Glenelg Estuary and Discovery Bay Ramsar Site

Ecological Character Description

VICTORIA State Government | Environment, Land, Water and Planning

Acknowledgements

This document was informed by the following technical working group participants: Gavin Prentice, Jarred Obst, Helen Arundel and Stephen Ryan (Glenelg Hopkins Catchment Management Authority), David Ryan, Marcel Hoog Antink and Don Tumney (Parks Victoria), David Pitts, Rachel Pritchard and Garry Peterson (DELWP), Mark Bachmann, Lachlan Farrington, Lauren Veale and Bryan Haywood (Nature Glenelg Trust), Maureen Christie (Birdlife South East SA), Golo Mauer (formerly Birdlife Australia), Nelson Coastcare Group, local landholders and the Nelson and Tarragal communities. In addition, Damein Bell, Gunditj Mirring Traditional Owner Aboriginal Corporation, provided guidance in relation to indigenous values. The Commonwealth Department of Environment and Energy provided valuable feedback during document development. Leila Huebner provided key reference material, historical correspondence regarding restoration of Long Swamp, technical input at workshops, and the list of wetland plant species presented in Appendix D, her contributions were invaluable. We also acknowledge the authors of publications referenced in this document for additional information and advice provided.

Symbols for diagrams courtesy of the Integration and Application Network (ian.umces.edu/symbols), University of Maryland Centre for Environmental Science.

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Citation

Department of Environment, Land, Water and Planning (2017). Ecological Character Description for Glenelg Estuary and Discovery Bay Ramsar Site. Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

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Photo credit

Bridgewater Lakes R. Butcher

ISBN 978-1-76047-943-5 (pdf/online)

Accessibility

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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), Resolution IX.1 Annex A). 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), Resolution IX.1 Annex A).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	All the types of taxa present in a community (ANZECC and ARMCANZ 2000).
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; 159 as at March 2010. 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”.] (Resolution IX.1 Annex A) (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	Include 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), Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002).
Ecosystem services	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”.

Electrical conductivity	*See Salinity below*
Endemic	*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. 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.
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 and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values.
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 upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and conservation measures taken and needed.
Ramsar List	The List of Wetlands of International Importance.
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	"birds ecologically dependent on wetlands" (Article 1.2). This definition thus includes any wetland bird species. However, 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, waders (or shorebirds), gulls, skimmers and terns: *Charadriiformes;* coucals*: Cuculiformes;* and wetland related owls: *Strigiformes*.
Wetlands	Are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland types	As defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/ris/key_ris.htm#type].

Abbreviations

CAMBA	China Australia Migratory Bird Agreement
CMA	Catchment Management Authority
DEDJTR	Department of Economic Development, Transport, Jobs and Resources (Victorian Government)
DELWP	Department of Environment, Land, Water and Planning (Victorian Government), formerly Department of Environment and Primary Industries
DEPI	Department of Environment and Primary Industries, now Department of Environment, Land, Water and Planning
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
EPA Victoria	Environment Protection Authority, Victoria
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Glenelg Hopkins CMA	Glenelg Hopkins Catchment Management Authority
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
MAs	Management Actions
MCA	Multiple Criteria Analysis
MER	Monitoring, Evaluation and Reporting
PSC	Project Steering Committee
RCT	Resource Condition Target
RIS	Ramsar Information Sheet
RMP	Ramsar Management Plan
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement
SRW	Southern Rural Water
TAG	Technical Advisory Group
VWMS	Victorian Waterway Management Strategy

Executive summary

The Glenelg Estuary and Discovery Bay Ramsar Site includes a diverse wetland system located in the southwest corner of the state of Victoria within the South East Coast (Victoria) Drainage Basin. The site is situated immediately south of the small rural town of Nelson, which has a population of approximately 300. The site is bounded by the South Australia – Victoria border to the west, the Southern Ocean to the south and incorporates a portion of the Lower Glenelg National Park and the majority of the Discovery Bay Coastal Park (Figure 1).

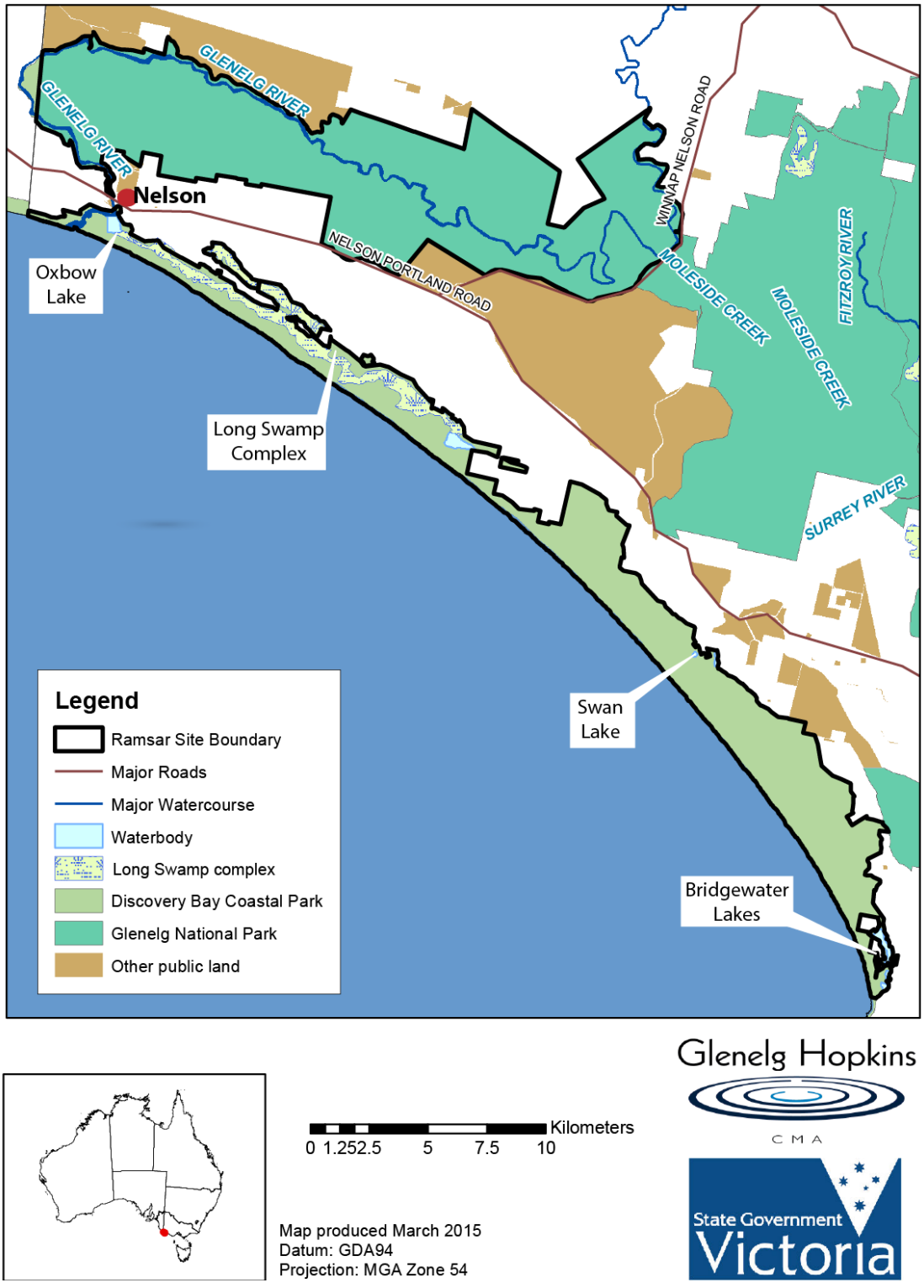

Figure 1: Location of the Glenelg Estuary and Discovery Bay Ramsar Site.

Ramsar Criteria

The Glenelg Estuary and Discovery Bay Ramsar Site meets the following five Ramsar nomination criteria:

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.

This site meets this criteria through its unique combination of geomorphological features (dune slacks) and wetland types, including groundwater dependent ecosystems, several of which are recognised as globally threatened wetland types: fens, wet grasslands and temporary pools.

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 a threatened ecological community, two species of threatened plant and six threatened animal species listed nationally (EPBC) and / or internationally (IUCN).

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 meets this criterion for supporting migratory species of waterbirds and fish and by acting as a drought refuge during adverse conditions. Specifically, the site provides habitat for 95 waterbird species including 24 species listed under international migratory bird agreements. Native fish populations include 14 species which are diadromous, migrating between habitats for part of their lifecycle.

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 site provides a range of fish species with sources of food, spawning grounds and nurseries, and acts as a migration path on which diadromous fishes of the region depend.

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 site meets this criterion for the ancient greenling (*Hemiphlebia mirabilis*). The sub-population at Long Swamp likely represents more than 1% of the total population for this species.

Critical components, processes and services

A simple conceptual model for Glenelg Estuary and Discovery Bay 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 Glenelg Estuary and Discovery Bay 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).

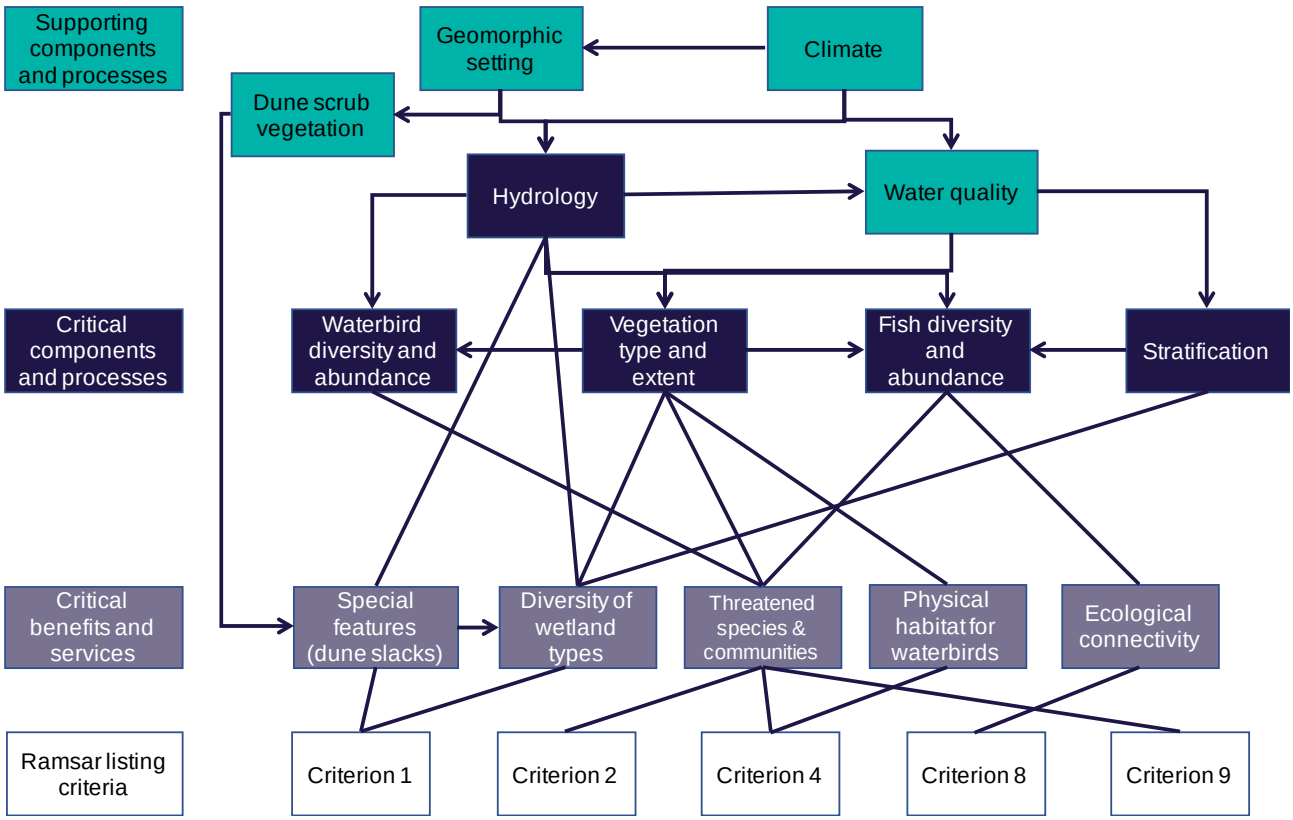

Figure 2: Simple conceptual model showing the key relationships between components and processes; benefits and services (CPS) and the criteria the site meets as a Wetland of International Importance.

Table 1: Summary of supporting components within the Glenelg Estuary and Discovery Bay Ramsar Site.

Component / process	Description
Climate	Rainfall is winter dominant and plays a significant role in supporting the local groundwater aquifers. Average annual rainfall is in the order of 800 millimetres per year. Evaporation exceeds rainfall in the non-winter months.
Geomorphic setting	Geomorphic setting is a key driver of wetland ecology exerting a strong influence on surface and groundwater connections and influencing the hydrological regime.The Glenelg Estuary and Discovery Bay wetlands are located on the southern Victorian coastal plain in a barrier complex geomorphic unit (Rowan et al. 2000). The geology, topography and soils are described as belonging to three land systems: Discovery Bay land system, which comprises the area from the coast to behind the barrier dunes, Long Swamp land system which runs parallel to the coast and comprises a chain of low lying wetlands and the Nelson land system, which covers the Glenelg Estuary. Soils are peat, calcareous and alkaline (Gibbons and Downes 1964).
Water quality – nutrients, pH, turbidity	Available water quality data for the freshwater lakes (Long Swamp complex, Bridgewater Lakes) indicate that nitrogen levels are moderately high, while phosphorus levels are low. The wetlands are typically clear, fresh and alkaline. Water clarity in the estuary is influenced by freshwater inputs from the Glenelg River as well as inflowing marine water. Water clarity is generally high (i.e. low turbidity), particularly when tidal exchange is high, but can vary with high turbidity inflows from the Glenelg River.
Dune scrub vegetation	Dune scrub vegetation is a terrestrial community that is critical for stabilising the matrix of dunes within the site and the dune slacks in which the many of the site's freshwater wetlands are formed.

Table 2: Summary of critical components, processes and services (CPS) within the Glenelg Estuary and Discovery Bay Ramsar Site.

CPS	Description
Components	
Hydrology	While a knowledge and quantification of ecosystem water regimes is limited, it is understood that many of the wetlands in the site, including the Glenelg Estuary are groundwater dependent. It is suspected that groundwater is a significant water source for these systems, at times contributing more than surface water sources. The hydrology of the Glenelg Estuary is influenced by the tidal cycle, when the estuary is open and freshwater river inflows, the latter of which are seasonal. A range of wetland water regimes are present and several of the wetlands, such as the Bridgewater Lakes are permanently inundated.
Vegetation – type and extent	Nationally threatened coastal saltmarsh is present at Oxbow Lake. Freshwater sedgelands and tall marsh vegetation extend across the Long Swamp wetlands Lake bed macrophytes - submerged macrophyte communities are a characteristic of the permanent lakes, and the Bridgewater Lakes supports a charophyte community.
Fish – diversity and abundance	Fifty-three native fish species from 29 families have been recorded in the site, 28 of which are considered to be regularly supported. This includes fish with a range of life-history strategies including freshwater, estuarine, marine and diadromous species that move between habitats. The site provides feeding, spawning and nursery areas for a range of fish species including several that are recreationally important such as black bream.
Waterbirds – diversity and abundance	Ninety-five species of waterbird have been recorded within the site, including 24 listed under international migratory bird agreements. Complete counts are not available and waterbird abundance is a knowledge gap for the site. Nine species have been recorded breeding in the site, including several beach nesting species such as red-capped plover and little terns.
Process	
Stratification	The Glenelg Estuary is a seasonally closed salt-wedge estuary with three distinct layers which vary under different tidal and freshwater inflow conditions. Salinity follows a spatial gradient from the lower to the upper estuary. The salt wedge most of the time extends up the entire length of the estuary, with bottom water salinity often close to seawater and only occasional differences between the lower and upper estuaries. Stratification is important for maintaining aquatic flora and fauna and in particular acts as a cue for reproductive cycles in many fish species such as black bream.
Services	
Diversity of wetland types	The site comprises a network of interconnected wetland types including freshwater permanent wetlands, intermittently inundated marshes, estuarine waters and intertidal sandy beaches.
Special geomorphic features	The site is significant for a number of geological and geomorphic features; in particular the dune slack system is rare, if not unique within the bioregion.
Provides physical habitat (for waterbirds)	The site provides a network of habitats for waterbird feeding, roosting and breeding. Species that are supported by the site represent a wide range of functional groups (e.g. fishers, waders, ducks) each with different habitat requirements.
Threatened wetland species and communities	One nationally listed ecological community and eight nationally or internationally listed species of conservation significance are supported by the site.
Ecological connectivity	The Ramsar site has a range of distinct wetland types which are both hydrologically and ecologically connected. The connection between the marine, estuarine and freshwater components is significant for fish migration and reproduction.

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 Glenelg Estuary and Discovery Bay Ramsar Site have been developed for critical components, processes and services and are summarised in Table 3.

Table 3: LAC for the Glenelg Estuary and Discovery Bay Ramsar Site.

