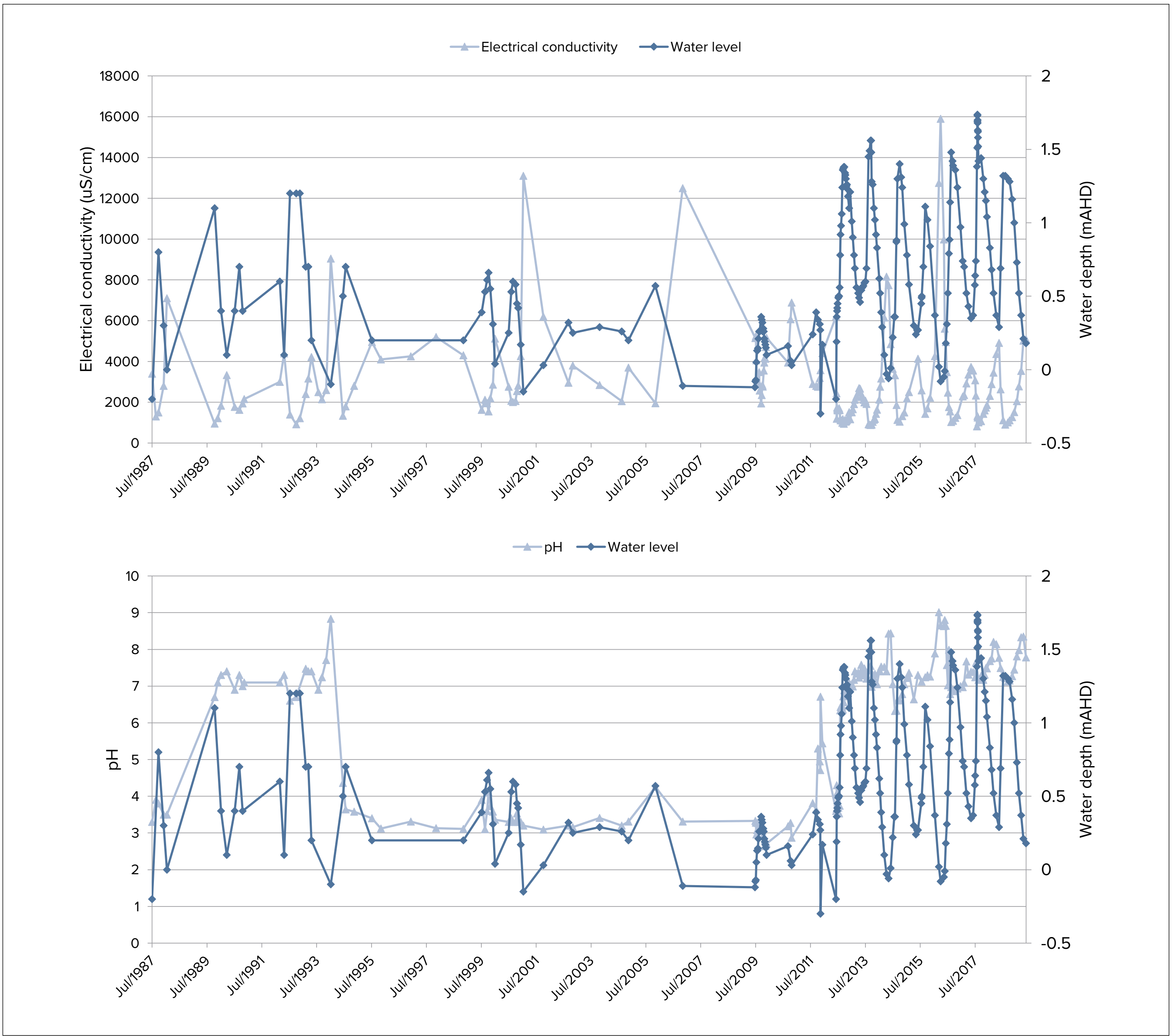


Figure 45: Water levels and electrical conductivity (top) and pH (bottom) at Lake Mealup from 1987 to 2019 (data provided by the Lake Mealup Preservation Society, unpublished data)

6.4 Trends in waterbird abundance, diversity and breeding

Trends in waterbird usage at the site are difficult to interpret. The Peel-Yalgorup Ramsar site provides a network of habitats and when considered as a whole, there is no clear change in total waterbird abundance since 1995. There is also no clear change in the maximum abundance of Australian shorebirds, ducks or herbivores. There appears to be an increase in the number of fish-eating waterbirds in recent years and a clear decline in the number of international shorebirds (Figure 46).

The reasons for the decline in these species may be beyond the boundaries of the Ramsar site. There have been a large number of investigations into the decline of shorebirds in the East Asian-Australasian Flyway, with habitat declines particularly at staging areas in the Yellow Sea recognised as the most significant impact factors (MacKinnon et al. 2012, Murray et al. 2015, Hua et al. 2015). The assertion that the decline in international migratory shorebirds in the site is unrelated to altered habitat conditions in the site is supported by the lack of a trend in Australian shorebirds (Figure 46) which use the same habitat.

Figure 46: Maximum annual abundance and five year moving average of waterbirds across the Ramsar site from 1995 to 2019 (data from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002a, b; Mr. B. Russell and Mr. D. Rule). Red line represents LAC

There have also been some changes in individual species. While the abundance of most species is either too low or variable to detect trends, the site regularly supports greater than one percent of the population of eight species, for which varying trends can be detected (Figure 47).

For the majority of the eight species in Figure 47 (for which the site regularly supports greater than one percent of the population), there is no discernible consistent trend. There does appear to have been an increase in hooded plover in the early 2000s, followed by a decline, and a clear decline in red-necked stints. The cause for the former is unknown, but the red-necked stint is an international migrant and the decline may be a result of factors outside the site as mentioned above.

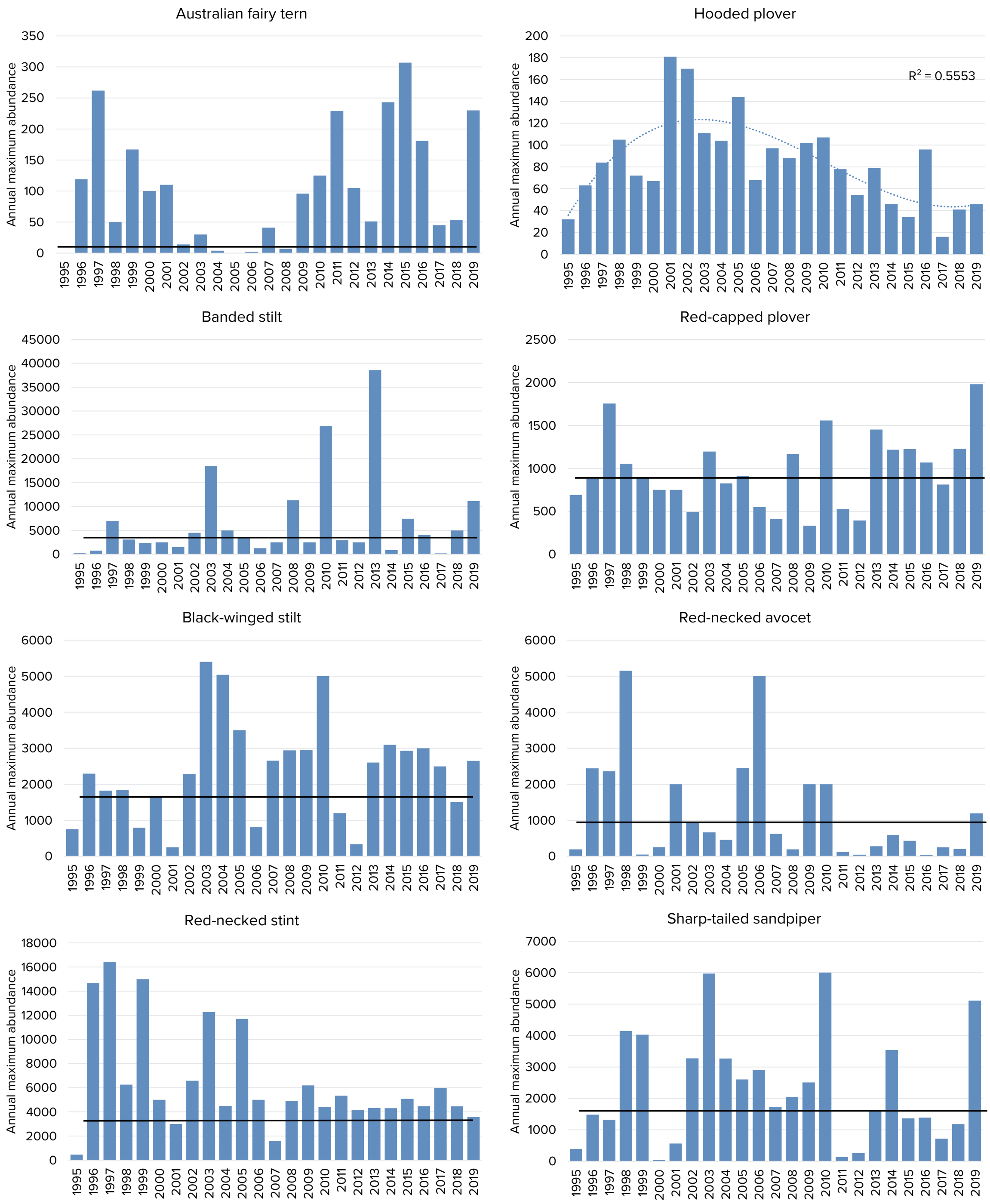
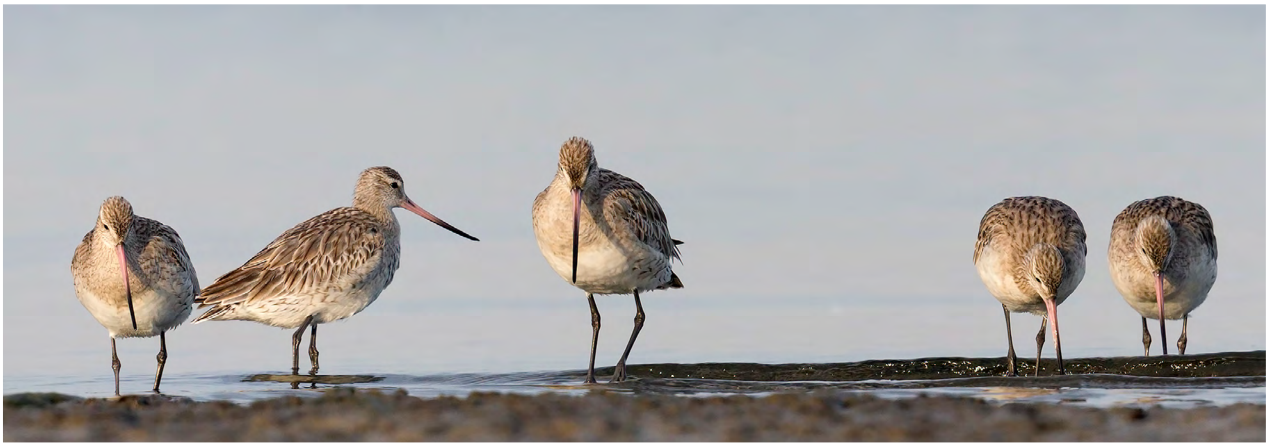