Critical CPS	Limit of Acceptable Change
Hydrology	Bridgewater Lakes, Lake Moniboeng, Swan Lake, Malseed Lake and Cain Flat Swamp will not dry. The Glenelg Estuary will not remain closed for three consecutive years or open for greater than five continuous years.
Stratification	See LAC for hydrology (Glenelg Estuary)
Vegetation type and extent	Vegetation extent will not fall below the following: • Coastal saltmarsh - 13 hectares • Freshwater sedges and tall marsh - 470 hectares, with at least 270 hectares of *Baumea* sedgelands.
Fish diversity and abundance	Native fish within the Ramsar site will represent each of the following life history strategies: estuarine dependent, estuarine opportunists, marine migrants, diadromous and obligate freshwater species.
Waterbird diversity and abundance	Absence of the following waterbird guilds in any three out of five years: • Ducks, swans and grebes • Fishers • Large wading birds • Australian waders • International waders • Gulls and terns • Sanderling abundance falls below 0.7% of the global population in three out of five years.
Diversity of wetland types	See LAC for vegetation type and extent and hydrology.
Special geomorphic features: dune slack	No LAC. The formation of dune slack wetlands is a critical feature of the site and contributes to meeting criterion 1. This service, however, does not lend itself to having a threshold of change as it operates on geological time scales.
Physical habitat for waterbirds	See LAC for vegetation type and extent and hydrology.
Threatened species: plants	Absence of maroon leek-orchid (*Prasophyllum frenchii*) and or swamp greenhood (*Pterostylis tenuissima*) in three consecutive targeted surveys.
Threatened species: fish	Absence of Yarra pygmy perch (*Nannoperca obscura*) in any three out of five targeted surveys.
Threatened species: birds	Absence of hooded plover (*Thinornis rubricollis*) in three out of five years.
Threatened species: growling grass frog	Absence of growling grass frog (*Litoria raniformis*) in any three out of five targeted surveys.
Threatened species: ancient greenling	See LAC for vegetation type and extent (*Baumea* sedgelands).
Ecological connectivity	See LAC for hydrology (Glenelg Estuary) and fish (continued presence of diadromous fish).

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

1 Introduction

1.1 Site details

This document is the Ecological Character Description (ECD) and forms part of the required nomination documents (DSEWPAC 2012) for the Glenelg Estuary and Discovery Bay Ramsar Site as a Wetland of International Importance under the Ramsar Convention. The site details are summarised in Table 4.

Table 4: Site details for the Lower Glenelg Estuary and Discovery Bay Ramsar Site.

Site Name	Glenelg Estuary and Discovery Bay Ramsar Site
Location in coordinates	Latitude (GDA94): 37° 59'S to 38° 20'S. Longitude (GDA94): 140° 58'E to 141° 24'E.
General location of the site	The site is located in the south western corner of Victoria, 430 km west of Melbourne. It is located on the coast adjacent to the state border with South Australia and includes the Victorian sections of the Glenelg Estuary a series of wetland complexes (the Long Swamp wetlands complex; Lake Malseed complex and Bridgewater Lakes) and approximately 50km of coast down to the low water mark.
Area	22,289 hectares
Date of Ramsar site designation	TBC
Ramsar/DIWA Criteria met by wetland	Ramsar criteria met: 1,2,4,8,9
Management authority for the site	The land manager is Parks Victoria.
Date the ECD applies	2017
Status of Description	This represents the first ECD for the site.
Date of Compilation	October 2017
Name(s) of compiler(s)	Rhonda Butcher on behalf of the GH CMA, all enquires to Gavin Prentice, Glenelg Hopkins Catchment Management Authority 79 French Street, Hamilton, Victoria, Australia, 3300. (Tel: +61 5564 2616, Fax: +61 55712935).
References to the Ramsar Information Sheet (RIS)	Glenelg Estuary and Discovery Bay Ramsar Site compiled October 2017.
References to Management Plan(s)	Glenelg Estuary and Discovery Bay Ramsar Site Management Plan compiled October 2017.

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 for signatories and local site managers. 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*
>
> *"…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 have 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* (DEWHA 2008).

In Australia, the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) provides a legal framework for regulating actions that will have or are likely to have a significant impact on the ecological character of a Ramsar wetland and managing Ramsar wetlands (Figure 3).

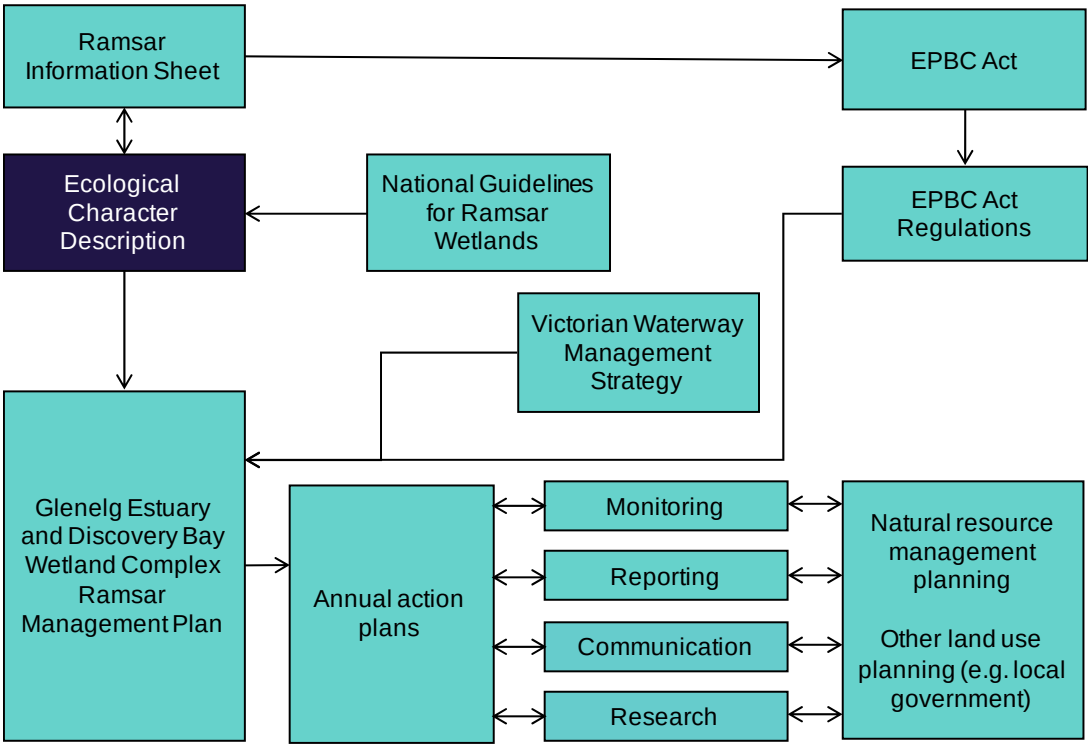

Figure 3: The ecological character description in the context of other requirements for the management of Ramsar sites.

The 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 that would indicate when the ecological character has or is likely to change. McGrath (2006) detailed the general aims of an ECD as follows:

1. To assist in implementing Australia's 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 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 is relevant to the description of the ecological character of the 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:
    - JAMBA (Japan Australia Migratory Bird Agreement)
    - CAMBA (China Australia Migratory Bird Agreement)
    - ROKAMBA (Republic of Korea Australia Migratory Bird Agreement)
    - The Bonn Convention on Migratory Species (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)).*
- *EPBC Regulations (2000): Australian Ramsar Management Principles.*
- *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.

Victorian legislation and policy

- *Environment Protection Act 1970* establishes the Environment Protection Authority and makes provision for the Authority's powers related to improving the air, land and water environments.
- *Wildlife Act 1975* ensures procedures are in place to protect and conserve Victoria's wildlife and prevent any taxa of wildlife from becoming extinct.
- *Crown Land (Reserves) Act 1978* provides the framework for the administration and management of Crown land reserves including nature conservation reserves.
- *Water Act 1989* establishes rights and obligations in relation to water resources and provides mechanisms for the allocation of water resources.
- *Flora and Fauna Guarantee Act 1988* is the legislative and administrative framework for the conservation of biodiversity in Victoria.
- *Catchment and Land Protection Act 1994* establishes a framework for the integrated management and protection of catchments.
- *Environment Effects Act 1978* establishes the processes for assessment of proposed projects (works) that are capable of having a significant effect on the environment.
- *Planning and Environment Act 1987* sets out procedures for preparing and amending the Victoria Planning Provisions and planning schemes, obtaining permits under schemes, settling disputes, enforcing compliance with planning schemes, and other administrative procedures.
- *Fisheries Act 1995* provides a framework for the regulation, management and conservation of Victorian fisheries.
- *Aboriginal Heritage Act 2006* provides for the protection and management of Victoria's Aboriginal heritage.

Victorian and regional strategies

- *Victorian Waterway Management Strategy (VWMS) (2013*)**.** The VWMS provides the policy for nominating new Ramsar sites in Victoria. The VWMS also sets out the ongoing policies and actions for managing Victoria's Ramsar sites. These are to (DEPI 2014):
  - adhere to the national Australian Ramsar Management Principles and national Ramsar site guidance for describing the ecological character of Ramsar sites, mapping site boundaries, notifying change in ecological character and preparing Ramsar site management plans;
  - monitor and report on the ecological character of Ramsar sites, including any change in ecological character at individual sites every three years; and
  - maintain up-to-date documentation for Ramsar sites, including Ramsar information sheets, ecological character descriptions, management plans, site descriptions and maps.
- Glenelg Hopkins Waterway Strategy 2014-2022 (GHWS**)** is a key planning document for river, estuary and wetland management in the Glenelg Hopkins region, which includes the Ramsar site.
- *Ngootyoong Gunditj Ngootyoong Mara South West Management Plan* (superseding the previous Lower Glenelg National Park Management Plan) is a strategic guide for managing and protecting over 130 parks, reserves and Indigenous Protected Areas in south-west Victoria (Parks Victoria 2015).

1.4 Preparing the ECD

This ECD for the Glenelg Estuary and Discovery Bay Ramsar Site is based on 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 4.

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

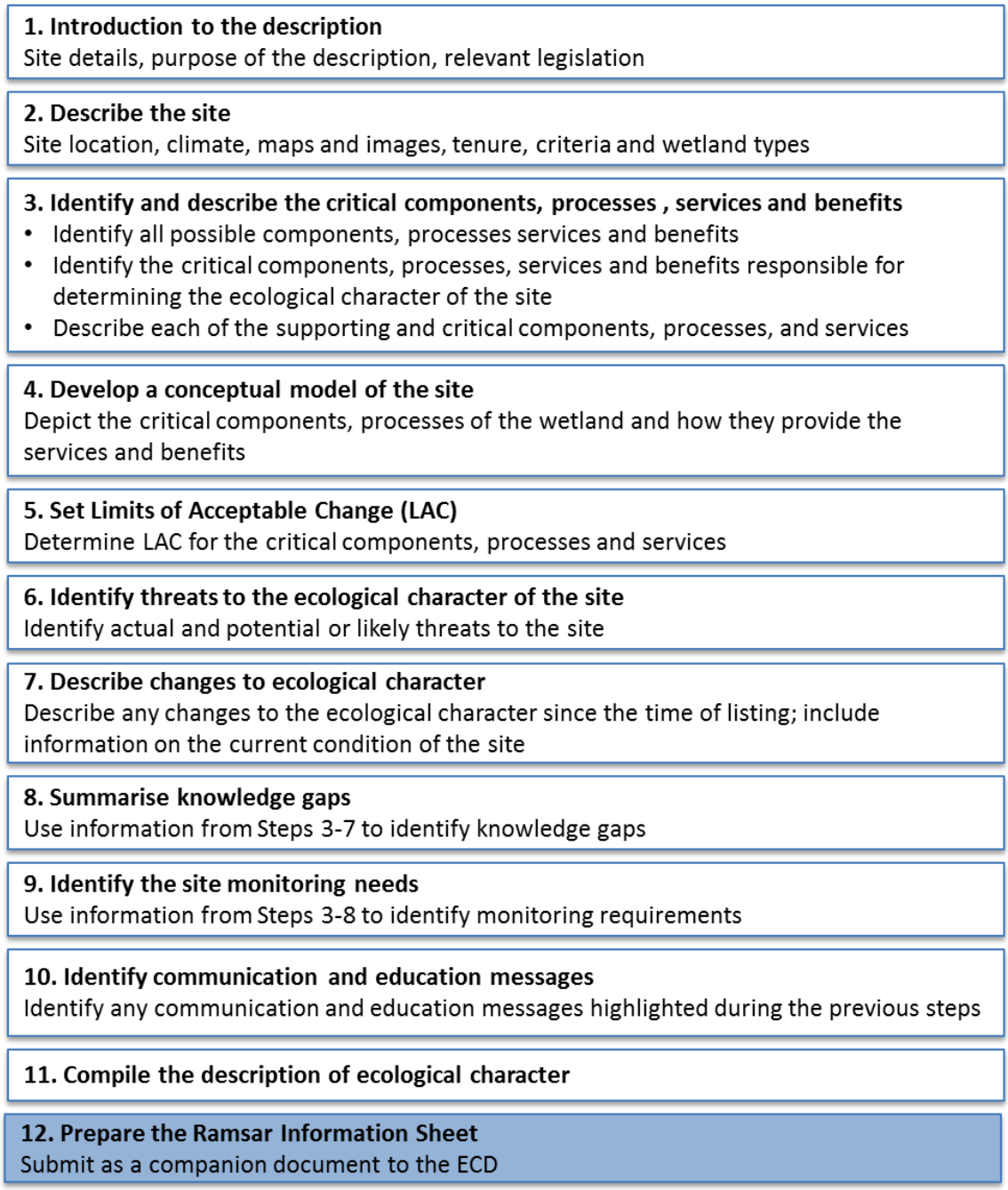

Figure 4: Twelve step process for developing an ECD (adapted from DEWHA 2008)

2 General description of the Glenelg Estuary and Discovery Bay Ramsar Site

2.1 Location

The proposed Glenelg Estuary and Discovery Bay Ramsar Site is situated in western Victoria in the Glenelg Hopkins Catchment Management Authority (GHCMA) region. The region supports various agricultural industries (e.g. livestock grazing, soft and hardwood plantations), and includes major population centres at Portland and Hamilton in Victoria and Mount Gambier in South Australia. The site is located adjacent to the Victorian-South Australian border, approximately 430 kilometres west of Melbourne (Figure 5). Nelson is the township closest to the Ramsar site (Figure 6).

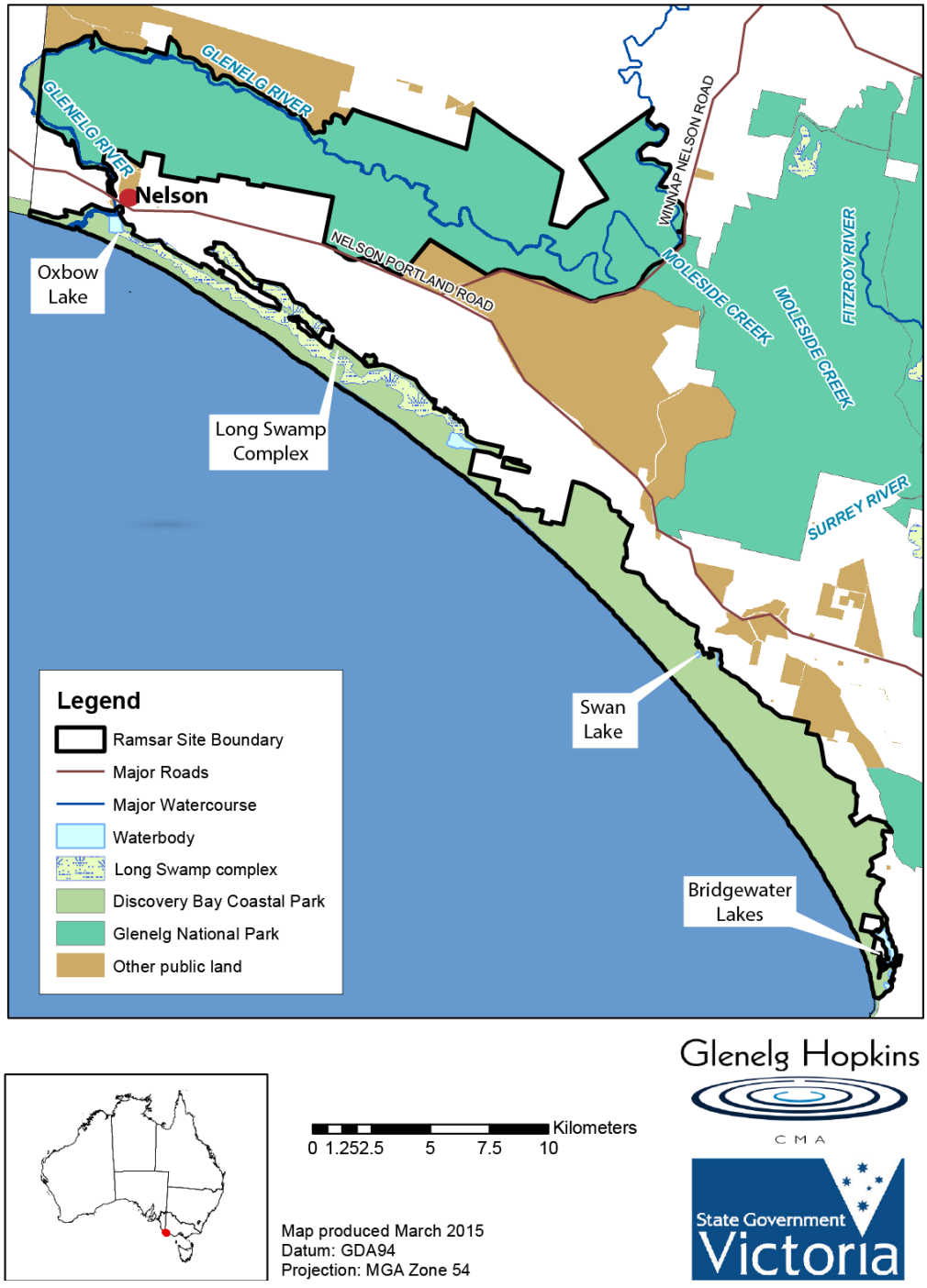

Figure 5: Location of the Glenelg Estuary and Discovery Bay Ramsar Site.

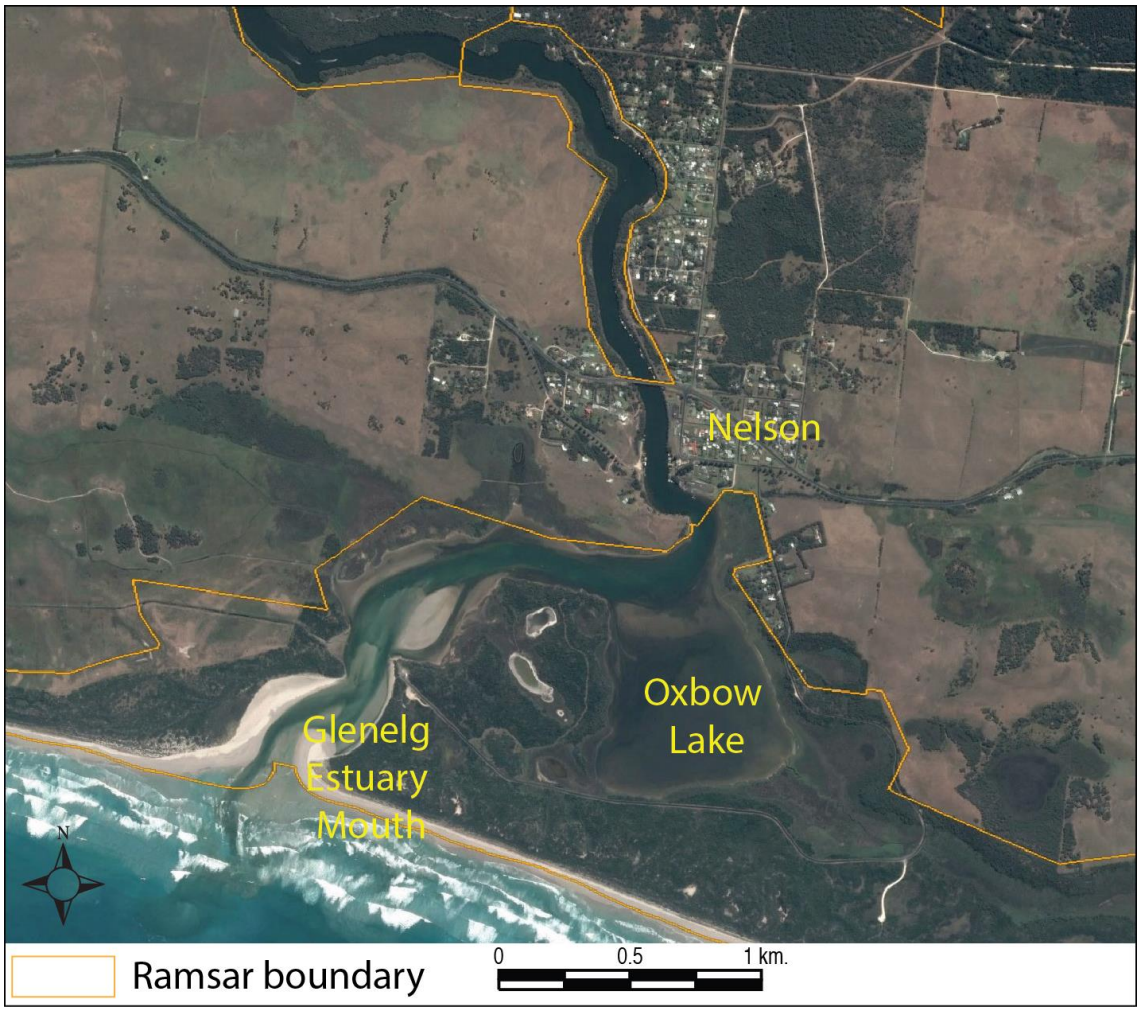

Figure 6: Close-up of Ramsar site boundary near the town of Nelson. Note the 600m stretch of river excluded from the site, the estuary mouth and Oxbow Lake.

2.2 Overview of the site

The Ramsar site covers approximately 22,289 hectares and comprises the western part of Lower Glenelg National Park from the South Australian border to the Nelson - Winnap Road, most of the Discovery Bay Coastal Park and the Nelson Streamside Reserve. The boundary excludes the portions of the Glenelg Estuary that lie within South Australia as well as 600 metres of the estuary channel adjacent to the town of Nelson (see Figure 6). More detail is provided in the Boundary Description for the Site.

Major land uses adjacent to the site include forestry (primarily pine plantations) and grazing of improved and natural pastures (Figure 7). Land tenure within the Ramsar site is summarised in Table 5. Both the National Park and Coastal Park are managed by Parks Victoria in partnership with local stakeholders (Parks Victoria 2015).

The Ramsar site comprises three broad systems that support different wetland types: freshwater wetlands, the Glenelg Estuary and the beach and dune system. These systems support a diversity of waterbird, fish and plant assemblages including a significant number of threatened species and ecological communities (Glenelg Hopkins CMA 2014 and 2006a, Parks Victoria 2015). The area is popular for recreational and tourism activities, including sightseeing, walking, camping, and recreational fishing. Importantly, the Gunditjmara Indigenous people have a living association with the Ramsar site, which has great cultural significance for them, as it is part of their Koonang (sea) and Bocara Woorrowarook (river forest) country (Parks Victoria 2015).

Table 5: Land tenure within Glenelg Estuary and Discovery Bay Ramsar Site.

Description	Area (hectares)
Crown land – National Park managed by Parks Victoria in partnership with local stakeholders	13,276
Crown land – Crown reserve	36
Crown land – Coastal Park managed by Parks Victoria in partnership with local stakeholders	8,977

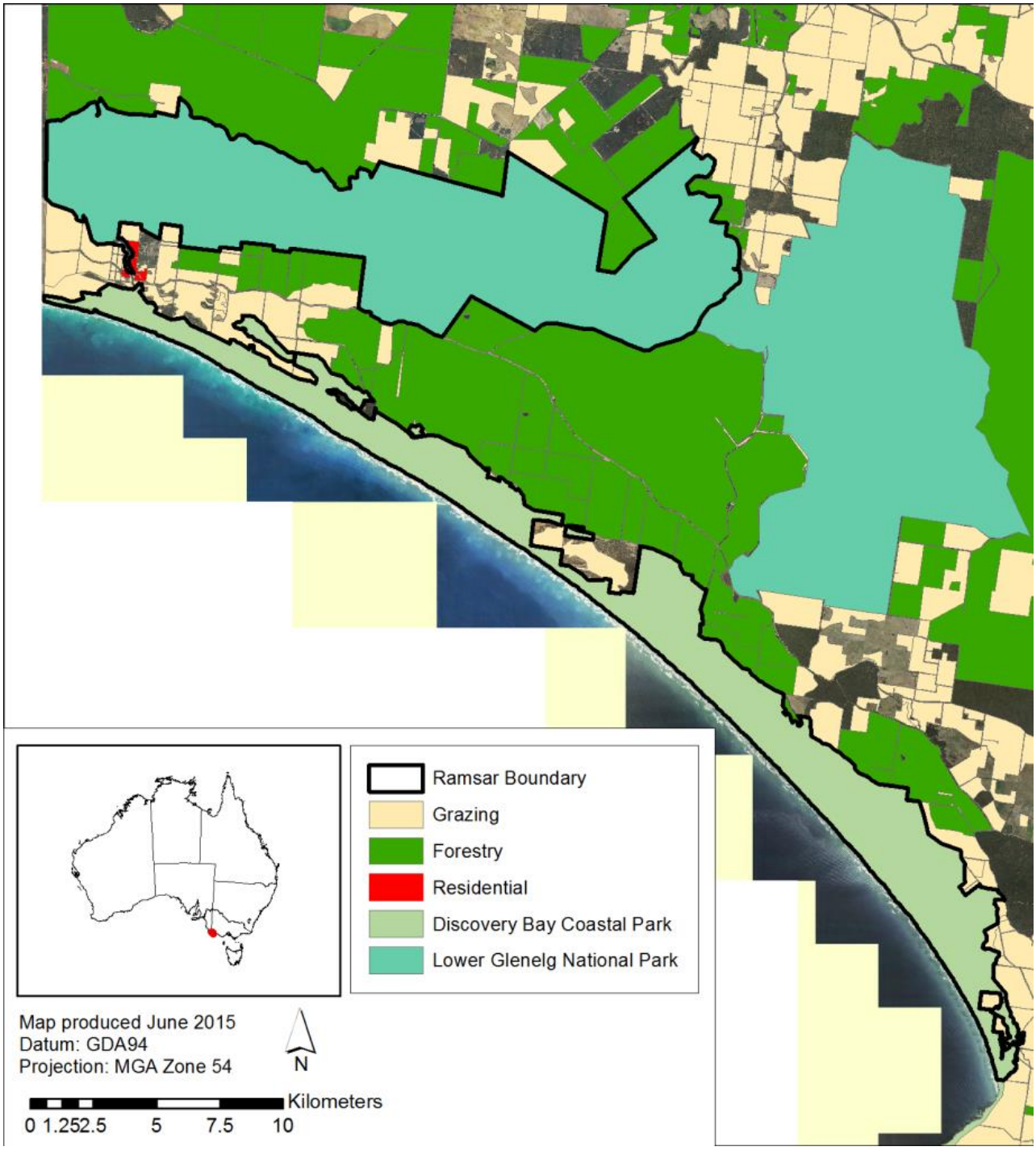

Figure 7: Major land use adjacent to the Glenelg Estuary and Discovery Bay Ramsar Site.

2.3 Wetland types

2.3.1 Freshwater wetlands

The freshwater wetlands found within the Ramsar site consist of several wetland complexes, which lie in a chain behind the dune system. From west to east they are: Long Swamp complex, Lake Malseed complex and the Bridgewater Lakes. The Long Swamp complex includes Sheepwash Lagoon, Cains Hut Swamp, and several unnamed lagoons, Lake Moniboeng (also called Lake Bung Bung) as well as Black Swamp, McFarlanes Swamp and Eel Creek (Reynolds 2007). The Long Swamp complex is connected to the Glenelg Estuary at Oxbow Lake via Eel Creek. The Malseed complex includes Malseed Lake, Swan Lake and Boomer Swamp (Head 1987). The Bridgewater Lakes (Figure 8) are a sequence of five freshwater lakes at the south eastern end of the site, approximately three kilometres north of the town of Bridgewater (DEPI 2015).

Some of these wetlands are part of a humid dune slack system – see section 2.2.3 below.

Figure 8: Aerial image of Bridgewater Lakes (wetland type O, permanent freshwater lakes) looking west October 2015 (© Marcel Hoog Antink).

2.3.2 Glenelg Estuary

The Glenelg Estuary is a seasonally closed, salt wedge type estuary and the longest estuary in Victoria (Pope unpublished), with a volume of approximately 22 gigalitres and a surface area of approximately 510 hectares. It extends 75 kilometres from its mouth near the township of Nelson, to just below the township of Dartmoor (Sherwood et al. 1998 cited in Glenelg Hopkins CMA 2006a). The estuary comprises the long channel as well as Oxbow Lake, a coastal lagoon that extends from the channel and connects to the Long Swamp complex via Eel Creek (Figure 9). The estuary is surrounded by small areas of coastal saltmarsh and temporary marshes dominated by sea rush (*Juncus kraussii*) and *Gahnia filum*.

Figure 9: Lower Glenelg Estuary component of Ramsar site (from Google Earth – 2014), note open mouth of estuary.

2.3.3 Beach and dune system

Discovery Bay forms a long sandy intertidal beach, broken at intervals by outcrops of the underlying rocky limestone (Pleistocene calcarenite; Figure 10). It has a south-westerly aspect, resulting in a high-energy coastline, backed by an extensive dune system (Head 1987). The beach and sand dunes of Discovery Bay are recently deposited sands and extremely mobile, representing the most active sands of the Victorian coastline (Gibbons and Downes 1964), (DEPI 2015). A large part of the dune system can be classified as humid dune slacks, a rare and very poorly documented wetland type in the bioregion (and Australia). Dune slacks are depressions in the dune system that hold “slack” (still or slow moving) water either from groundwater or high tides (section 3.7.2 for further information).

Figure 10: Nobles Rocks along beach and fore dune with Long Swamp behind fore dune, October 2015 (© Marcel Hoog Antink).

2.3.4 Ramsar 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 E (sandy shores) and Type G (intertidal sand flats) both apply to the beach section of the Ramsar site, and Type F (estuarine waters) and Type B (marine sub-tidal beds) are applicable to Oxbow Lake. 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 6.

Table 6: Wetland types within the Glenelg Estuary and Discovery Bay Ramsar Site (in descending order of dominance, estimated from multiple lines of evidence, Victorian wetland mapping, vegetation mapping and Sinclair and Sutter 2008).

Ramsar type	Description	Locations within the site
F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas.	Glenelg Estuary including channel to tide extent and the permanent Oxbow Lake (Figure 11 and Figure 12).
E	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.	Shoreline and coastal dunes along the beach area from low water mark to the foot of the dunes, and the dunes themselves, which include the dune slacks (Figure 13).
G	Intertidal mud, sand or salt flats.	Includes the intertidal beach area as well as smaller locations within the Glenelg Estuary, particularly when the estuary is open and subject to tidal exchange.
U	Non-forested peatlands; includes shrub or open bogs, swamps, fens.	Long Swamp depressions (Figure 14), comprising of areas of dense sedge wetlands dominated by twig –sedge (*Baumea* spp.) and mixed swamp scrub of woolly tea-tree (*Leptospermum lanigerum*), scented paperbark (*Melaleuca squarrosa*) and saw-sedge (*Gahnia* spp.).
O	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.	Bridgewater Lakes (North and South), Lake Moniboeng.
Tp	Permanent freshwater marshes/pools; ponds (below 8 ha.	Swan Lake, Malseed lake, Cains Hut Swamp (Figure 15).
H	Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.	Western and eastern shore of the Glenelg River channel and the western and eastern shore of Oxbow Lake. Includes patches of coastal saltmarsh dominated by either saw-sedge (*Gahnia filum*) or beaded glasswort (*Sarcocornia quinqueflora*) (Figure 16).
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools.	Intermittent saline meadows around three depression basins located between the river channel and Oxbow lake.
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.	Intermittent marshes within the Long Swamp complex.
N	Seasonal/intermittent rivers, streams and creeks.	Outlet Creek connecting Long Swamp to the sea through the dunes.
B	Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows.	Scattered seagrass recorded in lower reaches of the Glenelg estuary.

Figure 11: Aerial of Glenelg Estuary and mouth, with Oxbow Lake in background (Ramsar type F). Mouth is closed (© Marcel Hoog Antink).

Figure 12: Glenelg Estuary – high view on Great South West Walk, illustrating constrained nature of channel in Lower Glenelg River National Park, Ramsar type F (R. Butcher).

Figure 13: Beach (sand and intertidal) and fore dune, Ramsar types E and G (Nelson end of site) (A. White).

Figure 14: Long Swamp Wetland near Nobles Rocks outlet showing fen and shrub wetlands, Ramsar type U, October 2015 (© Marcel Hoog Antink).

Figure 15: Swan Lake, Ramsar type Tp, November 2015 (R. Butcher).

Figure 16: Coastal saltmarsh, Ramsar type H, November 2015 (R. Butcher).

2.4 Ramsar criteria

The site meets five of the nine Ramsar listing criteria (Table 7). An assessment against each of the Ramsar criteria for the Glenelg Estuary and Discovery Bay wetlands is presented below. Further data collection focusing on elements of biodiversity and waterbirds may result in this site also meeting criterion 3 and 6 in the future and this can be addressed through the regular updates of the Ramsar Information Sheet (RIS) and potential addenda to the ECD.

Table 7: Ramsar listing criteria with those met at the Glenelg Estuary and Discovery Bay 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% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Fish	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Fish	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend
Criterion 9	Other taxa	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species

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 East Coast (Victoria) Drainage Division extends from the New South Wales – Victorian

border along the coast to the Millicent basin in South Australia. The Ramsar guidance for this criterion indicates that the justification should be based on wetland type and hydrology. The Glenelg Estuary and Discover Bay Ramsar Site meets this criterion with respect to rare wetland types in the bioregion (and globally) because of its peat wetlands and dune slack wetlands; and the Glenelg Estuary, which is considered a good near-natural representative of wetland type E in the bioregion.

The peatlands of the Ramsar site are fen wetlands (i.e. groundwater dependent) and largely have an intact hydrology. These are a rare wetland type globally, with nearby Piccaninnie Ponds Karst Wetlands Ramsar Site perhaps representing the only other significant fen wetland in the bioregion.

The site is geomorphically significant as it includes a humid dune slack system, which is rare in Australia. The dune slack system supports peatlands, wet grassland habitats and temporary pools, which are identified by the Ramsar Convention as globally significant (Ramsar Convention 2003).

The geomorphology and hydrology of the estuary section of the Ramsar site is unusual within the bioregion and can be considered a good representative of wetland type E. It is characterised by:

- being the longest estuary in Victoria (75 kilometres),
- having a groundwater dominated hydrology, and
- significant areas of limestone gorge for most of its length upstream of Nelson.

This site clearly meets criterion 1, through its unique combination of geomorphological features and wetland types, including groundwater dependent ecosystems which include several of the most globally threatened wetland types: fens, wet grasslands and temporary pools.

Criterion 2

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

In the Australian context, it is recommended that this criterion should only be applied to nationally threatened wetland dependent species and communities, listed under the *EPBC Act* 1999 or the International Union for Conservation of Nature (IUCN 2012b) Red List. The site regularly supports one threatened ecological community, two species of threatened plant and seven threatened animal species (Table 8).

Table 8: Threatened wetland dependent species recorded at the Glenelg Estuary and Discover Bay wetlands. CE = critically endangered; En = endangered; Vu = vulnerable: listed under EPBC Act and IUCN Red List (IUCN 2015) May 2015. Strength: Certain = annual records; High = records for most years but some data gaps, high level of confidence still at the site.