Figure 47: Maximum annual abundance of eight species across the Ramsar site from 1995 to 2019 (data from BirdLife Australia, Atlas of Living Australia, Dr M. Craig, Lane et al. 2002a, b; Mr. B. Russell and Mr. D. Rule). Black line represents 1 percent population threshold, dotted line on hooded plover is trend

Birds



7 Knowledge Gaps

Throughout this ECD Addendum for the Peel-Yalgorup Ramsar Site, mention has been made of knowledge gaps and data deficiencies for the site. 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. 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. Overall, the Peel-Yalgorup Ramsar site is a well-studied and documented location with substantial research and monitoring data available for a variety of components and processes. As such 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 relatively few and listed in Table 27.

Table 27: Knowledge gaps and recommended actions.

COMPONENT / PROCESS	KNOWLEDGE GAP	RECOMMENDED ACTION
Water Quality – Toxicants	The recent assessment of elevated levels of mercury in Caspian tern was linked to feeding within the Peel-Harvey Estuary (Dunlop and McNeill 2017). If this is the case, then other top end predator waterbirds (fish eating species) as well as dolphins may also be at risk / affected. Little is known about the source, type and severity of toxicants in the system..	Investigation into source, bioavailability and risk posed by toxicants.
Aquatic plants	There is no recent information on the extent and condition of aquatic plants in the lakes. Of particular concern is the apparent decline in the charophyte 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 presence and extent of charophytes at Lake Pollard and the extent and duration of Cladophora on the thrombolites
Salinity and water levels at Lake Clifton	While it is certain that salinity has increased and water levels declined in Lake Clifton, the causes for this, particularly with respect to groundwater use, remain unknown.	Investigate the cause of hydrological change at Lake Clifton and potential management interventions.
Thrombolites	There are indications of a decline in the extent of active thrombolites at Lake Clifton. Whether this is an ongoing trend or there are any management options remains unknown.	Regular assessment of thrombolite extent and condition. Increase understanding of the extent of active thrombolites and potential management levers.
Waterbirds	Current waterbird monitoring programs are limited to a small number of target projects (hooded plover, cormorant breeding) and the National Shorebird Monitoring Program program which collects data in summer each year. This arguably does not capture peak abundances of all waterbird guilds and consistent data on waterfowl, for example, is lacking for the site. In addition, waterbird breeding is not well documented (with the exception of cormorant colonies). The site was once considered important for Australian pelicans, but no recent data has been collected.	Biannual (winter and summer) waterbird surveys. Regular breeding surveys of known or suspected important sites.
Hooded plover	There appears to be a decline in hooded plover at the Yalgorup Lakes and a decrease in breeding success. The reasons for this remain unclear.	Continued monitoring of hooded plover breeding and investigate potential causes for decline.

8 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 EPBC Act 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.

Defining a comprehensive monitoring program is beyond the scope of an ECD. What is provided is an identification of monitoring needs required to both set baselines for critical components and processes and to assess against limits of acceptable change. It should be noted that the focus of the monitoring recommended in an ECD is an assessment against LAC and determination of changes in ecological character. This monitoring is not designed as an early warning system whereby trends in data are assessed to detect changes in components and processes prior to a change in ecological character of the site. This must be included as part of the monitoring program within the management plan for the site.

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 28.

Table 28: Monitoring requirements for the Peel-Yalgorup Ramsar Site

PROGRAM	INDICATORS AND METHOD	FREQUENCY	RESPONSIBILITY	LINKAGES TO EXISTING PROGRAMS	LOCATIONS
Seagrass and macroalgae	Extent mapping and condition consistent with Valesini et al. (2019).	Every five years	DBCA	Most recently performed through the ARC Linkage Project LP 150100451 (2016-2019).	Peel-Harvey Estuary
Saltmarsh and paperbark	Extent and condition of vegetation communities consistent with Hale and Kobryn (2009)	Every five years	PHCC	Most recently performed in 2017 through once-off funding from State Government	All
Freshwater aquatic vegetation	Extent and community composition	Every two years	Lake Mealup Preservation Society		Lake Mealup
Thrombolites	Novel methods for assessing active thrombolites may need to be developed.	Every two years	DBCA PHCC when funded	Currently supported by once off funding 2018 to 2023 from Australian Government (National Landcare Program – Regional Land Partnerships)	Lake Clifton
Marine invertebrates	Fisheries Harvest Strategy	Annual	DPIRD (Fisheries)	Annual commercial blue swimmer crab fishery catch assessments. Annual review of Marine Stewardship Council Certification (blue swimmer crab fishery).	Peel-Harvey Estuary
Native fish: abundance and trends	Abundance and diversity	Annual	TBD	Most recently performed through the ARC Linkage Project LP 150100451 (2016-2019).	Peel-Harvey Estuary
Waterbird abundance	Bi-annual counts; BirdLife Australia standard methods.	Twice yearly	BirdLife WA, PHCC and volunteers	Shorebird 2020 annual count (2008 to 2019). BirdLife WA & PHCC coordinate with volunteers doing the annual count	All
Waterbird breeding	Annual surveys of nest numbers and breeding success (i.e. fledgling)	Annual	BirdLife WA, PHCC and volunteers	Cormorants – Ornithological Technical Services have been engaged in 2010, 2016, 2019	Important breeding locations
Marine mammals	Annual surveys to assess breeding success	Annual	DBCA, PHCC and volunteers	The Dolphin Watch program is a Citizen Science program organised by DBCA and supported by the Estuary Guardians, PHCC community groups (Mandurah Volunteer Dolphin Rescue Group, Murdoch University Megafauna Research Group, Mandurah Cruises)	Peel-Harvey Estuary

9 COMMUNICATION AND EDUCATION MESSAGES

The Ramsar Convention's Programme on communication, capacity building, education, participation and awareness (CEPA), was updated in 2015. The programme identifies the importance of strategic and targeted communications to address the alarming world-wide loss of wetlands (64 percent lost last century) through promotion of wetlands and their vital role for humanity (https://www.ramsar.org/activity/the-ramsar-cepa-programme).

The program calls for coordinated international and national wetland education, public awareness and communication. In response to this, Australia's Ramsar CEPA National Action Plan 2016-2018 has been prepared through consultation with Australian Government departments and agencies, state and territory governments and wetland NGOs. It sets out Australia's contribution to implementing the Ramsar Convention's Programme on CEPA for 2016-2024, which was agreed at the 12th Conference of the Contracting Parties to the Ramsar Convention on Wetlands in 2015 (http://www.environment.gov.au/water/wetlands/publications/australias-ramsar-cepa-national-action-plan-2016-2018).

In 2017 the PHCC published the Wetlands and People Plan Peel-Yalgorup System, a CEPA Action Plan for Ramsar Site 482. This is Australia's first stand-alone, site specific CEPA Plan.

Guided by this plan a number of programs are currently in place, which focus on communication and education of wetland values in the Ramsar Site. Key CEPA messages for the Peel-Yalgorup Ramsar Site arising from this ECD, which should be promoted through these programs, include:

- The Ramsar values of the site and the importance of the Ramsar Site as a network of spatially disconnected wetlands, which together provide habitat for shorebirds and waterfowl to meet different needs in their lifecycles.
- The significance of the site for international migratory birds; their journey through the East Asian-Australasian Flyway, the habitats they use within the site and the potentially significant consequences of disturbance from walking, bird watching, boating, vehicles and domestic pets.
- The significance of the site in general, and Yalgorup Lakes in particular for colonial waterbird breeding.
- Climate change, the potential impacts on the benefits and services of the Ramsar site and adaption strategies that may be possible to minimise impacts associated with climate change, particularly to inland aquatic and coastal environments.
- The need for cooperative and coordinated management across this complex site with the large number of stakeholders and bodies responsible for management.

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A
APPENDIX

DESCRIPTION OF THE PEEL-HARVEY ESTUARY AT THE TIME OF LISTING

This Appendix describes the ecological character of the Peel-Harvey Estuary portion of the Ramsar site prior to the opening of the Dawesville channel. A summary of supporting components and process as well as critical components, process and services at the time of listing is provided in Table 29 and described in further detail below.

Table 29: Table (Brearley 2005): Summary of supporting components and processes within the Peel- Site Harvey Estuary at the time of listing (1990)

COMPONENT / PROCESS	DESCRIPTION
Supporting components and processes	
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 Spring Nodularia blooms in the Harvey Estuary
Critical components and processes	
Seagrass and macroalgae	Macroalgal dominated benthic plant community with high biomass of green algae, particularly Cladopora montagnaea. Seagrass in the estuary was dominated by two species Ruppia megacarpa and Halophila ovalis.
Littoral vegetation	Saltmarsh communities around the shorelines Paperbark communities in the Harvey River delta
Invertebrates	Commercially significant taxa include blue swimmer crabs and western king prawns
Fish	Estuarine and marine species Migratory route for some species
Waterbirds	High diversity and abundance of waterbirds Regularly supports greater than 20,000 waterbirds (maximum recorded 150,000 individuals) Breeding recorded for twelve species

Supporting components and processes

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 metres 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 metres 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 led 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 metres kept the connection open (Hodgkin et al. 1981).