Community/Species	IUCN	EPBC	Records	Strength of evidence for regularly supports/residency
Communities				
Subtropical and temperate coastal saltmarsh		Vu	2008, 2014	Certain – recent vegetation mapping indicates this threatened community occurs in the estuary section of the site.
Plants				
Maroon Leek-orchid - *Prasophyllum frenchii*		En	2004, 2008, 2014	High – lack of recent records, however believed still to be present. Twenty four plants recorded in 2004 (Duncan 2010), and 216 recorded in the Discovery Bay Park in 2008 (Victorian Biodiversity Atlas (VBA) extract).
Swamp greenhood - *Pterostylis tenuissima*		Vu	2004, 2008, 2009, 2010 2014	High – located at a number of sites within the Ramsar site (Dickson et al. 2012)
Waterbirds				

Community/Species	IUCN	EPBC	Records	Strength of evidence for regularly supports/residency
Australasian bittern - *Botaurus poiciloptilus*	En	En	1979, 1991, 1992, 2003, 2012, 2015	High – there are a number of records for this cryptic species from within the site, within the Long Swamp complex and the Fringing areas of the Glenelg Estuary (records from BirdLife Australia Bird Atlas).
Fairy tern – *Sterna nereis nereis*	Vu	Vu	1999, 2001-2004, 2007, 2011	High – records from 1999 – 2004; some recent observations on the Atlas of Living Australia.
Hooded plover - *Thinornis rubricollis*	Vu	En	Biennial count since 1980	Certain – solid long term records for this species at the site. The number of birds recorded at the site increased between 2010 and 2012 (Ewers et al. 2011, Mead et al. 2012).
Fish				
Yarra pygmy perch – *Nannoperca obscura*	Vu	Vu	2012, 2014, 2015	Certain – recorded in substantial numbers in recent surveys Lake Moniboeng and Long Swamp.
Amphibians				
Growling grass frog - *Litoria raniformis*	En	Vu	1998, 1999, 2012	High – Audio calls from Long Swamp (Bachmann et al. 2013). Earlier records from Swan Lake, Lake Moniboeng and Bridgewater Lakes (Bachmann et al. 2013).
Invertebrates				
Ancient greenling – *Hemiphlebia mirablis*	En		2008-2014	Certain – recent investigations estimate a very large population at Long Swamp (Cordero Rivera 2014). Records are available from Long Swamp 2008-2010 (Crowther 2011).

There are records for several other species from the site that may be regularly supported, but for which there is insufficient evidence at this stage to include them in the justification for this criterion. This includes two international migratory shorebirds the curlew sandpiper (*Calidris ferruginea*) and Eastern curlew (*Numenius madagascariensis*) and the Southern bent-wing bat (*Miniopterus orianae bassanii*). There are very sparse records and low counts of both the bird species from within the site, despite semi-regular counts of shorebirds. In the case of the southern bent-wing bat, the species is present in several caves along the Glenelg Estuary; it is, however, not considered wetland dependent and so cannot contribute to the meeting of this criterion.

In 2015, the species Eastern dwarf galaxias (*Galaxiella pusilla*) was revised and the species that occurs in the Ramsar site is now called the little galaxias (*Galaxiella toourtkoourt*) (Coleman et al. 2015). While the little galaxias is listed under State threatened species legislation, it is not currently listed at the national or international level.

The Glenelg Estuary and Discovery Bay wetlands clearly meet this criterion supporting at least eight listed species and one ecological community on a regular basis.

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.

To adequately assess against this criterion the following minimum information is needed (Ramsar Convention 2012):

- an inventory of plant and/or animal species present at the site,
- a broad understanding of the elements which define the characteristic plant and animal diversity of the biogeographic region in which the wetland occurs, and

- a broad understanding of the significance of the specific wetland in the context of the wider regional biodiversity assessment.

There are no data available which suggests the site is a centre of species endemism, and incomplete records from the bioregion. A lack of survey effort, particularly at Bridgewater Lakes, Lake Malseed, Swan Lake and some of the other smaller wetlands makes it difficult to make a meaningful comparison with other locations in the bioregion.

Over 320 plant species have been recorded from the Discovery Bay Coastal Park (Parks Victoria 2006) with a number of species of conservation significance both nationally and at the state level, however, the proportion of these which are wetland dependent is currently unknown. Recent vegetation surveys have collected data for the Long Swamp and Oxbow Lake areas of the site, but complete surveys of wetland dependent vegetation across the whole site are lacking. There have been limited surveys of fish with at least 53 native species from the Ramsar site (Bachmann et al. 2013, Veale 2014, 2016), but this too is considered a knowledge gap.

Overall the typical evidence (i.e. species richness, high levels of endemism), of the standard required under Ramsar Convention guidance to test this criterion is currently unavailable (DEPI 2014), and the site is not deemed to meet this criterion.

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 long term intention of this criterion is to ensure wetlands within the Ramsar estate include those which are vital for providing habitat during critical life stages (breeding and migration) and or in periods of adverse conditions (Ramsar Convention 2009).

Specifically, the site provides habitat for 95 waterbird species including 24 species listed under international agreements: CAMBA (24), JAMBA (24), ROKAMBA (21), BONN (21) and 34 Australian migratory or marine species. Beach nesting birds such as hooded plover (*Thinornis rubricollis*) and red-capped plover (*Charadrius ruficapillus*) are regularly recorded nesting on the dunes of the Discovery Bay Coastal Park, albeit in low numbers (Ewers et al. 2011, Mead et al. 2012). The site also supports 14 species of native fish which are diadromous, migrating between habitats for part of their lifecycle. In addition, the permanent wetlands of the Long Swamp complex and Bridgewater Lakes provide habitat for obligate aquatic species when the surrounding landscape is dry and during drought conditions.

The site meets this criterion for supporting migratory species of waterbirds and fish as well as beach nesting birds and providing freshwater habitat when the surrounding region is dry.

Criterion 5

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

The site supports aggregations of waterbirds; however, it does not support 20,000 or more on a regular basis. The site does not meet this criterion.

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). Discovery Bay beach is an internationally important non-breeding area for Sanderling (*Calidris alba*) (Watkins 1993, Wetlands International, unpublished cited in DEPI 2004) and was considered the fourth most important site in Australia for Sanderling (DEPI 2004). There are recent records from within the site, above the one per cent threshold in 2008 and 2009. Numbers in 2010 to 2013, however, were below the threshold (Parks Victoria, unpublished data). At present, there is insufficient data to meet 'regularly

supports' part of the criterion (see Text Box 1). With further monitoring this criterion may be met in the future, but currently the data do not meet this criterion.

Table 9: Waterbirds species for which maximum counts exceed one percent of the relevant population (those with sufficient evidence to meet the provision of "regularly supports"; Text Box 1).

Common name	Species name	Population (one percent)	Maximum count	Years with counts above threshold
Sanderling	*Calidris alba*	220	610 (in 2005)	1981, 1983, 2005, 2008, 2009

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

i. the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or

ii. the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).

In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus, in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. For some countries or sites where there is very little information, single counts can help establish the relative importance of the site for a species.

The International Waterbird Census data collated by Wetlands International is the key reference source.

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

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.

The fish species records for the site include 53 species from 41 genera and 25 families, with a moderate level of biodisparity in regard to morphology and life history strategy. Compared to some other, larger Ramsar sites within the bioregion the fish species richness is low (e.g. Western Port 92 species, Gippsland Lakes over 170 species). The site is not considered to be significant at the bioregion or global scale and as such does not meet this criterion.

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.

Under the guidelines for this criterion coastal wetlands are identified as important feeding, spawning nursery habitats and as such supporting essential ecological processes for fish stocks, even if they do not necessarily harbour large adult fish populations themselves (Ramsar Convention 2009).

The Glenelg Estuary provides nursery habitat for several species of recreationally important fish including black bream (*Acanthopagrus butcheri*) and estuary perch (*Macquaria colonorum*). In particular, the seasonal opening and closing of the estuary is considered important in providing conditions for spawning of black bream (Jenkins et al. 2008).

In addition, the site supports at least 14 species of fish that migrate between habitats for parts of their lifecycle including: short finned eel (*Anguilla australis*), tupong (*Pseudaphritis urvillii*), estuary perch (*Macquaria colonorum*) and common galaxias (*Galaxias maculatus*). A recent tagging study has indicated that mulloway that feed in the Glenelg Estuary may migrate up to 400 kilometres to the Murray Mouth to spawn (Lieschke and Stoessel, in prep.).

The site provides a range of fish species with sources of food, spawning grounds and nurseries, and acts as a migration path on which diadromous fishes of the region depend, as such it is deemed to meet this criterion.

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. While several species may be supported in numbers greater than one percent of the population (e.g. growling grass frog (*Litoria raniformis*); Yarra pygmy perch (*Nannoperca obscura*)), there is insufficient data to determine population sizes. As such an assessment against this criterion for these species is not possible at this time.

There are recent data on the Ancient greenling (*Hemiphlebia mirabilis*) with the species first recorded at Long Swamp in 2008 and a detailed mark and recapture program completed in 2013 (Cordero-Rivera 2015). The species is the only extant representative of this superfamily of damselfly globally.

To date, 24 sites have records for the species across Victoria (19), South Australia (3) and Tasmania (2) (Crowther 2011, D. Crowther unpublished data), however four of the Victorian sites lack recent sightings. The sub-population at Long Swamp likely represents more than 1% of the total global population for this species, possibly as much as 5%, as Long Swamp represents the largest known area of habitat with the species present (D. Crowther unpublished data, Crowther 2011, Cordero Rivera 2013, Cordero-Rivera 2015).

This criterion is met on the basis of the site supporting more than 1% of the population of ancient greenling.

Figure 17: Ancient greenling adults in mating wheel at Long Swamp, Discovery Bay Coastal Park, Victoria (reproduced with permission, © Reiner Richter).

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 process 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; and
4. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics.

3.2 Identifying critical components and processes

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 but bring us no closer to understanding the system and how to best manage it. What is required is to identify the key components, the initial state of the systems, and the basic rules that link the key components and cause changes in state (Holland 1998). Thus, we need to identify and characterise 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 sites 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 Glenelg Estuary and Discovery Bay Ramsar Site was developed (Figure 18) to illustrate 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.

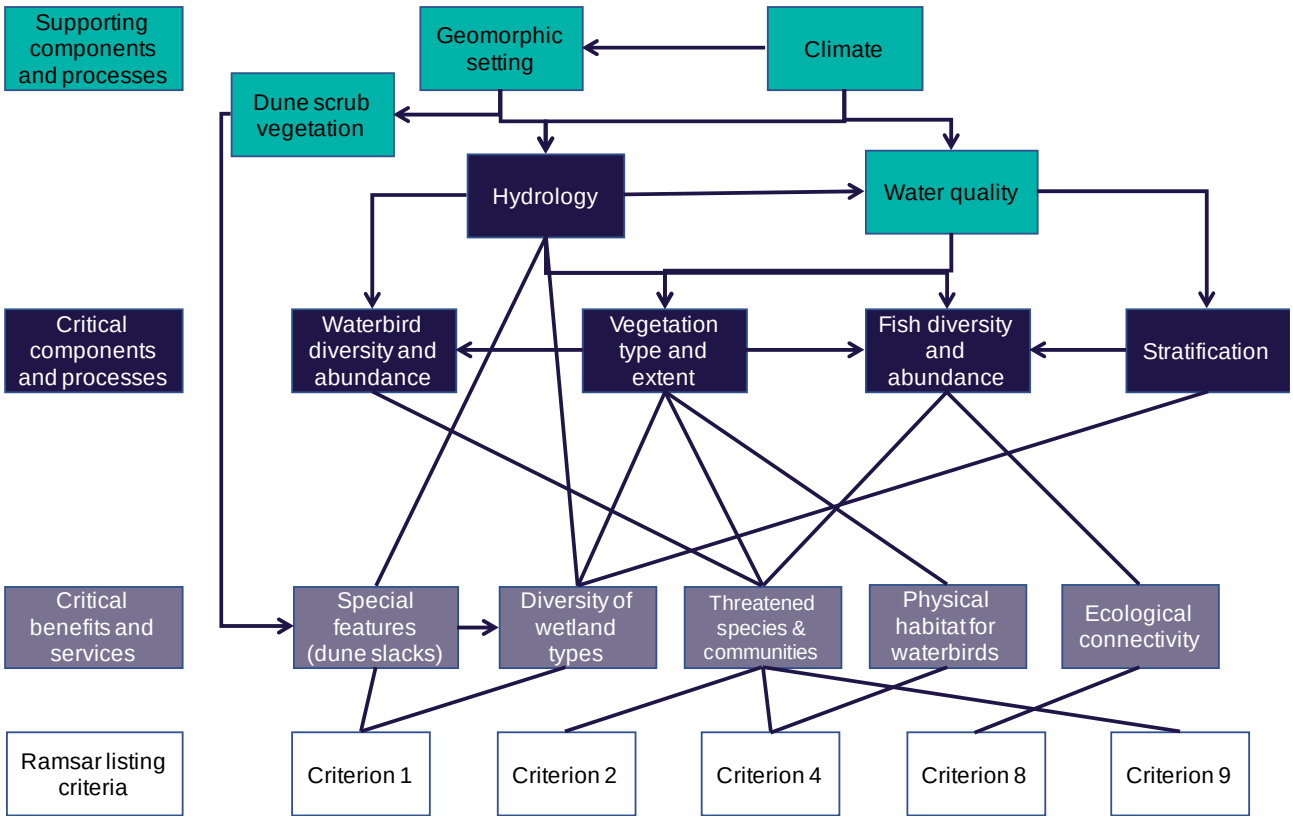

Figure 18: Simple conceptual model showing the key relationships between components and processes; benefits and services (CPS) and the reasons for the site being listed as a Wetland of International Importance.

The critical components, processes and services of the site are:

- **Components**:
  - Hydrology
  - Vegetation type and extent
  - Fish diversity and abundance
  - Waterbird diversity and abundance
- **Process**:
  - Stratification
- **Services**:
  - Special features (dune slacks)
  - Supports a diversity of wetland types
  - Supports threatened species
  - Provides physical habitat for waterbirds
  - Ecological connectivity

A complete list of services for the site and a justification for the selection of critical components, processes and services is provided in Appendix A. Descriptions of biota not considered critical to the ecological character of the site, but locally valued are described in Appendix B.

3.3 Supporting components and processes

Four components and processes have been identified as being important in supporting the critical CPS. 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 ECD includes a description of the following components and processes that are important in supporting the ecological character of the site (Table 10):

- Climate
- Geomorphic setting
- Water quality
- Dune scrub vegetation

Table 10: Summary of supporting components and processes within the Glenelg Estuary and Discovery Bay Ramsar Site.

Component / process	Description
Climate	Rainfall is winter dominant and plays a significant role in supporting the local groundwater aquifers. Average annual rainfall is in the order of 800 millimetres per year. Evaporation exceeds rainfall in the non-winter months.
Geomorphic setting	The Glenelg Estuary and Discovery Bay Ramsar Site is located on the south Victorian coastal plain in a barrier complex geomorphic unit (Rowan et al. 2000). The geology, topography and soils are described as belonging to three land systems: Discovery Bay land system, which comprises the area from the coast to behind the barrier dunes, Long Swamp land system which runs parallel to the coast and comprises a chain of low lying wetlands and the Nelson land system, which covers the Glenelg Estuary. Soils are peat, calcareous and alkaline (Gibbons and Downes 1964).
Water quality – nutrients, pH, turbidity	Available water quality data for the freshwater lakes (Long Swamp complex, Bridgewater Lakes) indicate that nitrogen levels are moderately high, while phosphorus levels are low. The wetlands are typically clear, fresh and alkaline. Water clarity in the estuary is influenced by freshwater inputs from the Glenelg River as well as inflowing marine water. Water clarity is generally high (i.e. low turbidity), particularly when tidal exchange is high, but can vary with high turbidity inflows from the Glenelg River.
Dune scrub vegetation	Dune scrub vegetation is a terrestrial community that is critical for stabilising the matrix of dunes within the site and the dune slacks in which the many of the site's freshwater wetlands are formed.

3.3.1 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). Temperatures affect evaporation and transpiration, rainfall has a direct influence and solar radiation and day length affect the biological components of wetland systems.

The Glenelg Estuary and Discovery Bay Ramsar Site is situated within the temperate (moderately dry winter, warm summer) climate zone of south-eastern Australia (Bureau of Meteorology 2011, http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/IDCclimclasgrids.jsp).

Rainfall is winter dominated with the highest monthly median rainfall in July (104 millimetres) and lowest in February (20 millimetres; Figure 19). Annual average rainfall at Nelson is in the order of 800 millimetres per year. As indicated above, there is some degree of variability in annual rainfall (ranging from around 200 millimetres up to 900 millimetres in the past five decades) (Figure 20).

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 10 times greater than rainfall (Figure 21).

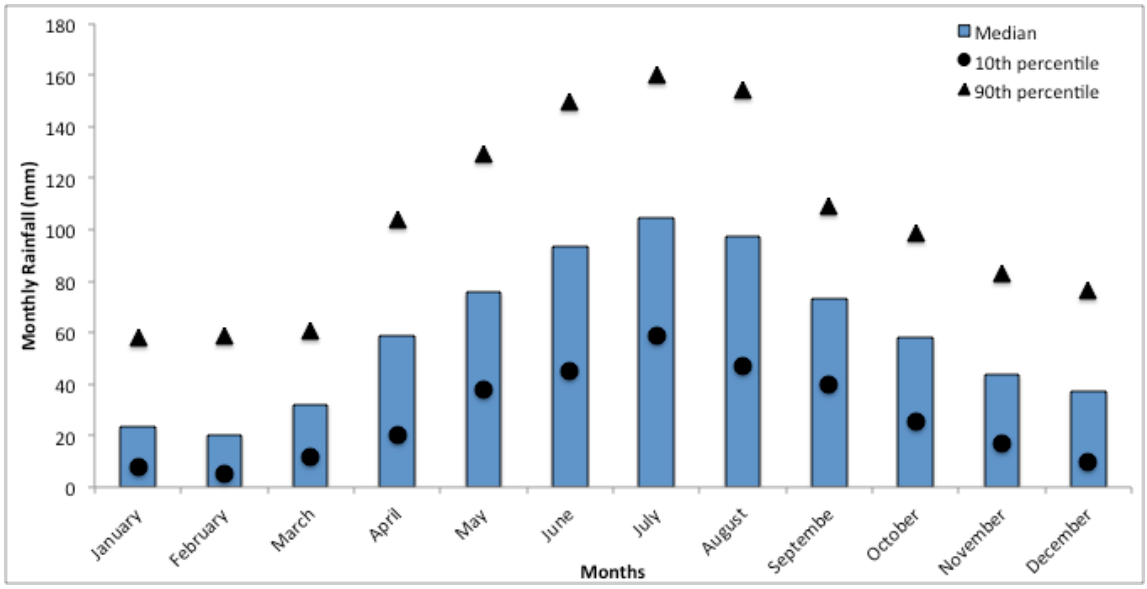

Figure 19: Median, 10th and 90th percentile monthly rainfall at Nelson (1859 – 2010; Bureau of Meteorology).

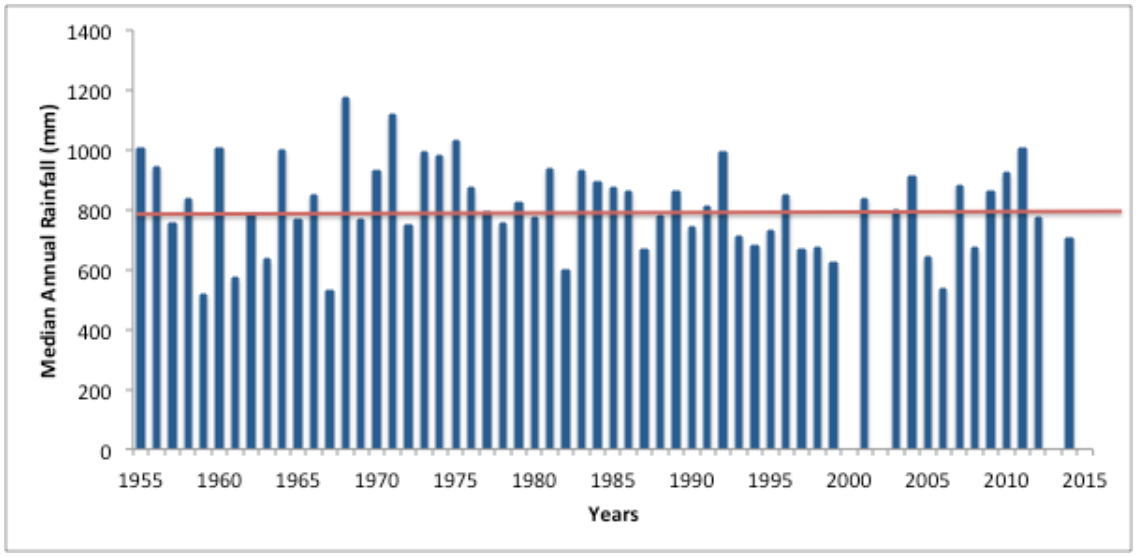

Figure 20: Average annual rainfall at Nelson (1955 – 2014; Bureau of Meteorology). Note horizontal line shows long term average.

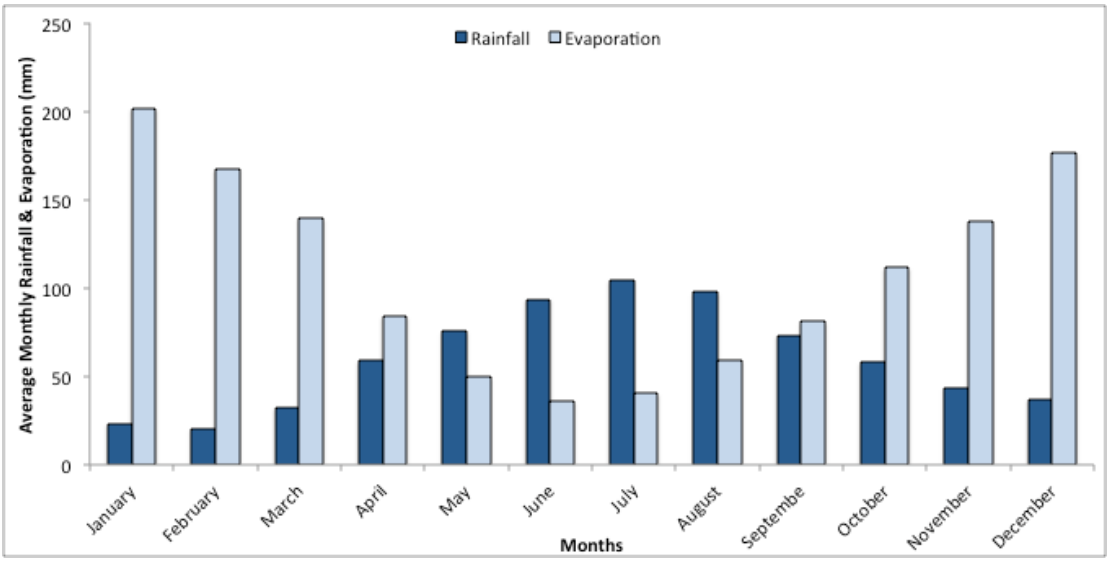

Figure 21: Average monthly rainfall (Nelson) and evaporation (Mt Gambier) (1940 – 2014; Bureau of Meteorology).

Temperatures are moderate year round (Figure 22), with average summer maximum temperatures around 22 degrees Celsius and average minimum temperatures around 12 degrees Celsius. During winter, average maximum temperatures are cooler (13 to 15 degrees Celsius) as are average minimum temperatures (six to seven degrees Celsius).

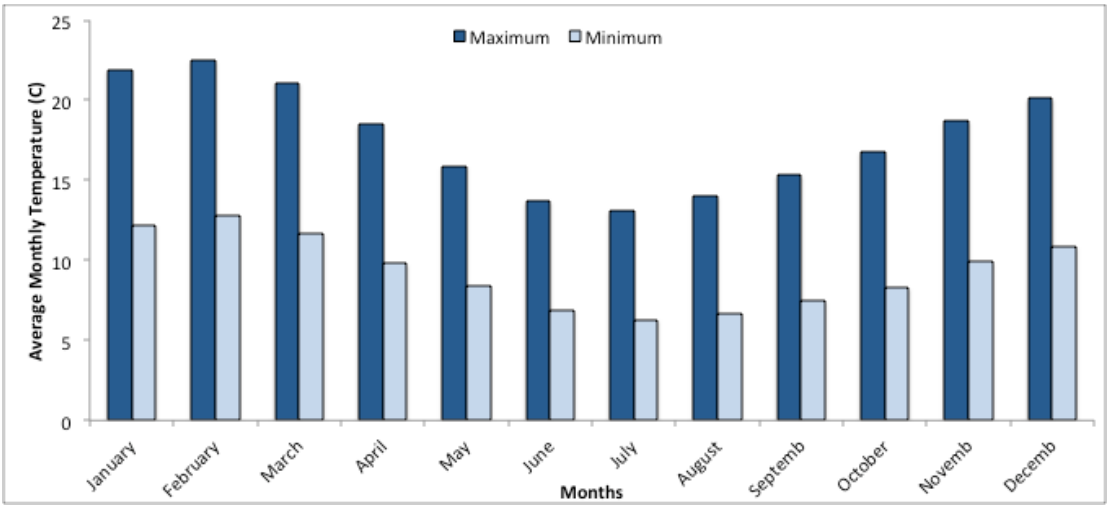

Figure 22: Average monthly maximum and minimum temperatures at Portland (1982 – 2014; Bureau of Meteorology).

3.3.2 Geomorphic setting

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 Glenelg Estuary and Discovery Bay Ramsar Site is located on the south Victorian coastal plain in a barrier complex geomorphic unit (Rowan et al. 2000). The geology, topography and soils are described as belonging to three land systems: Discovery Bay land system, which comprises the area from the coast to behind the barrier dunes; Long Swamp land system, which runs parallel to the coast and comprises the low lying swamps, and former lakes behind the dune system and Nelson Land system which covers the

estuarine portion of the site (Figure 23 and Figure 24, Gibbons and Downes 1964). The region is underlain by Tertiary limestone deposited in the early Miocene, resulting in large karst areas (underground drainage and cave systems).

The Discovery Bay land system is characterised by steep dunes of highly calcareous sands made up largely of finely broken sea shells. The soils are mineral, with increasing organic material inland from the sea. These soils have been described as unique, with high alkalinity (pH > 9), which limits the types of plants that can survive (Gibbons and Downes 1964). The dunes vary along the site, but are largely mobile and unstable with constant shifting sands a feature in several locations.

The Long Swamp land system is a narrow stretch of low lying, poorly draining land between the coastal dunes of the Discovery Bay land system, and the Pleistocene inland dunes of the Nelson land-system. The aquatic ecosystems of the freshwater wetland complexes lie within this land system. Soils are peat, calcareous and alkaline (Gibbons and Downes 1964). The landscape diagram shows the position of the low lying freshwater wetlands between the two dunes systems (Figure 24).

The Nelson land-system is associated with the hardened limestone dunes of the coastal plains and the less-acid sands derived from them. The profile is low; ranging from dunes at the seaward side to inland plains and soils vary from sandy loam to orange sands further inland with pockets of acid white sand. There is a density of cave systems surrounding and underneath the Glenelg Estuary (White 1998).

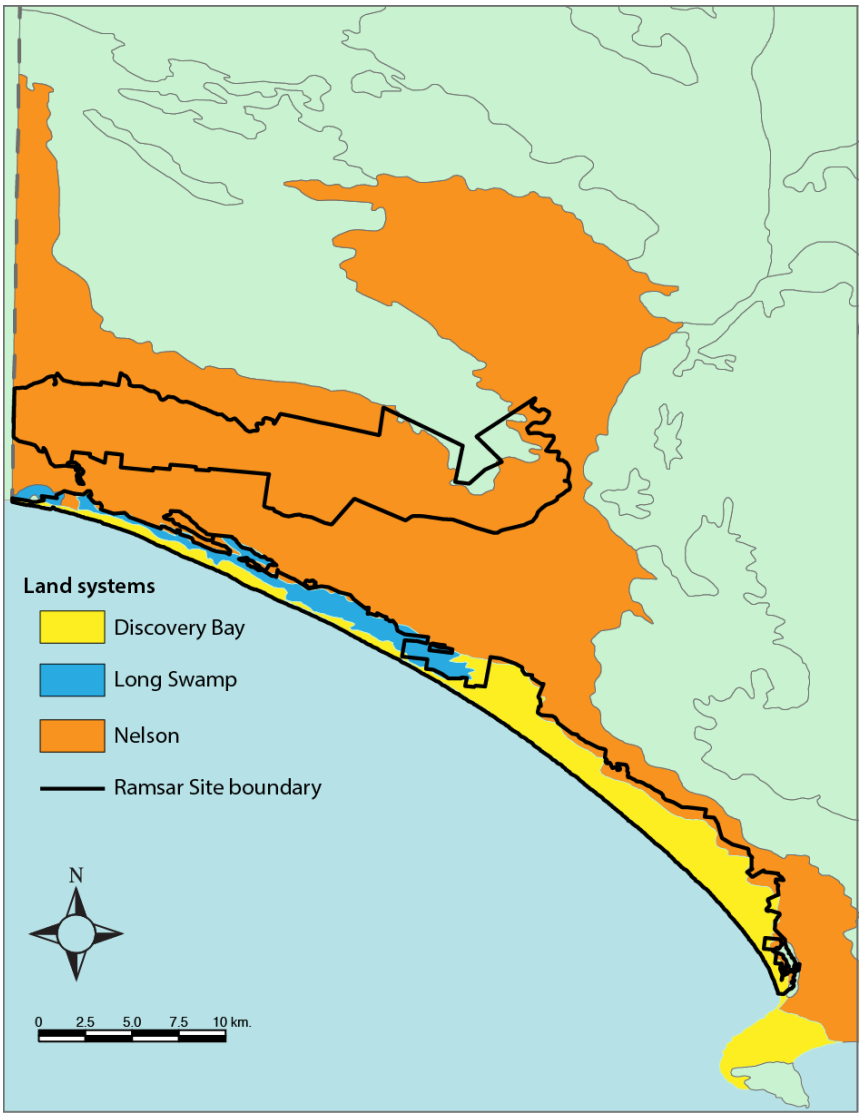

Figure 23: Land systems in the Glenelg Estuary and Discovery Bay Ramsar Site (Gibbons and Downes 1964).

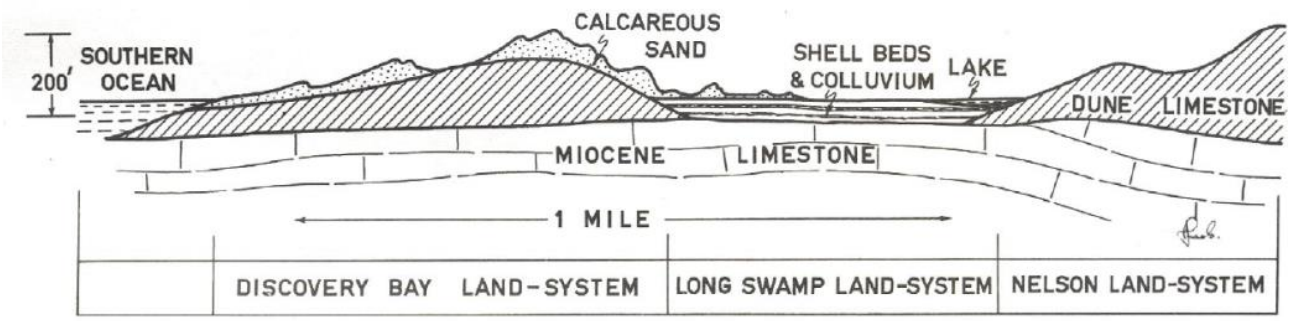

Figure 24: Landscape diagram showing the position of the three dominant land-systems "Discovery Bay", "Long Swamp" and "Nelson" on a transect running inland from the ocean (Gibbons and Downes 1964).

3.3.3 Water quality

The supporting components associated with water quality include water clarity, nutrients and phytoplankton biomass (for a description of the critical processes associated with stratification (salinity and dissolved oxygen) see 3.5.1 below). 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.

Water quality data for the aquatic ecosystems within the Ramsar site are limited. Data collected in the Lower Glenelg Estuary indicate a dynamic system that is heavily influenced by inflowing river water, tidal exchange and entrance conditions. Water clarity in the lower estuary is generally high, particularly at times when tidal exchange is the dominant factor. Data from 2002 to 2008 indicate turbidity is generally less than the detection limit, but can exceed 100 NTU on occasions. Monthly water quality monitoring at four sites (upstream at Dartmoor to downstream at Nelson) illustrates the generally low turbidity levels with occasional peaks (Figure 25). Of note are the occasional peaks in turbidity (e.g. April 2004; November 2007 and in 2010 – 2012). These coincide with periods of high freshwater inflow and represent both a movement of sediment into the estuary from upstream and resuspension of sediments within the estuary itself.

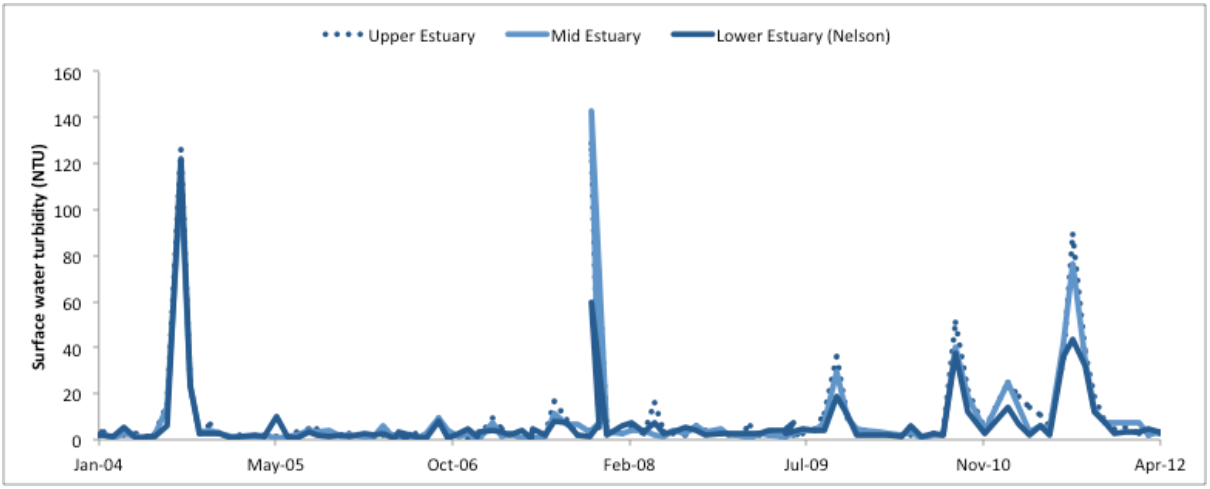

Figure 25: Turbidity (NTU) in surface waters at three sites in the Glenelg Estuary and one upstream (Dartmoor) from October 2003 to April 2012 (data provided by Glenelg Hopkins CMA).