The geomorphology and bathymetry of the Peel-Harvey Estuary during the 1990s is summarised in Table 30. The Peel Inlet is approximately 10 kilometres in diameter and circular in shape. It is shallow with large areas less than 0.5 metres in depth at high water and a small central basin of approximately 2 metres 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 kilometres x 2-3 kilometres) that runs roughly parallel to the coast. Similar to the Peel Inlet it is shallow with large areas less than 0.5 metres and a deeper (approximately 2 metres) 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 30: Dimensions of the Peel-Harvey Estuary (Hodgkin et al. 1981)

LOCATION	DIMENSIONS	
Mandurah Channel	Length	5 kilometres
	Width	200 metres
Peel Inlet	Area	75 square kilometres
	Volume	11700 gigalitres
Harvey Estuary	Area	56 square kilometres
	Volume	15200 gigalitres

The Peel-Harvey Estuary is covered in approximately three metres 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 percent (Hodgkin et al. 1981). However, at the time of listing there were large areas where surficial sediments were dominated by high carbon content (12 percent) black mud (ooze) of recent origin from algal material and faecal pellets.

The geomorphology of the Peel-Harvey Estuary had been modified by 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 through an intertidal area at South Yunderup near to the Murray River Delta 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).

Hydrology

A conceptual water budget of the Peel-Harvey Estuary was developed in the 1970s (Hodgkin et al. 1981; Figure 48) and is equally applicable to the estuarine system of the 1990s prior to the opening of the Dawesville Channel. This illustrates both the sources and the relative magnitude of inflows and outflows of the system at the time of listing.

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 km2, of which 6,900 km2 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 Murray River). 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.

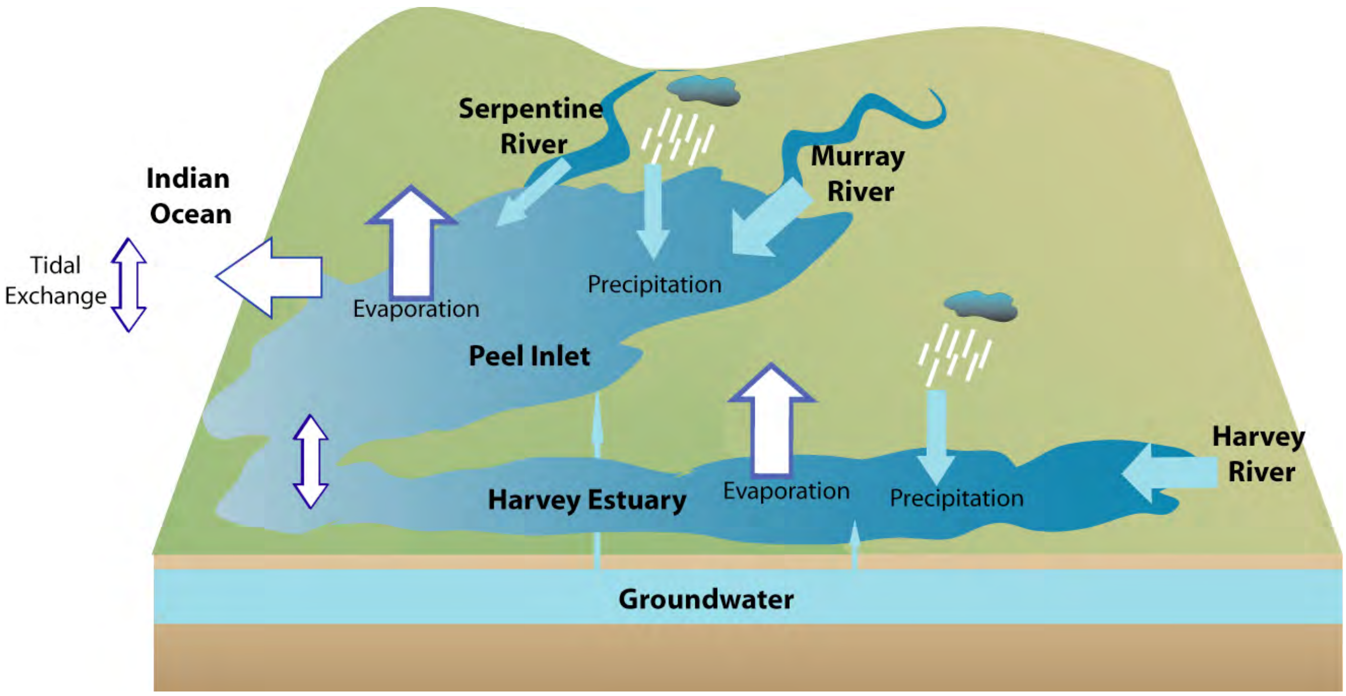

Figure 48: Conceptual water budget of the Peel-Harvey Estuary (adapted from Hodgkin et al. 1981). Blue arrows represent inflows, white arrows represent outflows, and the width of the arrow represents relative magnitude

The combined surface water inflows from the catchment accounted for approximately 85 percent of the total inflows to the system. Most surface flow to the Peel Inlet came from the Murray River, which on average contributes twice that of the Serpentine. The Harvey River and drains contributed on average 225,000 megalitres, just over a third of the total river inflows, despite the large amount of water diverted directly to the sea (Table 31).

Table 31: Table (McComb and Humphries 1992): Average annual river flows (megalitres) from 1977 – 1988 (McComb and Humphries 1992)

SOURCE	MINIMUM	MAXIMUM	MEAN	PERCENT 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

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 centimetres, the tidal range in the estuary was predominantly less than 10 centimetres (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 led 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 indicated a range from a maximum of 53 centimetres above mean water level to a minimum of 40 centimetres below mean water level. 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 metres, respectively and taken up to 10 days to return to tidal level (DAL, 1997).

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 49 and (Hale and Paling 1999)). During winter and spring when freshwater flows from the rivers were highest, salinity was lowest. Over the period 1985 to 1991 mean surface water salinity during winter and spring was 19 parts per thousand in the Peel Inlet and 13 parts per thousand 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 parts per thousand) 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 freshwater measurements of less than one parts per thousand 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 parts per thousand in the Peel Inlet and 32.5 parts per thousand 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 water became hyper-saline with measurements greater than 40 parts per thousand common and on occasion greater than 50 parts per thousand.

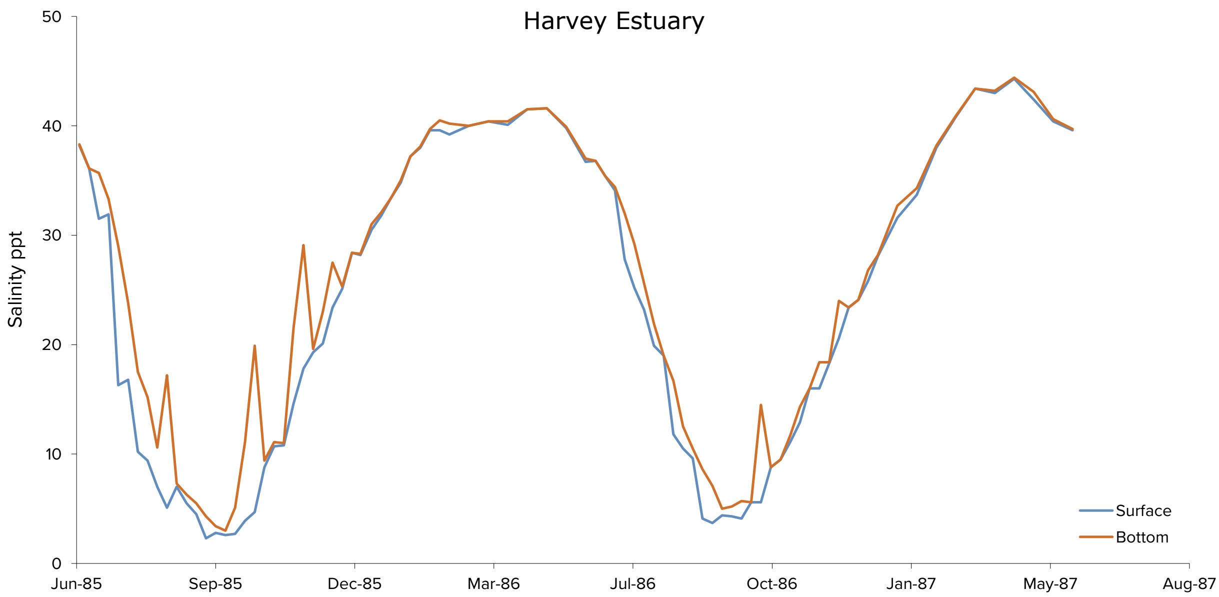

Figure 49: Typical seasonal pattern of salinity in the Harvey Estuary (centre site, June 1985 to August 1987; data from Hale and Paling 1999)