A snapshot of nutrients in the Glenelg Estuary during 2002 indicated moderately high levels of total nitrogen (600 – 800 microgram per litre) and total phosphorus (5 – 60 microgram per litre), which were in excess of ANZECC water quality guidelines for marine and estuarine systems (Mondon et al. 2003). However, there is insufficient data to determine if this is typical of the estuary or what seasonal or longer-term cycles may be. Data from reaches of the Glenelg River upstream of the Ramsar site (at Dartmoor) indicate high concentrations of both nitrogen and phosphorus (Figure 26) much of which would flow through into the estuary. The extent of nutrient retention, versus flushing into the ocean would be a factor of tidal flows and entrance conditions.

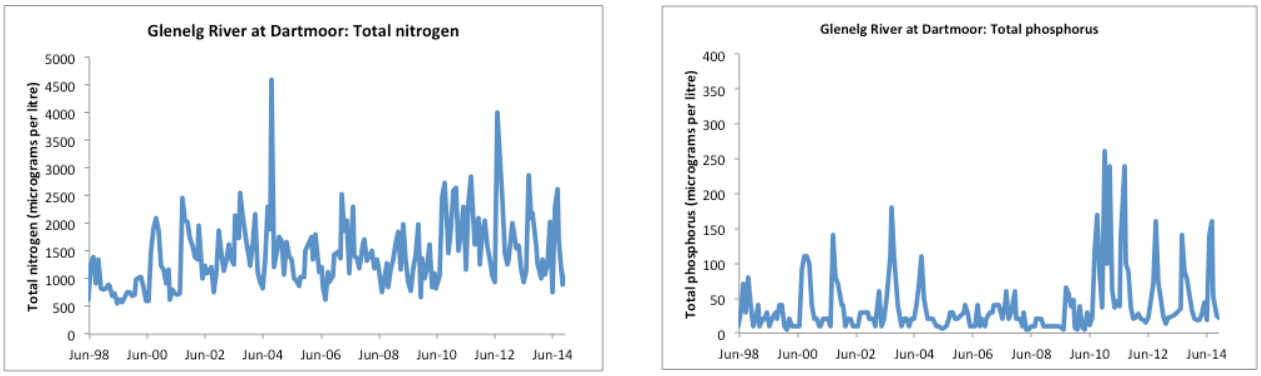

Figure 26: Total nitrogen (left) and total phosphorus (right) in the Glenelg River at Dartmoor; upstream of the Ramsar site (data from Victorian Water Information System http://data.water.vic.gov.au/monitoring.htm).

The Lower Glenelg Estuary is neutral to slightly alkaline, with median pH from 2002 to 2008 of eight (Glenelg Hopkins unpublished data). This is typical of estuaries, as seawater has a high carbonate content and buffering capacity. There is no indication from available data of instances of acidity (low pH).

Data is limited, but the results of snap-shot water quality sampling in mid-1970s (Timms 1977) and 2007 (EPA Victoria 2010) indicate generally good water quality in the freshwater lakes of the system. The water in Lake Bridgewater is fresh (electrical conductivity, 940 – 1500 micro Siemens per centimetre); clear (turbidity < 2 NTU) and alkaline (pH, 7.7 – 8.9). Concentrations of total nitrogen are moderately high (500 – 900 microgram per litre) but concentrations of total phosphorus are low (5 – 10 μg/L), and concentrations of bioavailable dissolved inorganic nutrients (e.g. nitrate-nitrite and filterable reactive phosphorus) are generally very low (< 5 microgram per litre). Phytoplankton biomass (as indicated by chlorophyll-a is also generally low (< 5 microgram per litre) although periodic peaks of up to 10 μg/L have been recorded.

Available data indicate that water quality in Lake Moniboeng (part of the Long Swamp complex) is similar to that of Lake Bridgewater (EPA Victoria 2010), with high concentrations of total nitrogen, but remaining parameters are indicative of good water quality conditions. Similarly, the water quality of the other wetlands indicates fresh, clear (except for tannin stained Sheepwash Lagoon) and alkaline conditions (Table 11).

Table 11: Summary of water quality of the some of the lakes within the Ramsar site (Timms 1977). Note that all values are approximate and the names of the lakes are as described by Timms 1977.

Lake	Water clarity	Mean salinity (ppt)	Mean pH
Lake Mombeong (Bong Bong)	High – bottom visible	0.3	8.2
Sheepwash Lagoon	High – bottom visible	0.4	8.0
Cains Hut Swamp	High – bottom visible	0.5	8.1
Lagoon No. 4	High – bottom visible	0.4	7.6
Malseed Lake	High – bottom visible	0.4	8.5
Swan Lake	Moderate	0.4	7.8
Main Bridgewater Lake	High	0.6	8.5

3.3.4 Vegetation community: Dune scrub

Dune scrub vegetation distribution has been modelled by DEWLP 2005 as two Victorian Ecological Vegetation Classes (EVC): Coastal dune scrub (EVC 160) along the primary dune and coastal alkaline scrub (EVC 858) across the remainder of dune field that covers the site. The latter EVC incorporates the extensive areas of bare sand associated with actively migrating dunes and formation of blowouts when vegetation is lost.

Coastal dune scrub occupies the primary dune along the full length of the ocean beach of Discovery Bay. It is a closed scrub to three meters tall with occasional emergent trees on siliceous and calcareous sands that are subject to high levels of salt spray and continuous disturbance from onshore winds. It includes a narrow

band of grassland immediately adjacent to the beach, common native species include hairy spinifex (*Spinifex sericeus*) and coast fescue (*Austrofestuca littoralis*). This transitions to a wind-pruned scrub and heath on the dunes with dominant shrubs including coast tea-tree (*Leptospermum laevigatum*), coast wattle (*Acacia longifolia var. sophorae*), drooping she-oak (*Allocasuarina verticillata*), and sweet bursaria (*Bursaria spinosa*), with an understorey of common beard-heath (*Leucopogon parviflorus*), sea box (*Alyxia buxifolia*) and coast everlasting (*Ozothamnus turbinatus*).

Behind the dunes, coastal dune scrub transitions into coastal alkaline scrub which forms the dominant matrix of vegetation covering the deep calcareous (alkaline) and largely stable sand dunes and swales of the site in which wetlands habitats are embedded. The coastal alkaline scrub is a low woodland or tall shrubland to eight metres tall, typically with a medium shrub layer, small shrub layer and sedges, grasses and herbs in the ground layer. The species canopy composition is dominated by "moonah" (*Melaleuca lanceolata* ssp. *lanceolata*) and other canopy species similar to coastal dune scrub. The scrub is patchily distributed in some areas playing a critical role stabilising shifting sand dunes. Large and frequent "blow-outs" of bare unstable sand are common within this vegetation type, particularly in the eastern end half of the site (Figure 27).

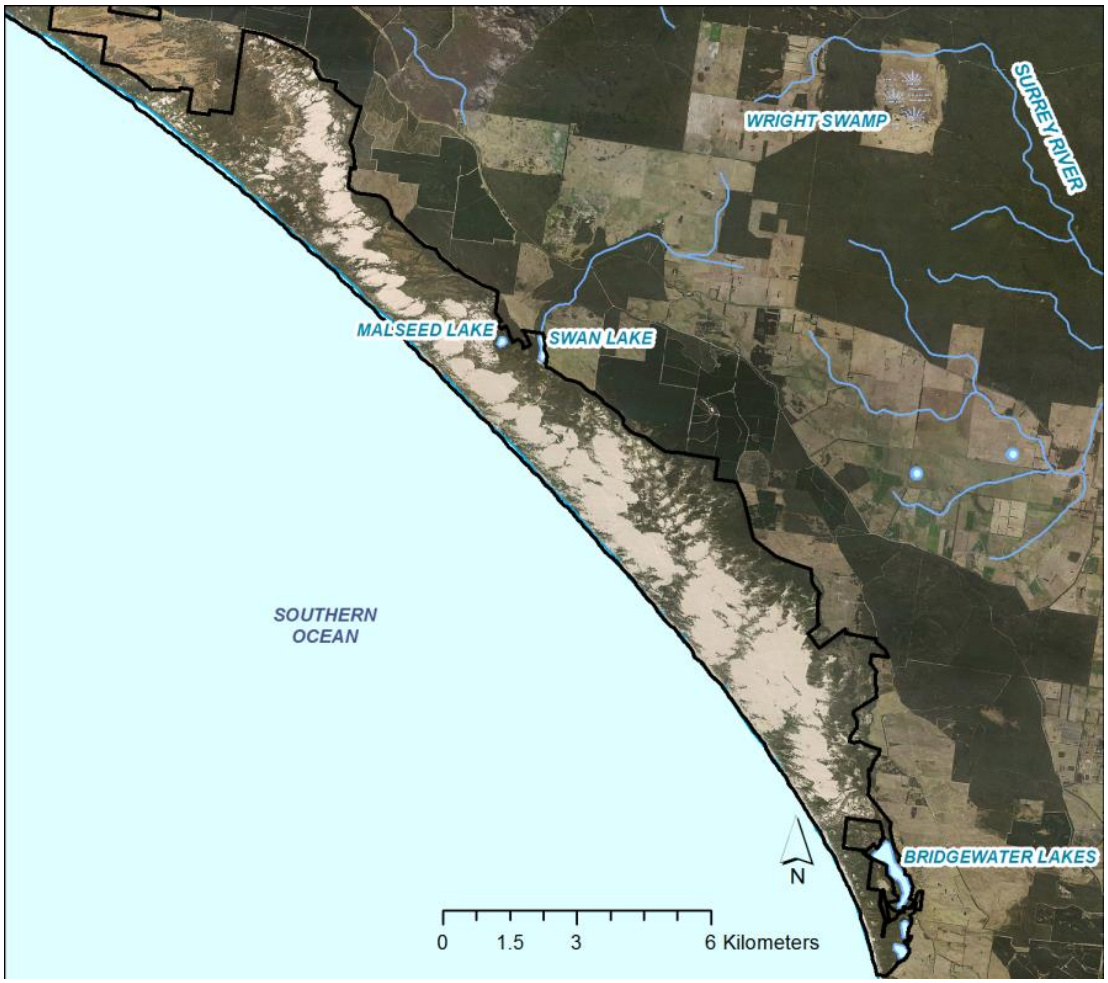

Figure 27: Large bare "blow-outs" of sand sprinkled with coastal alkaline scrub dominate the eastern end of the dune field in Ramsar site (boundary shown as black line).

3.4 Critical components

The attributes and characteristics of each of the identified critical components of Glenelg Estuary and Discovery Bay Ramsar Site are described below (sections 3.4.1 to 3.5.3). 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 critical components within the Glenelg Estuary and Discovery Bay Ramsar Site is provided in Table 12.

Table 12: Summary of critical components within the Glenelg Estuary and Discovery Bay Ramsar Site.

Component	Description
Hydrology	While a knowledge and quantification of ecosystem water regimes is limited, it is understood that many of the wetlands in the site, including the Glenelg Estuary are groundwater dependent. It is suspected that groundwater is a significant water source for these systems, at times contributing more than surface water sources. The hydrology of the Glenelg Estuary is influenced by the tidal cycle, when the estuary is open and freshwater river inflows, the latter of which are seasonal. A range of wetland water regimes are present and several of the wetlands, such as the Bridgewater Lakes are permanently inundated.
Vegetation – type and extent	Nationally threatened coastal saltmarsh is present at Oxbow Lake. Freshwater sedgelands and tall marsh vegetation extend across the Long Swamp wetlands Lake bed macrophytes - submerged macrophyte communities are a characteristic of the permanent lakes. Bridgewater Lakes supports a submerged macrophyte community dominated charophytes, although the diversity and extent of this community is a knowledge gap.
Fish – diversity and abundance	Fifty-three native fish species from 29 families have been recorded in the site, 28 of which are considered to be regularly supported. This includes fish with a range of life-history strategies including freshwater, estuarine, marine and diadromous species that move between habitats. The site provides feeding, spawning and nursery areas for a range of fish species including several that are recreationally important such as black bream.
Waterbirds – diversity and abundance	Ninety-five species of waterbird have been recorded within the site, including 24 listed under international migratory bird agreements. Complete counts are not available and waterbird abundance is a knowledge gap for the site. Nine species have been recorded breeding in the site, including several beach nesting species such as red-capped plover and little terns.

3.4.1 Hydrology

Groundwater connectivity is a critical component of the Ramsar site, with large areas of habitat at the site being groundwater dependent (Figure 28). However quantitative information on groundwater levels, connectivity and variability is limited.

Hydrological information for the site is largely limited to the Long Swamp complex and the Glenelg Estuary. The other components of the site are largely data deficient. The Bridgewater Lakes are permanent, but variability in water levels and information on primary sources of water (surface and groundwater) are unknown.

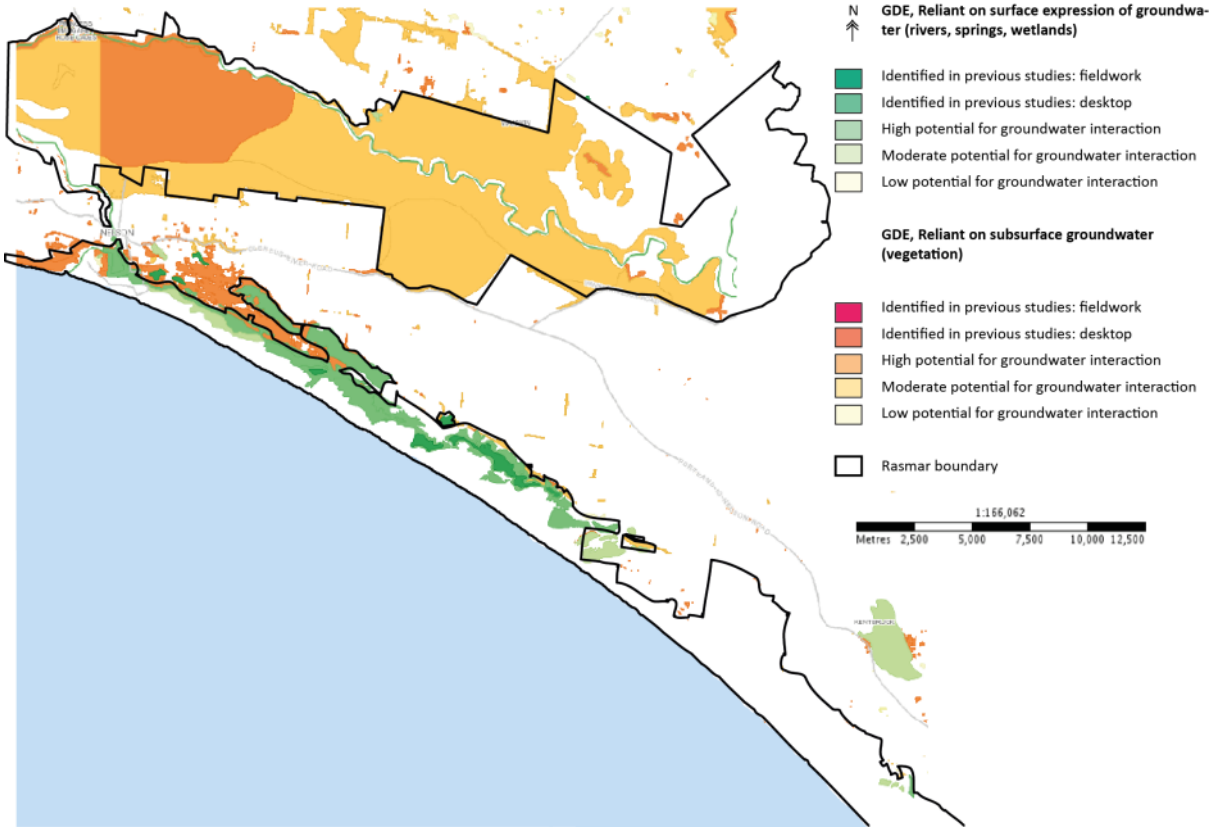

Figure 28: Groundwater dependent ecosystems reliant on surface and subsurface expression of groundwater showing Lower Glenelg National Park and Long Swamp complex (modified from GDE Atlas reports from Bureau of Meteorology, http://www.bom.gov.au/jsp/weave/gde.html?max=true accessed September 2015). Bridgewater Lakes not shown.

Long Swamp

The hydrology of Long Swamp appears to be complex, the source of water being a mixture of local runoff/rainfall inputs and groundwater connectivity to the estuary via Eel Creek and the sea via Nobles Rocks and White Sands (Figure 29). The frequency and duration of inundation varies across the site and has been described historically as being deeper and more permanent than at present. A local long-time resident, Edna Millhouse, stated that

> "*around about 1944-45 some misguided person or persons cut a channel from the long swamp to drain into the sea near Noble Rocks. The long swamp used to run from Lake M…g into the estuary near the mouth of the Glenelg River. As the years went by the channel became wider and more water went to the sea the swamp became nearly dry. As no water flowed along the course the sand drift became bad. What was once teeming with bird life, eels, tench and spotted trout and little fish all have gone along with the water*"
> Letter from Edna Millhouse, aged 89, 19/2/2009.

Two channels were cut through the coastal dune, one at White Sands and one at Nobles Rocks, the locations most likely dictated by the narrowness of the dune, to increase the land available for agriculture (Reynolds 2007). The effect of this was to reduce the duration, extent and frequency of inundation within the complex.

During the Millennium drought, the channel at White Sands naturally closed, and in 2014, works were completed to close the channel at Noble Rocks. While insufficient time has passed to adequately characterise the water regime under current (restored) conditions, early observations indicate increased duration, depth and extent of inundation and restored connectivity between the chain of wetlands that comprise the Long Swamp complex (Figure 30) and potentially the Glenelg Estuary (Bachmann unpublished).