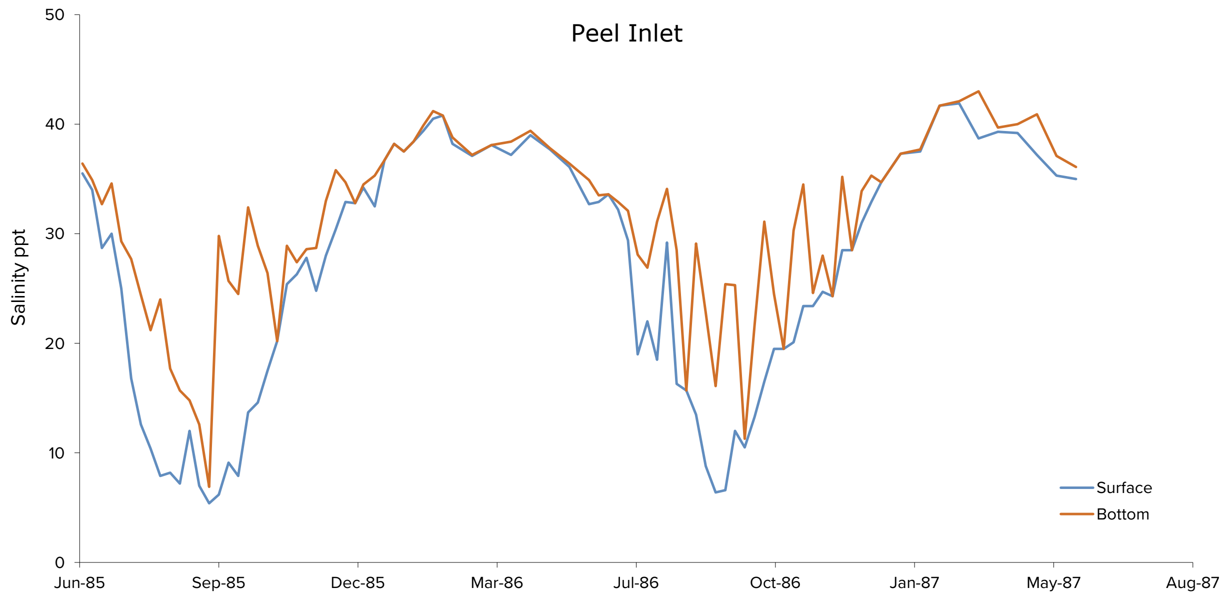

Figure 50: Typical seasonal pattern of salinity in the Peel Inlet (centre site, June 1985 to August 1987; data from Hale and Paling 1999)

Dissolved oxygen

The shallow nature of the Peel-Harvey Estuary, together with the high winds, increased the mixing 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, 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 one metre above the sediment on average between 10 percent and 40 percent 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 and the Harvey River and associated drains contributed the greatest phosphorus loads (Table 32). Due to the seasonality of river flow, 80 to 90 percent 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 32: Annual nitrogen and phosphorus loads to the Peel-Harvey Estuary 1977 – 1988 (McComb and Lukatelich 1995)

RIVER	TOTAL NITROGEN LOAD (TONNES / YEAR)			TOTAL PHOSPHORUS LOAD (TONNES / YEAR)		
	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 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 less than 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. Ammonia-ammonium (hereafter 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 greater than 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 one centimetre 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 was stratified and the dissolved oxygen at the sediment water interface was low, nutrients in the form of orthophosphate and ammonium were released into the water column (Figure 51).

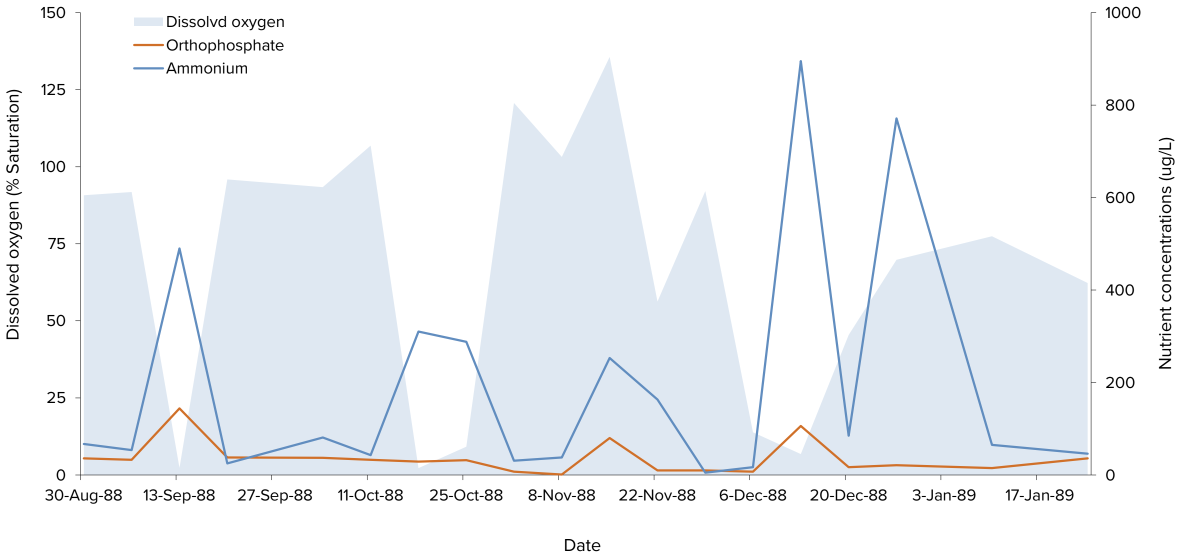

Figure 51: An example of the relationship between dissolved oxygen (shaded blue) and release of nutrients from the sediment in the Harvey Estuary (data from Hale and Paling 1999)

Phytoplankton

The effects of eutrophication led 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 52). 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.

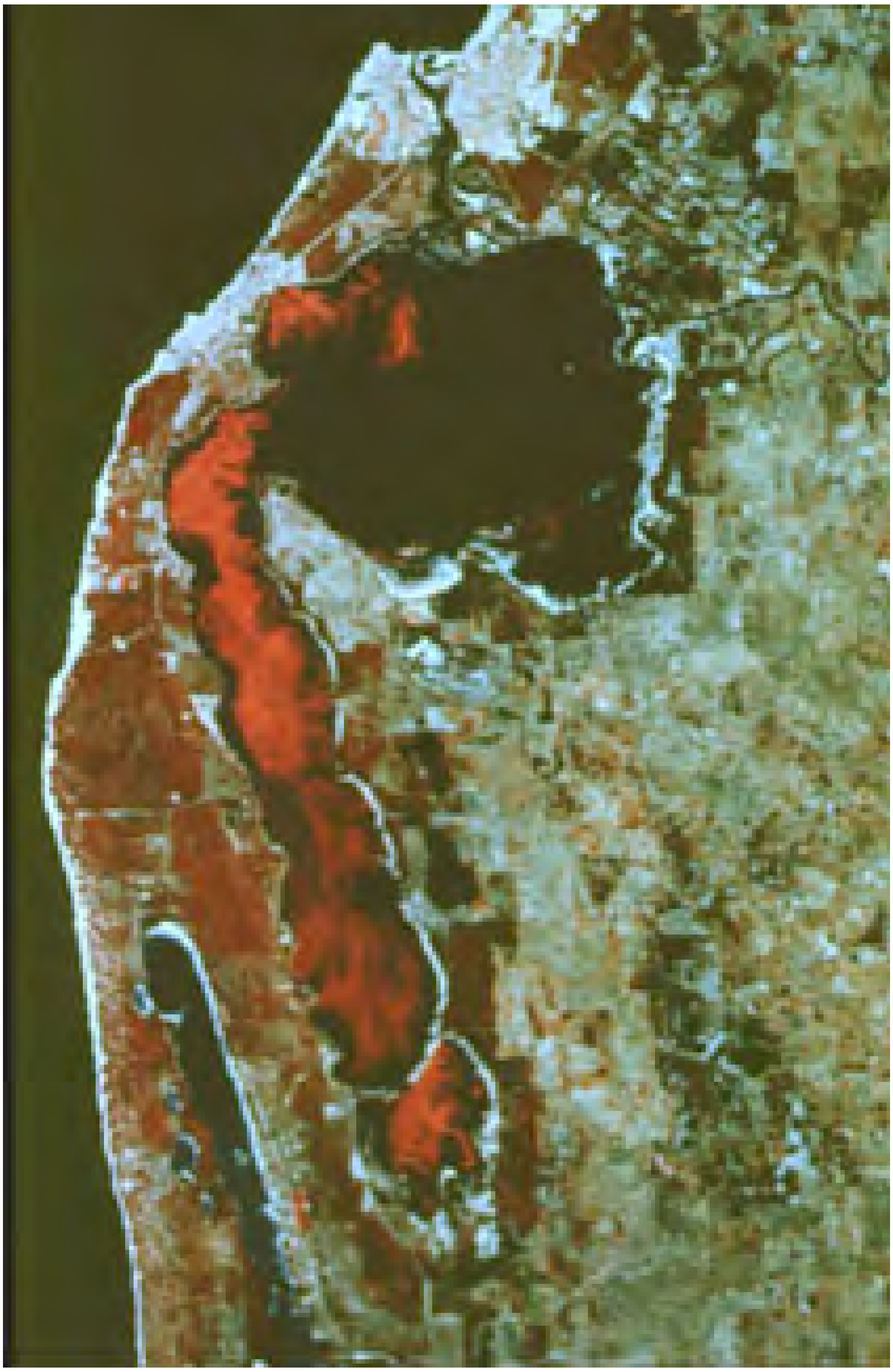

Figure 52: Landsat image showing the extent of a Nodularia bloom across the Harvey Estuary in the 1980s

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 greater than 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 greater than 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 53.

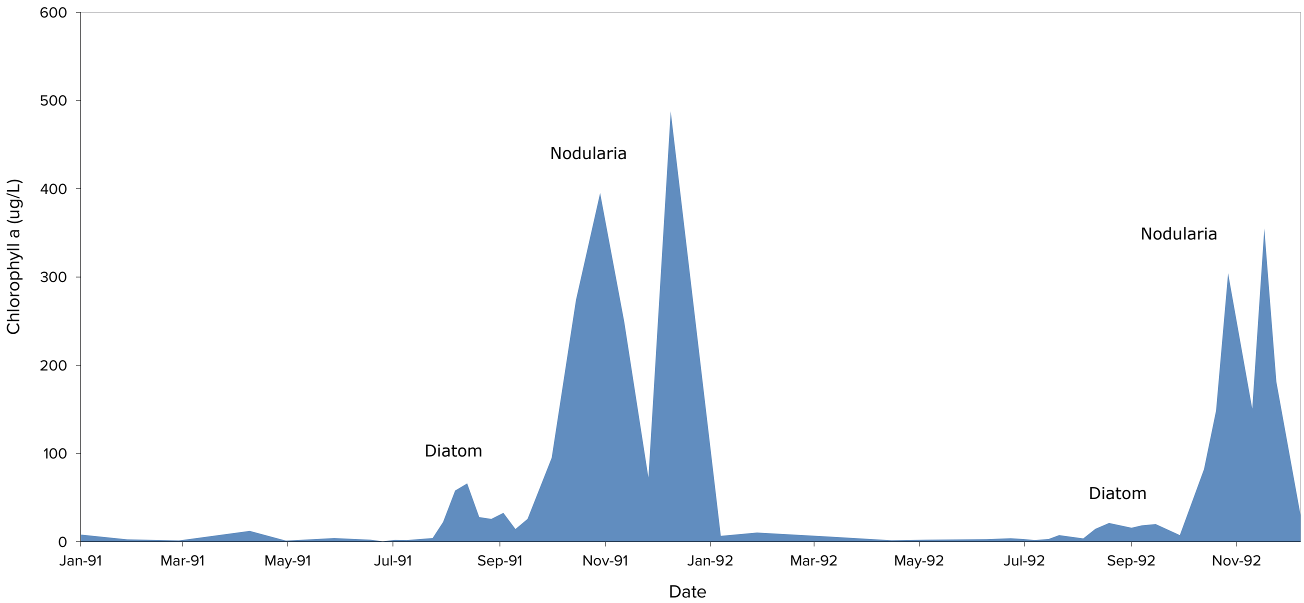

Figure 53: Phytoplankton biomass (as indicated by chlorophyll a concentrations) in the Harvey Estuary 1991 – 1992

Critical components and processes

Seagrass and macroalgae

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, *Cladophora montagnaea* was the dominant taxa (McComb and Lukatelich 1995) and biomass estimates of greater than 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 centimetres in diameter (Figure 54). This free-floating growth form occurred in large beds across the estuary floor 1 – 10 centimetres 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.

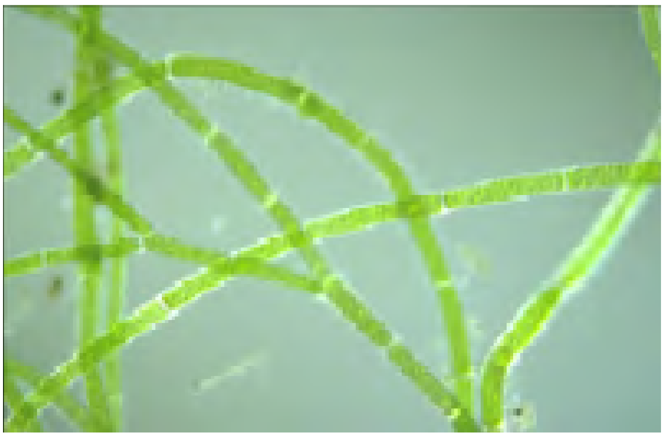

Figure 54: Cladophora showing growth form in balls (left, A. McComb) and filament structure (right, Tsukii)

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 greater than 90 percent 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 55) 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).

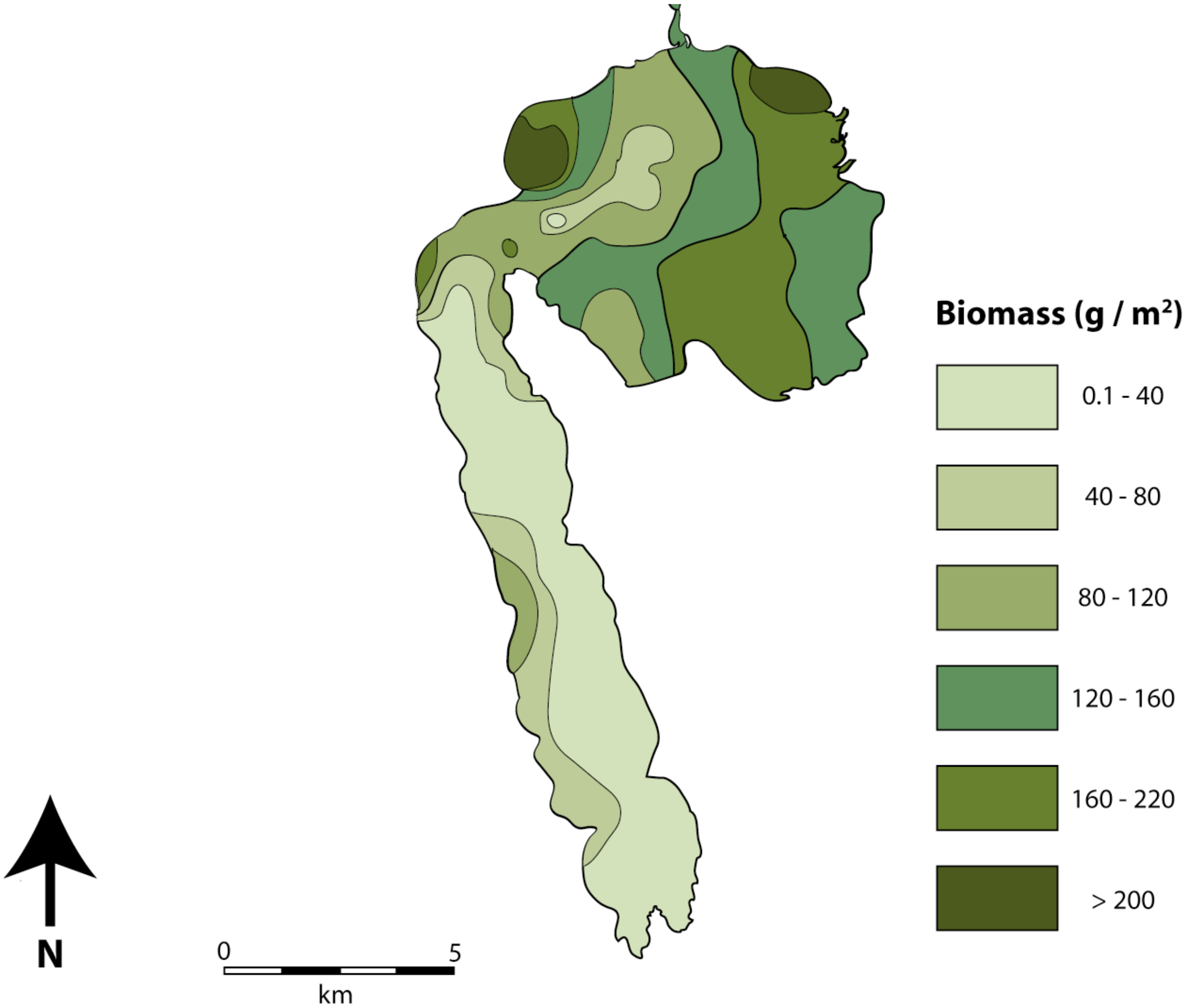

Figure 55: Mean biomass and distribution of macroalgae 1985 – 1991 (adapted from Wilson et al. 1999)

Saltmarsh and paperbark

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 square kilometres 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 (Murray et al. 1995). 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 percent of the year (Murray et al. 1995).

Figure 56: Extent and location of salt marsh (shown in red) in the Peel-Harvey Estuary 1986 (Glasson et al. 1995)

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[24]. 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 percent loss between 1965 and 1986 (Glasson et al. 1995). 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 33: Extent of Samphire (hectares) 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**

In addition to saltmarsh there were areas of the estuary that contained littoral vegetation dominated by trees. Behind the saltmarsh 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 (Monks and Gibson 2000). These areas contained a mixture of freshwater and estuarine vegetation including tree species such as *Melaleuca rhaphiophylla* (freshwater 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 (Monks and Gibson 2000).

Invertebrates

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 (DAL 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).

Several of the lager species, such as the western school prawn, western king prawn' and blue swimmer crabs, were important fisheries in the Peel-Harvey Estuary (Hodgkin, 1981; de Lestang et al. 2000; Malseed and Sumner 2001; DAL 2002). The blue swimmer 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, which 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. 2003). Eutrophication and algal blooms contributed to fish kill events where large numbers of dead blue swimmer crabs were observed in the estuary system (Potter et al. 1983).

Fish

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

24 Note that not all of the Creery Wetlands are 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.

an increase in abundance of fish (Lenanton and Potter 1987). 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 kills, 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).

Waterbirds

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 1980 to 1985 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 included the Australian pelican, pied cormorant, grey teal, blue-billed duck, common greenshank, red knot, sharp-tailed sandpiper, curlew sandpiper, silver gull, whiskered tern, Caspian tern and crested tern. Eastern curlew, osprey, white-bellied sea eagle, little egret, spoonbill, greater 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).

B

APPENDIX

DESCRIPTION OF PROPOSED EXTENSION – 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 34 and described below.

Table 34: Ecosystem components and processes of Lakes Goegrup and Black.

COMPONENT	SUMMARY DESCRIPTION
Supporting components and processes	
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
Critical components and processes	
Vegetation	• High phytoplankton biomass • Samphire at low elevations in the littoral zone • Paperbark communities at high elevations
Waterbirds	• Data deficient • Supports waterbirds

Geomorphology

Lakes Goegrup and Black are riverine wetlands on the Serpentine River approximately 5 kilometres upstream of the discharge to the Peel Inlet. Goegrup Lake spans the main channel of the Serpentine River and is connected to Black Lake, which is off channel, by a narrow channel (Figure 57). Black Lake is actually the local name given to a series of lakes and comprises of Black Lake (proper), Wolyanup, Bulbiba and Road Lakes.

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. 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.

Water Quality

Water quality in the lakes has not been monitored, however, the water quality monitoring program from the Serpentine River has 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 (less than 0.5 ppt). However, the influence of the tide and the decreased river flow during summer leads to hypersaline conditions with salinity greater than 50 ppt. The water column is generally neutral to alkaline (pH 7 to 8.5) with no obvious seasonal pattern. Dissolved oxygen concentrations are typically low (less than 65 percent 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, nutrients concentrations are low. Peak concentrations are reached during winter and spring. Results from monitoring in 2005 to 2006 indicated nitrate-nitrite concentrations ranging from less than 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 less than 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.