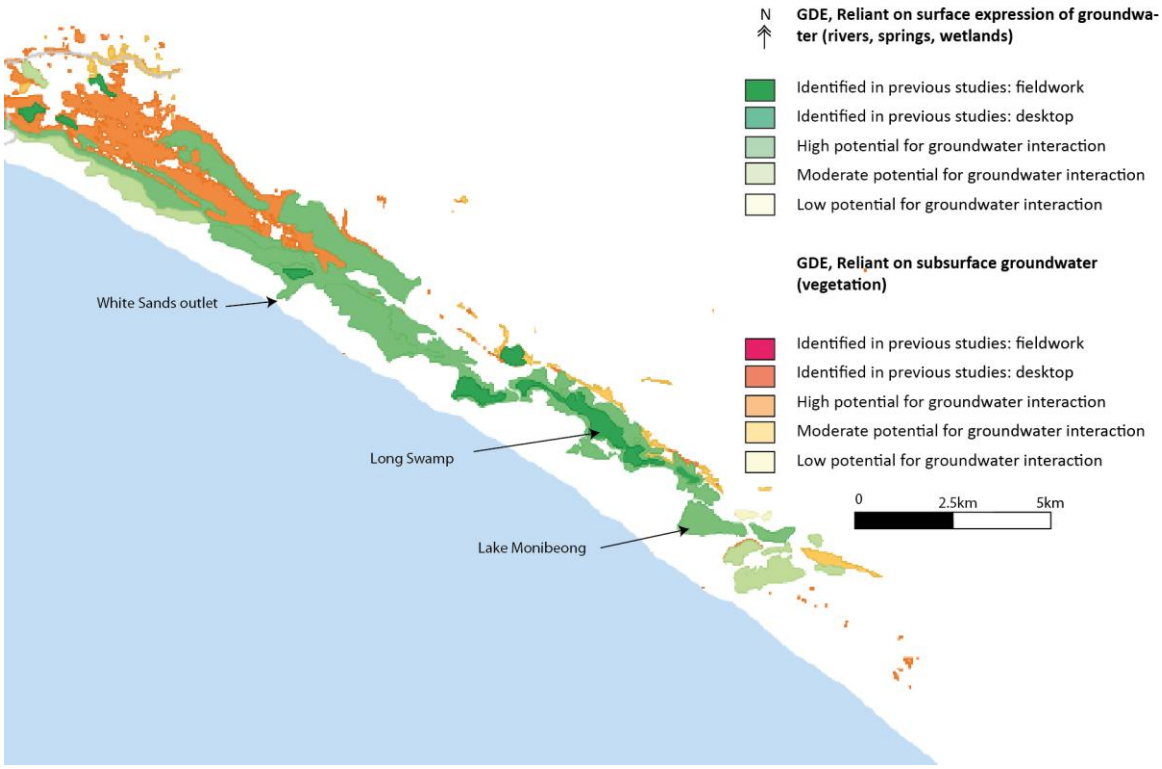

Figure 29: Groundwater dependent ecosystems reliant on surface and subsurface expression of groundwater of the Long Swamp to Moniboeng complex (modified from GDE Atlas reports from Bureau of Meteorology, http://www.bom.gov.au/jsp/weave/gde.html?max=true accessed September 2015).

Figure 30: Restoration of the water regime at Long Swamp.

While it is too early to describe the rehabilitated water regime of Long Swamp, modelling of the potential effects of the closure of the artificial outlets provides some indication of likely hydrology. Specifically it is predicted that (Cardno Lawson and Treloar 2008):

- Closure of the outlets (by raising the land to 4m AHD) to the open ocean may increase the depth and period of inundation significantly in some areas of Long Swamp, particularly for the average and high rainfall years.
- The greatest changes in the hydrological regime are predicted to occur near the closed outlets.
- Inundation extent in the swamp is unchanged under the closed outlet conditions. Flood depths may increase by over 50 centimetres near the outlets under the closed conditions.

The model output for difference between open and closed outlets in an average rainfall year is shown in Figure 31. See Cardno Lawson and Treloar (2008) for other scenarios for high rainfall events and large floods.

These predictions are modelled and the water regime of the freshwater wetlands remains a knowledge gap.

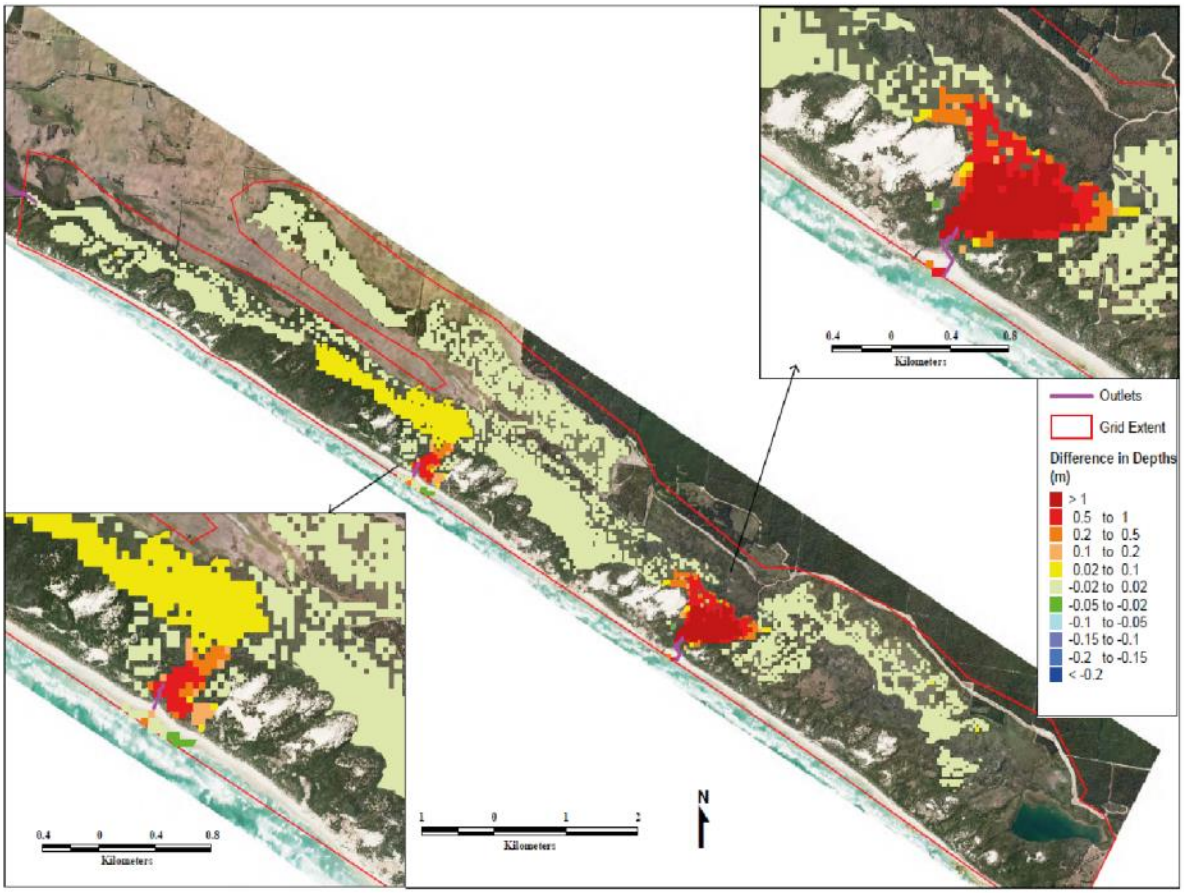

Figure 31: Difference in depths – closed flood depths minus open flood depths for an average rainfall year (from (Cardno Lawson and Treloar 2008).

Glenelg Estuary

The Glenelg Estuary is a seasonally closed, salt wedge estuary (Glenelg Hopkins CMA 2006a). During summer, low river flows are unable to displace the sand deposited by low energy constructive waves at the river mouth. A sand barrier forms that restricts or completely isolates the estuary from tidal exchange with the sea. When completely closed, the estuary continues to fill with fresh water inflows from the catchment until the barrier bar is breached. The breach may be initiated naturally by wave action on the seaward side, or from the estuary when higher winter and spring flows raise the estuary water level to the point where hydrostatic pressure blows through the bar or high water levels overtop the bar. At this point the draining

estuary will erode an open channel through the barrier that generally remains open until the next summer low flow season. Glenelg Hopkins CMA can authorise the land manager (Parks Victoria) to artificially breach the sand barrier when rising estuary water levels threaten local assets with flooding or in response to poor water quality in the stagnant estuary (Barton and Sherwood 2004).

In the twenty year period from 1995 to 2014, the Glenelg Estuary closed 37 times (Figure 32). The duration of open and closed periods is highly variable and weather dependent. For example, while the average period of closure is 40 days; during the Millennium drought the estuary remained closed for over a year (January 2004 to June 2005). The estuary most often closes during autumn months (March to May) during periods of low river flow, although on occasion has closed during winter. Summary statistics for periods of open and closing of the estuary are provided in Table 13.

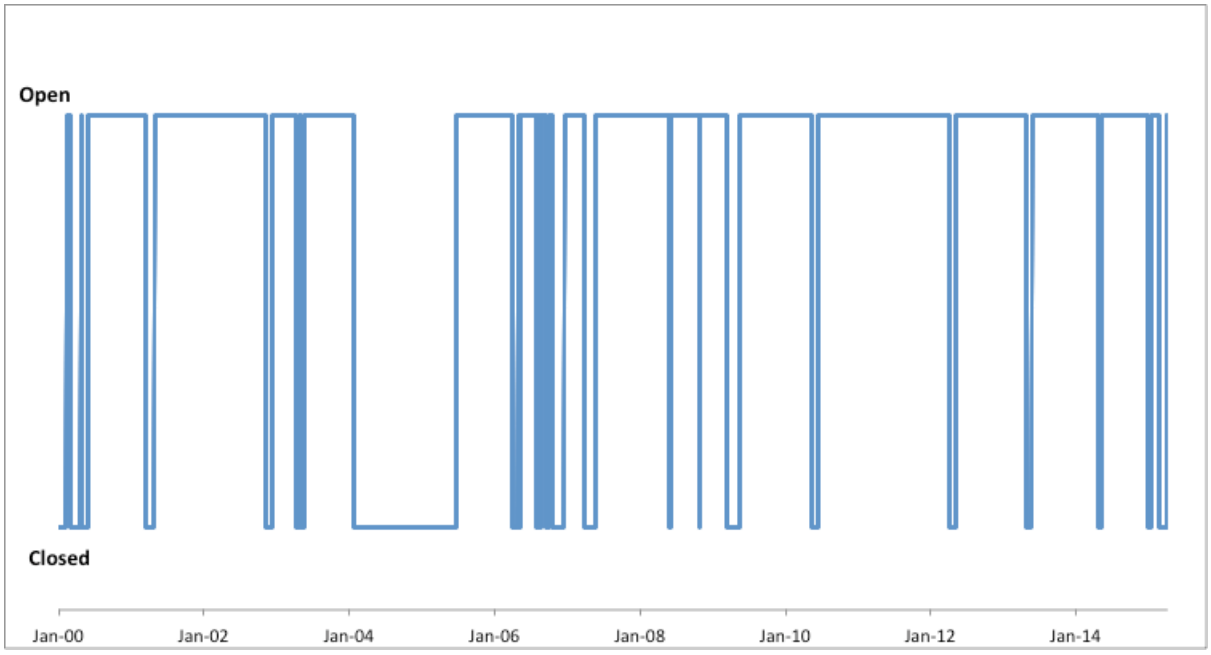

Figure 32: Records of estuary opening and closing from 1995 to 2014 (data provided by Glenelg Hopkins CMA).

Table 13: Summary statistics for the Glenelg Estuary opening and closing from January 1995 to December 2014 (data provided by Glenelg Hopkins CMA).

Parameter	Open periods	Closed periods
Mean duration	159 days	41 days
Median duration	92 days	25 days
Maximum period (duration)	658	513 days
Maximum period (date)	10/6/2010 to 4/4/2012	27/1/2004 to 23/06/2005
Minimum period (duration)	4 days	3 days
Minimum period (date)	30/4/2006 to 4/5/2006	17/10/1999 to 20/10/1999
% closure summer	N/A	13
% closure autumn	N/A	57
% closure winter	N/A	13
% closure spring	N/A	17

Stratification commonly occurs where low density fresh water flows over the top of dense saline water without mixing, forming a salt wedge on the estuary floor that is pushed upstream by tidal flows. During low

flow conditions the salt wedge of the Glenelg Estuary often penetrates over 75 kilometres upstream almost reaching Dartmoor (GHCMA 2006). During higher flows the wedge moves downstream as it mixes with turbulent freshwater flows until flows are sufficient to break down the stratification entirely. River flows of approximately 6,000 megalitres per day are needed to flush the saltwater from the river and estuary entirely (Sherwood et al. 1998 cited by Glenelg Hopkins CMA (2006a).

When the estuary is open, it experiences a diurnal (twice-daily) tidal cycle. Tides are somewhat moderated from those experienced in the Southern Ocean, outside the estuary and get weaker at distance upstream. An example of tidal ranges (Figure 33) indicates a 1 – 1.2 metre tidal range in the Southern Ocean, a 0.2 to 0.3 metre tidal range in the Glenelg Estuary at Nelson, to a barely perceptible tidal range upstream at Dartmoor (Figure 33).

Freshwater inflows to the estuary are highly variable both seasonally and over longer climatic cycles. From 1995 to 2015, total annual discharge in the Glenelg River at Dartmoor ranged from nearly 900 gigalitres in 1996 to just 73 gigalitres during the drought in 2006 (Figure 34). Most of the freshwater inflow to the estuary occurs in late winter, early spring although there are occasional high flows during summer.

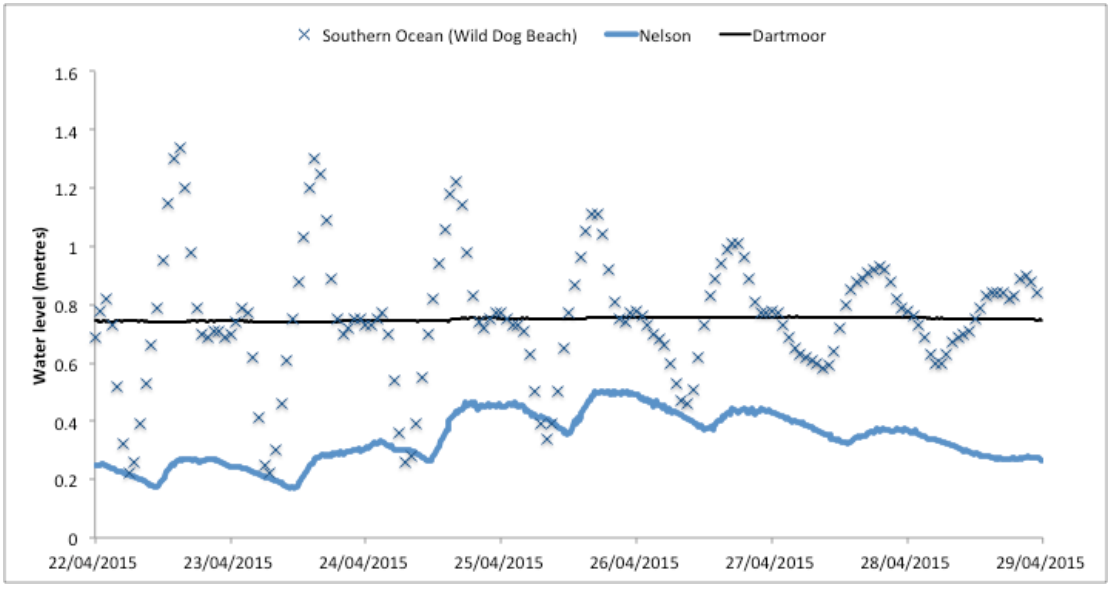

Figure 33: Hourly water levels at three sites: Southern Ocean (Wild Dog Beach); Glenelg Estuary at Nelson; and Glenelg River at Dartmoor (data from Glenelg Hopkins CMA, Victorian Water Measurement Information System and Bureau of Meteorology).

Water sources for the Glenelg Estuary include direct rainfall, river inflows, groundwater and tidal exchange with the Southern Ocean. A water balance model for the Glenelg Estuary was completed for periods when the estuary was closed in summer and autumn of 2006 and 2007, when river flows were low and there was no tidal exchange. The study indicated that during these periods, groundwater was a significant source of water to the estuary, accounting for up to 45% of total inflows (Figure 35). However, during times when the estuary is open, marine water would account for a large proportion of the total volume and during periods of high river flow, freshwater surface flows would be more important.

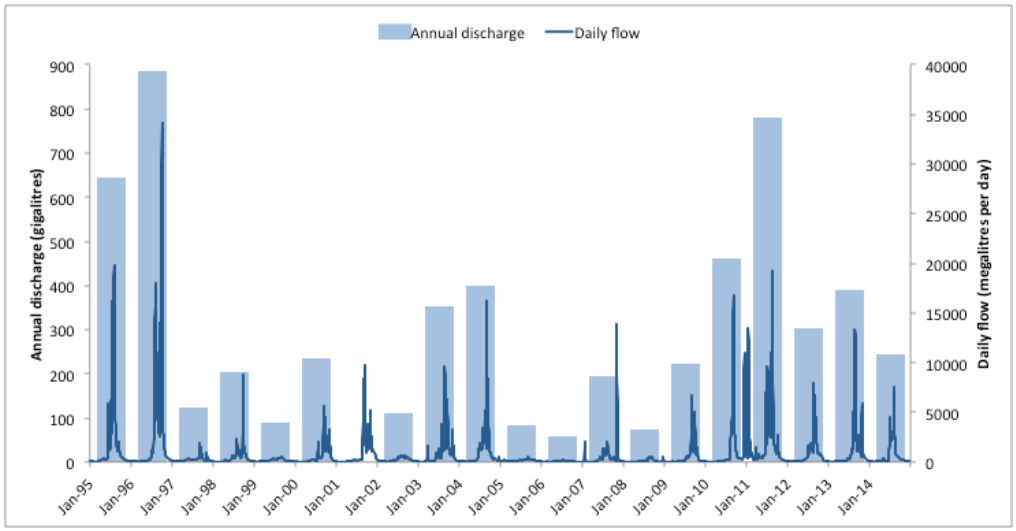

Figure 34: Daily flow (megalitres per day) and total annual discharge (gigalitres) for the Glenelg River at Dartmoor (data from the Victorian Water Measurement Information System).