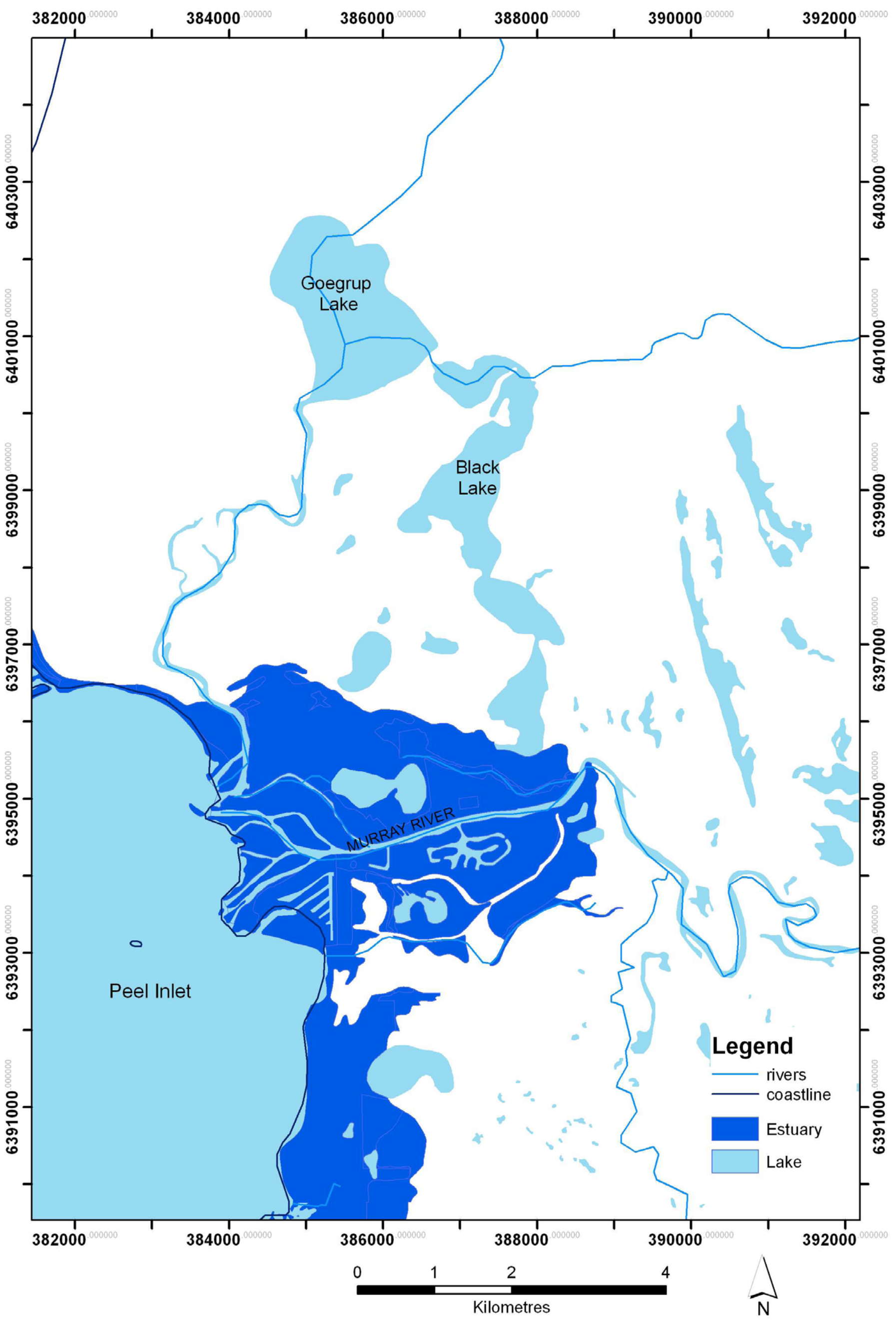

Figure 57: Location of Lakes Goegrup and Black

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 on the Serpentine River just upstream of Lake Goegrup (2005 – 2006) indicated relatively high cell counts of phytoplankton (greater than 10,000 cells per mL for much of the year. Blooms (greater than 20,000 cells per mL) are recorded during winter/spring and summer/autumn. For example, an autumn bloom (greater than 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 percent of the surface area of Lake Goegrup. This was present as floating mats in January and February and then sank 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.

Saltmarsh and paperbark

Littoral vegetation communities at Lakes Goegrup and Black were assessed in 2017 along three transects extending from open water to higher ground (Hale and Kobryn 2017). Saltmarsh dominated by beaded glasswort occurred at the start of the transects in Lakes Goegrup and Black. The two Lake Goegrup transects immediately landward of the lake were lower elevation with submerged and / or floating aquatic plants. All transects had tree dominated communities at the higher elevations, with swamp sheoak (Casuarina obesa) in the northern Goegrup transect and distinct saltwater (Melaleuca cuticularis) and freshwater paperbark (Melaleuca raphiophylla) communities at Goegrup South and Black Lake.

The condition of saltmarsh and freshwater paperbark communities across the two lakes was evaluated as “good”. The saltwater paperbark community in the north of Lake Goegrup, however, was characterised as poor with high weed growth in the understorey and poor canopy condition.

Mapping of vegetation communities at Lakes Goegrup and Black indicate that there is approximately 70 hectares each of saltmarsh and paperbark (Figure 58) and that this has remained stable from 2007 to 2017.

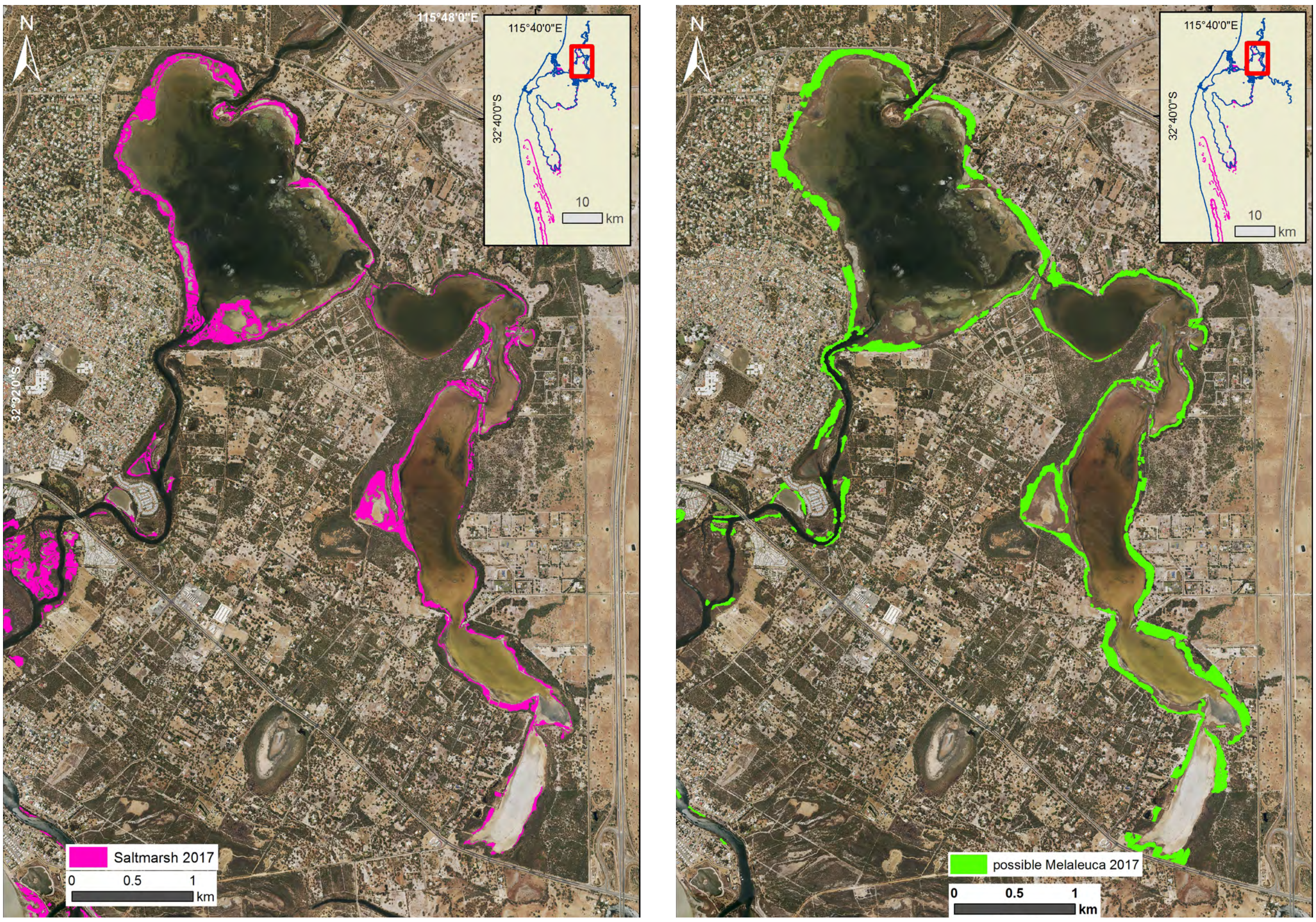

Figure 58: Mapped extent of saltmarsh (left) and paperbark (right) communities at Lakes Goegrup and Black in 2017 (Hale and Kobryn 2017)

Fish

A total of 21 species of native fish have been recorded from Lake Goegrup dominated by estuarine and some freshwater species (Potter et al. 1983, Loneragan et al. 1986). The most common species were sea mullet (*Mugil cephalus*), yellow-eye mullet (*Aldrichetta forsteri*) and common silvereye (*Gerres subfasciatus*) all of which are marine and estuarine opportunists. No species recorded were unique to Lake Goegrup and all fish from Lake Goegrup were commonly recorded in the Peel-Harvey Estuary.

Waterbirds

Goegrup and Black Lakes support moderate numbers of waterbirds, with 59 species recorded from 1989 to 2019 (Table 35). This includes 13 species that are listed under international migratory agreements (JAMBA and CAMBA) and an additional 15 Australian marine species protected under the EPBC Act (Appendix C). The number of international shorebirds recorded at the lakes is very small, with average counts from 2008 to 2019 of less than 50 individuals summed across all species (BirdLife Australia).

Table 35: Number of waterbird species recorded from within the Peel-Yalgorup Ramsar Site

FUNCTIONAL GROUP	DESCRIPTION	NUMBER
Ducks and small grebes	Ducks and small grebes that typically are omnivorous and shallow or open water foragers.	11
Herbivores	Black swans, swamphens and coots that have a plant diet.	2
Fish eating species	Gulls, terns, cormorants and grebes with a diet mainly of fish.	14
Australian shorebirds	Australian resident shorebird species that feed in shallow inland waters or mud and sand flats mainly on invertebrates.	7
International shorebirds	Palaearctic shorebird species that breed in the northern hemisphere and migrate to the southern hemisphere to feed.	11
Large wading birds	Long-legged wading birds with large bills, feeding mainly in shallow water and mudflats.	9
Other	Other birds that are wetland dependent such as birds of prey (swamp harrier), reed warblers and little grassbird.	5
Total		**59**

Lakes Goegrup and Black support moderate numbers of waterbirds, largely comprised of Australian shorebirds, fish eating species and ducks (Figure 59). Four species were recorded breeding at Goegrup and Black Lake: black swan, Australian shelduck, Pacific black duck and 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).

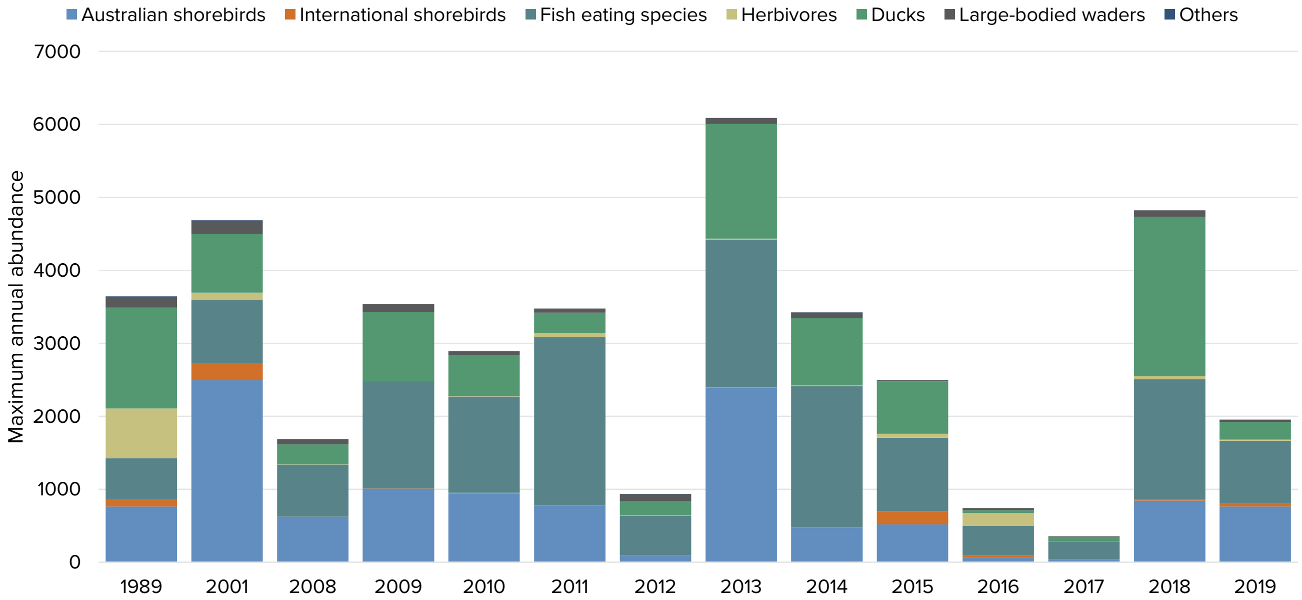

Figure 59: Maximum abundance [25] of waterbirds at Lakes Goegrup and Black (data from Bamford and Wilcox 2003; BirdLife Australia).

25 Calculated as the sum of the maximum abundance of each species observed within a calendar year.

C APPENDIX

SPECIES LIST

Fish of the Peel-Harvey Estuary

Life history (from Potter and Hyndes 1999): E= estuarine; E&M = estuarine and marine; F = freshwater; MEO = marine and estuarine opportunist; MS = marine straggler.

SPECIES NAME	COMMON NAME	LIFE HISTORY
Acanthaluteres brownii	Spiny-tailed leatherjacket	MS
Acanthaluteres spilomelanurus	Bridled leatherjacket	MS
Acanthaluteres vittiger	Brown leatherjacket	MS
Acanthopagrus butcheri	Black bream	E
Afurcagobius suppositus	South-western goby	E
Aldrichetta forsteri	Yellow-eye mullet	MEO
Ammotretis elongatus	Elongate flounder	MS
Amniataba caudavittatus	Yellowtail trumpeter	E
Arenigobius bifrenatus	Bridled goby	E&M
Arripis georgianus	Australian herring	MEO
Arripis truttaceus	Western Australian salmon	MEO
Atherinomorus vaigiensis	Ogilby’s hardyhead	MEO
Atherinosoma elongata	Elongate hardyhead	E
Brachaluteres jacksonianus	Pigmy leatherjacket	MS
Callogobius depressus	Flat headed gogy	E&M
Callogobius mucosus	Sculptured goby	E&M
Cnidoglanis macrocephalus	Cobbler	E&M
Contusus brevicaudus	Prickly toadfish	MEO
Craterocephalus mugiloides	Spotted hardyhead	E
Craterocephalus pauciradiatus	Few-ray hardyhead	E
Cristiceps australis	Southern crested weedfish	MS
Diodon nicthemerus	Globefish	MS
Dotalabrus alleni	Little rainbow wrasse	MS
Engraulis australis	Australian anchovy	MS
Enoplosus armatus	Old wife	MS
Favonigobius lateralis	Long-headed goby	E&M
Favonigobius punctatus	Yellowspotted sandgoby	MS
Filicampus tigris	Tiger pipefish	MS
Galaxias maculatus	Common galaxias	F
Galaxias occidentalis	Western galaxias	F
Gerres subfasciatus	Common silver belly	MEO
Gonorynchus greyi	Beaked salmon	MEO
Gymnapistes marmoratus	Devil fish or Bullrout	MEO
Haletta semifasciata	Blue weed whiting	MEO
Halichoeres brownfieldi	Brownfield’s wrasse	MS

SPECIES NAME	COMMON NAME	LIFE HISTORY
Hyperlophus vittatus	Sandy sprat	MEO
Hyporhamphus melanochir	Southern sea garfish	E&M
Hyporhamphus regularis	Western river garfish	E
Iso rhothophilus	Surf sardine	MS
Leptatherina presbyteroides	Swan River hardyhead	E&M
Leptatherina wallacei	Western hardyhead	E&F
Lesueurina platycephala	Flathead sandfish	MS
Meuschenia freycineti	Six-spined leatherjacket	MS
Microcanthus strigatus	Stripey	MS
Monacanthus chinensis	Fanbelly leatherjacket	MS
Mugil cephalus	Sea mullet	MEO
Myliobatis australis	Southern eagle ray	MS
Neatypus obliquus	Footballer sweeps	MS
Nematalosa vlaminghi	Perth herring	SA
Neoodax balteatus	Little weed whiting	MS
Notolabrus parilus	Brownspotted wrasse	MS
Omobranchus germaini	Germain's blenny	MS
Ostorhinchus rueppellii	Western gobbleguts	E&M
Papillogobius punctatus	Yellow-spotted sandgoby	E
Parapercis haackei	Wavy grubfish	MS
Pelates octolineatus	Western striped grunter	MEO
Pentapodus vitta	Western butterfish	MS
Petroscirtes breviceps	Shorthead sabretooth blenny	MS
Platycephalus laevigatus	Yank flathead	MS
Platycephalus speculator	Southern bluespotted flathead	MS
Pomatomus saltatrix	Tailor	MEO
Pseudocaranx georgianus	Silver trevally	MS
Pseudocaranx wrighti	Skipjack trevally	MS
Pseudogobius olorum	Swan River goby	E&F
Pseudorhombus jenynsii	Small-toothed flounder	MEO
Pugnaso curtirostris	Pugnose pipefish	E
Rhabdosargus sarba	Tarwhine or silver bream	MEO
Scobinichthys granulatus	Rough leatherjacket	MS
Scorpis georgianus	Banded sweep	MS
Sillaginodes punctatus	King George whiting	MEO
Sillago bassensis	School whiting	MS
Sillago burrus	Trumpeter sillago	MEO
Sillago schomburgkii	Yellow-finned whiting	MEO

SPECIES NAME	COMMON NAME	LIFE HISTORY
Sillago vittata	Western school whiting	MS
Siphamia cephalotes	Wood's siphonfish	E&M
Spratelloides robustus	Fringe-scale round herring	MS
Stigmatophora argus	Spotted pipefish	MS
Torquigener pleurogramma	Weeping toado / banded blowfish	MEO
Upeneus tragula	Bar-tail goatfish	MS
Urocampus carinirostris	Hairy pipefish	E&M

Wetland birds

Location: PH = Peel-Harvey; YL= Yalgorup Lakes; Mc = Lake McLarty; LM = Lake Mealup; GB = Lakes Goegrup and Black

X = present; B = breeding

Species listing: M = Listed as migratory or marine under the EPBC Act; J = JAMBA; C= CAMBA; R = ROKAMBA; B = Bonn; V = Vulnerable; E = Endangered

Functional group: I. wader = international migratory wader; A. wader = Australian wader; LBW = Large bodied wader; Fish = fish eating species

COMMON NAME	SCIENTIFIC NAME	LISTING	FUNCTIONAL GROUP	LOCATION				
				PH	YL	MC	LM	GB
American golden plover	*Pluvialis dominica*		I. wader			X		
Australasian darter	*Anhinga novaehollandiae*		Fish	B		B	B	X
Australasian grebe	*Tachybaptus novaehollandiae*		Fish	B	X	X	X	X
Australasian shoveler	*Anas rhynchotis*	M	Duck	B	X	X	X	X
Australian fairy tern	*Sternula nereis nereis*	V(EPBC)	A. wader	B	X	X		X
Australian painted snipe	*Rostratula australis*	E(EPBC)	A. wader			X		
Australian pelican	*Pelecanus conspicillatus*	M	Fish	B	X	X	X	X
Australian pied oystercatcher	*Haematopus longirostris*		A. wader	B	X			
Australian reed warbler	*Acrocephalus australis*		Other			X	X	
Australian shelduck	*Tadorna tadornoides*	M	Duck	B	B	B	X	B
Australian spotted crake	*Porzana fluminea*	M	LBW	X		X		X
Australian white ibis	*Threskiornis molucca*	M	LBW	B	X	X	X	X
Australian wood duck	*Chenonetta jubata*	M	Duck	B	X	X	X	X
Baillon's crake	*Porzana pusilla*	M	Herbivore	B		X		
Banded lapwing	*Vanellus tricolor*		A. wader	X	B	X		
Banded stilt	*Cladorhynchus leucocephalus*		A. wader	X	B	X	X	X
Bar-tailed godwit	*Limosa lapponica*	CE(EPBC), M, B, C, J, R	I. wader	X	X	X	X	X
Black swan	*Cygnus atratus*	M	Herbivore	B	B	B	X	B

COMMON NAME	SCIENTIFIC NAME	LISTING	FUNCTIONAL GROUP	LOCATION				
				PH	YL	MC	LM	GB
Black-faced cormorant	*Phalacrocorax fuscescens*	M	Fish	X	X	X		
Black-fronted dotterel	*Elseyornis melanops*		A. wader	X	X	B	X	X
Black-tailed godwit	*Limosa limosa*	M, B, C, J, R	I. wader	X	X	X		X
Black-tailed native-hen	*Tribonyx ventralis*		Herbivore	X	X	X	X	
Blue-billed duck	*Oxyura australis*	M	Duck		X	B	X	X
Bridled tern	*Onychoprion anaethetus*	M, J, C	Fish		X			
Broad-billed sandpiper	*Calidris falcinellus*	M, B, C, J, R	I. wader		X	X		
Buff-banded rail	*Gallirallus philippensis*		Duck	B		X		
Caspian tern	*Hydroprogne caspia*	M, J	Fish	X	X	X	X	X
Cattle egret	*Ardea ibis*	M	LBW	X	X	X		
Chestnut teal	*Anas castanea*	M	Duck	X	X	X		X
Common greenshank	*Tringa nebularia*	M, B, C, J, R	I. wader	X	X	X	X	X
Common sandpiper	*Actitis hypoleucos*	M, B, C, J, R	I. wader	X	X	X		X
Common tern	*Sterna hirundo*	M, C, J, R	Fish	X				
Crested tern	*Thalasseus bergii*	M	Fish	X	X	X		X
Curlew sandpiper	*Calidris ferruginea*	CE(EPBC), M, B, C, J, R	I. wader	X	X	X	X	X
Double-banded plover	*Charadrius bicinctus*	B	I. wader	X		X		
Dusky moorhen	*Gallinula tenebrosa*		Herbivore	X		B	X	
Eastern curlew	*Numenius madagascariensis*	CE(EPBC), M, B, C, J, R	I. wader	X		X		
Eastern great egret	*Ardea modesta*	M	LBW	X	X	X	X	X
Eastern reef egret	*Eastern reef egret*	M	LBW	X				
Eurasian coot	*Fulica atra*		Herbivore	X	X	B	X	X
Freckled duck	*Stictonetta naevosa*	M	Duck			B	X	
Glossy ibis	*Plegadis falcinellus*	M, B, C	LBW			X	X	
Great cormorant	*Phalacrocorax carbo*		Fish	X	X	X	X	X
Great crested grebe	*Podiceps cristatus*		Fish	X	B	B	X	X
Great knot	*Calidris tenuirostris*	CE(EPBC), M, B, C, J, R	I. wader	X	X	X		
Great pied cormorant	*Phalacrocorax varius*		Fish	X	X	X	X	X
Greater sand plover	*Charadrius leschenaultii*	V(EPBC), M, B, C, J, R	I. wader	X	X	X		
Grey plover	*Pluvialis squatarola*	M, B, C, J, R	I. wader	X	X	X		X
Grey teal	*Anas gracilis*	M	Duck	B	B	B	B	B
Grey-tailed tattler	*Tringa brevipes*	M, B, C, J, R	I. wader	X	X	X		X
Gull-billed tern	*Gelochelidon nilotica*	M, C	Fish		X			

COMMON NAME	SCIENTIFIC NAME	LISTING	FUNCTIONAL GROUP	LOCATION				
				PH	YL	MC	LM	GB
Hardhead	*Aythya australis*	M	Duck	X	X	X	X	X
Hoary-headed grebe	*Poliocephalus poliocephalus*		Duck	X	X	X	X	X
Hooded plover	*Thinornis rubricollis*	V(EPBC)	A. wader	X	X	X		
Intermediate egret	*Ardea intermedia*	M	LBW	X				
Latham's snipe	*Gallinago hardwickii*	M, J, R	I. wader			X		
Lesser sand plover	*Charadrius mongolus*	M, B, C, J, R	I. wader	X	X	X		
Little black cormorant	*Phalacrocorax sulcirostris*		Fish	B	X	X	X	X
Little curlew	*Little curlew*	M, B, C, J, R	I. wader			X		
Little egret	*Egretta garzetta*	M	LBW	X		X	X	X
Little grassbird	*Megalurus gramineus*		Other	X		X	X	X
Little pied cormorant	*Microcarbo melanoleucos*		Fish	B	X	B	X	X
Little ringed plover	*Charadrius dubius*	M, C, J, R	I. wader			X		
Long-toed stint	*Calidris subminuta*	M, B, C, J, R	I. wader	X		X		
Marsh sandpiper	*Tringa stagnatilis*	M, B, C, J, R	I. wader	X	X	X	X	X
Masked lapwing	*Vanellus miles*		A. wader			X		
Musk duck	*Biziura lobata*	M	Duck	X	X	B	X	X
Nankeen night-heron	*Nycticorax caledonicus*		LBW	X		X	X	X
Osprey	*Pandion cristatus*	M	Other	X	X	X	X	X
Oriental pratincole	*Glareola maldivarum*	M, C, J, R	I. wader			X		
Pacific black duck	*Anas superciliosa*	M	Duck	B	B	B	B	B
Pacific golden plover	*Pluvialis fulva*	M, B, C, J, R	I. wader	X	X	X		
Pacific gull	*Larus pacificus*	M	Fish	X				
Pectoral sandpiper	*Calidris melanotos*	M, B, J, R	I. wader	X		X		X
Pied stilt	*Himantopus himantopus*	M	A. wader	B	B	X	X	X
Pink-eared duck	*Malacorhynchus membranaceus*	M	Duck	X		X	X	X
Purple swamphen	*Porphyrio porphyrio*		Herbivore	X	X	B	X	
Red knot	*Calidris canutus*	V(EPBC), M, B, C, J, R	I. wader	X	X	X		
Red-capped plover	*Charadrius ruficapillus*	M	A. wader	X	B	B	X	X
Red-kneed dotterel	*Erythrogonys cinctus*		A. wader		X	B	X	
Red-necked avocet	*Recurvirostra novaehollandiae*	M	A. wader	X	X	X	X	X
Red-necked stint	*Calidris ruficollis*	M, B, C, J, R	I. wader	X	X	X	X	X
Royal spoonbill	*Platalea regia*		LBW	X				X
Ruddy turnstone	*Arenaria interpres*	M, B, C, J, R	I. wader	X	X	X		
Ruff	*Philomachus pugnax*	M, B, C, J, R	I. wader	X		X		

COMMON NAME	SCIENTIFIC NAME	LISTING	FUNCTIONAL GROUP	LOCATION				
				PH	YL	MC	LM	GB
Sacred kingfisher	*Todiramphus sanctus*		Other	X		B	X	X
Sanderling	*Calidris alba*	M, B, C, J, R	I. wader	X	X	X		
Sharp-tailed sandpiper	*Calidris acuminata*	M, B, C, J, R	I. wader	X	X	X	X	X
Silver gull	*Chroicocephalus novaehollandiae*	M	Gull	B	X	X	X	X
Sooty oystercatcher	*Haematopus fuliginosus*	M	A. wader	X				
Spotless crake	*Porzana tabuensis*	M	Duck		X	B	X	
Straw-necked Ibis	*Threskiornis spinicollis*	M	LBW	X	X	X	X	X
Swamp harrier	*Circus approximans*	M	Other	X	X	X	X	X
Terek sandpiper	*Xenus cinereus*	M, B, C, J, R	I. wader	X	X	X		
Wedge-tailed shearwater	*Ardenna pacifica*	M, J	Fish	X				
Whimbrel	*Numenius phaeopus*	M, B, C, J, R	I. wader	X	X	X		
Whiskered tern	*Chlidonias hybrida*	M	Fish	X		B	X	X
White-bellied sea eagle	*Haliaeetus leucogaster*	M, C	Other	X	X	B	X	X
White-faced heron	*Egretta novaehollandiae*		LBW	X	X	X	X	X
White-fronted chat	*Epthianura albifrons*		Other	X	X		X	
White-necked heron	*Ardea pacifica*		LBW	X		X	X	
White-winged black tern	*Chlidonias leucopterus*	M, C, J, R	Fish			B		X
Wood sandpiper	*Tringa glareola*	M, B, C, J, R	I. wader	X		X	X	
Yellow-billed spoonbill	*Platalea flavipes*		LBW	X	X	X	X	X

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