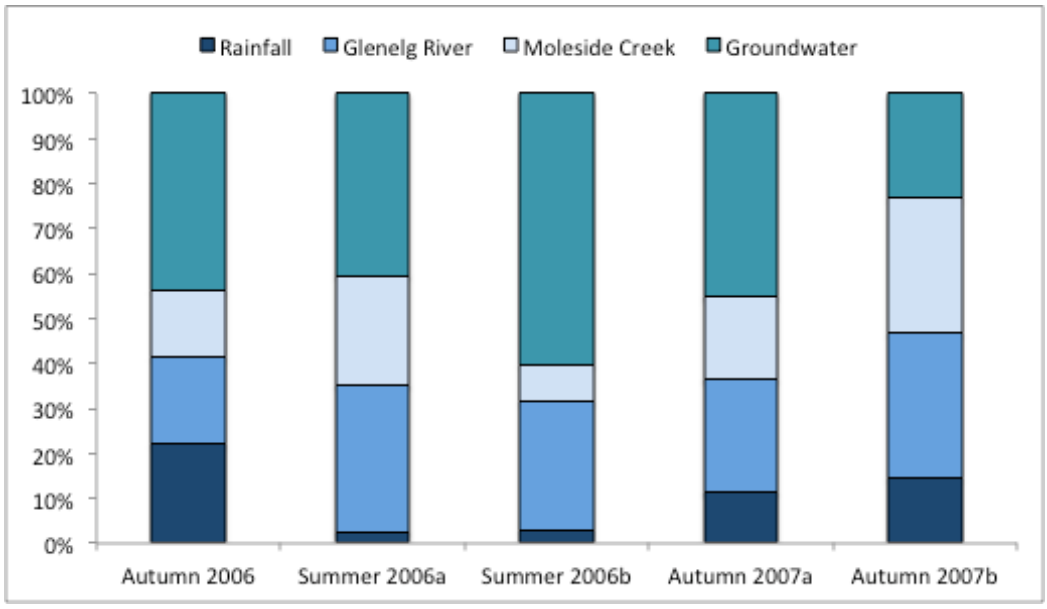

Figure 35: Relative contributions (percentage) of water sources to the Glenelg Estuary during periods of closure (data from Laurenson and Coates 2010).

3.4.2 Vegetation type and extent

The site is characterised by three major wetland dependent vegetation groupings that are critical to defining the character of the Ramsar site. These are (Figure 36, Table 14):

1. **Coastal saltmarsh** associated with the Glenelg Estuary including Oxbow Lake.
2. **Freshwater sedgelands and tall marsh** vegetation that comprise the Long Swamp wetlands
3. **Lake bed macrophytes** - submerged macrophyte communities of the permanent lakes.

The northern extent of the site that lies within the Lower Glenelg National Park is mostly terrestrial heathlands and woodlands that support the ecology of the estuary but are not considered critical to the wetland values of the site.

Table 14: Extent of major vegetation types critical to the ecological character of the Ramsar site.

Critical Components: Vegetation	Area (hectares)
Coastal saltmarsh	26
Sarcocornia herbland	8
Juncus krausii	9
Ghania filum	9
Freshwater sedgelands and tall marsh	939
Baumea sedgelands	270
Tall marsh	32
Gahnia sedge/swamp scrub complex	637
Lake bed macrophytes	137
Swan Lake	18
Lake Moniboeng	52
Malseed Lake	6
Bridgewater Lakes (North)	32
Bridgewater Lakes (South)	29

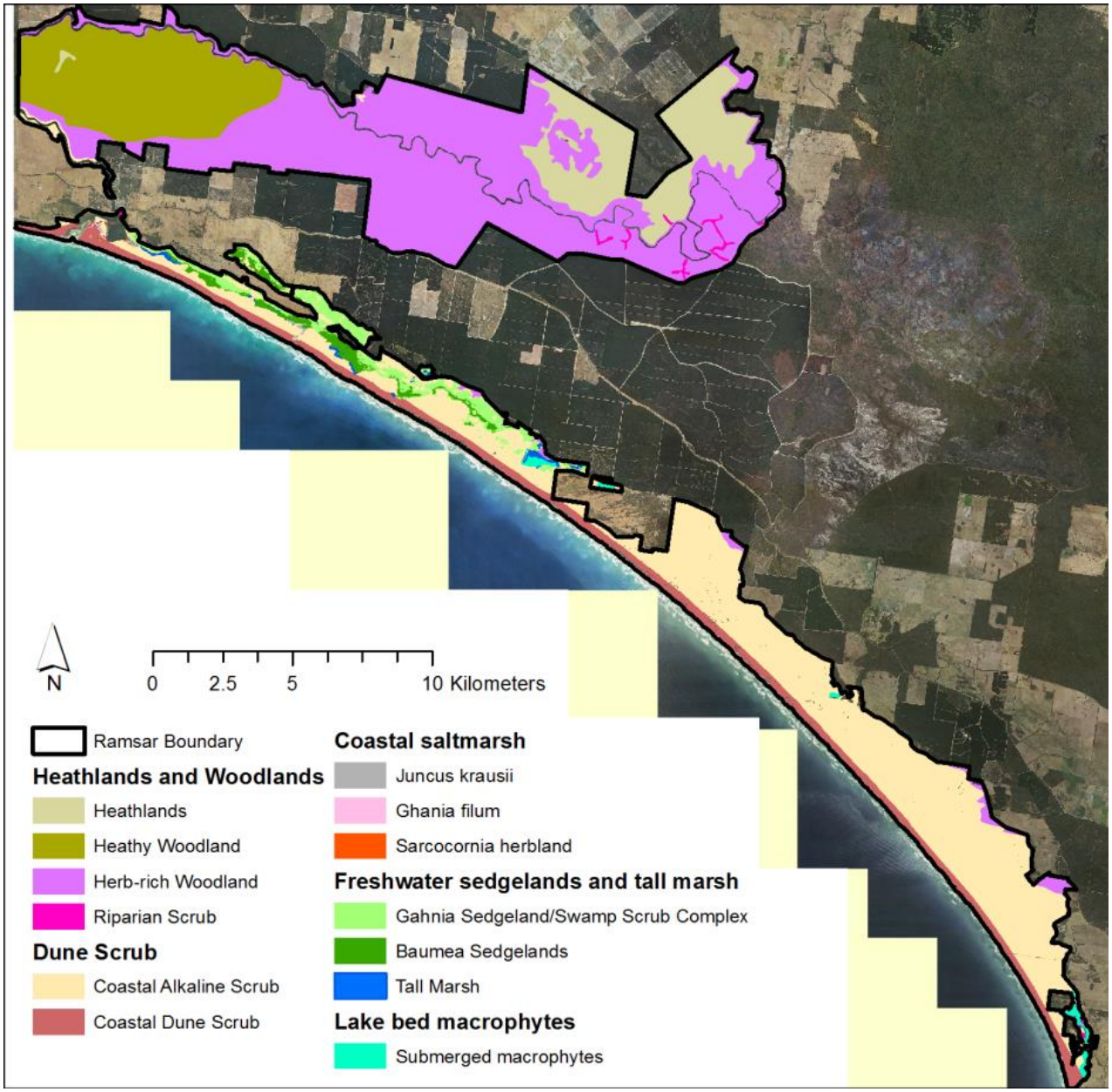

Figure 36: Major vegetation types within the Ramsar site, those considered critical to ecological character are: coastal saltmarsh, freshwater sedgelands and tall marsh, and lake bed macrophytes).

Coastal Saltmarsh

Coastal saltmarsh fringes Oxbow Lake and the Glenelg Estuary and was mapped in detail by Sinclair and Sutter (2008) (Figure 37). The saltmarsh comprises a low herbland dominated by beaded glasswort (*Sarcocornia quinqueflora*) with patches of taller estuarine wetland species such as sea rush (*Juncus kraussii*) and Chaffy saw-sedge (*Gahnia filum*) towards the drier landward zone. Coastal saltmarsh also fringes several saline depressions located between the Glenelg river channel and western shore of Oxbow lake. Other plant species found as scattered individuals include austral seablite (*Suaeda australis*), creeping brookweed (*Samolus repens*), streaked arrow-grass (*Triglochin striata*) and Australian Salt-grass (*Distichlis distichophylla*) (Sinclair and Sutter 2008).

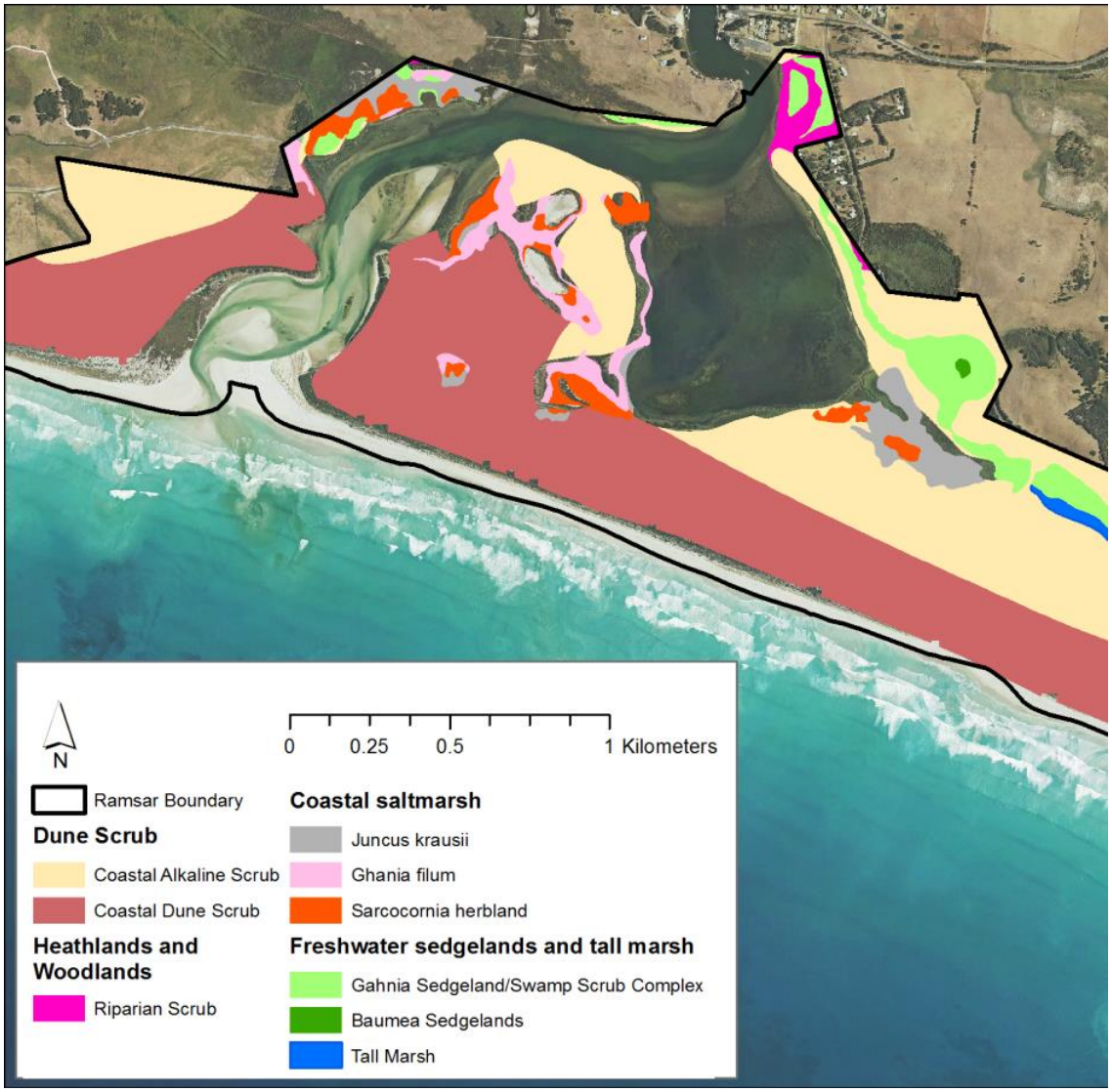

Figure 37: Major vegetation types associated with the Glenelg Estuary.

Freshwater sedgelands and tall marsh

The vegetation of Long Swamp was mapped in detail by Sinclair and Sutter (2008) into three main vegetation types that occur across a hydrological gradient from permanently inundated or waterlogged soils on the seaward side of the swamp to intermittently wet and damp peaty soils on the landward side (Figure 38). The wettest (most permanently inundated areas) support small stands of tall marsh dominated by common reed (*Phragmites australis*). This grades into large areas of dense sedge-lands composed almost

exclusively of twig-sedges (*Baumea arthrophylla* and *Baumea juncea*) that cover 250 hectares of waterlogged peaty soils. The drier landward side of the swamp supports 700 hectares of mixed swamp scrub composed of stunted woolly tea-tree (*Leptospermum lanigerum*) and scented paperbark (*Melaleuca squarrosa*) mixed with saw sedges (Chaffy saw-sedge *Gahnia filum* and tall saw-sedge *Gahnia clarkei*) (Sinclair and Sutter 2008).

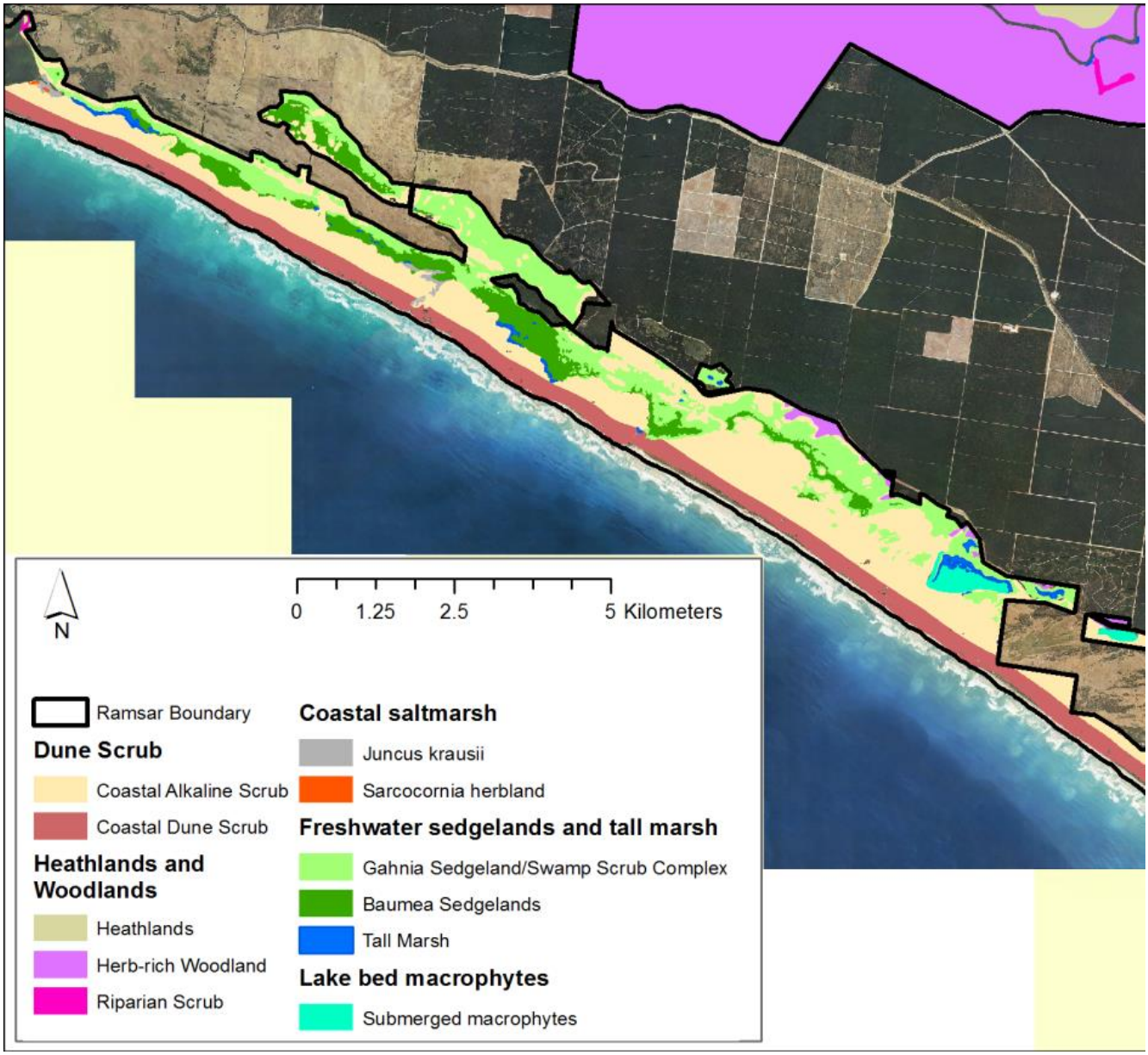

Figure 38: Major vegetation types associated with Long Swamp.

Lake bed macrophytes (Figures 39 and 40)

Very little information is available on this vegetation type and reflects a general lack of data on the main permanent lakes of the Ramsar site. The submergent vegetation of the lakes is considered a critical component as it represents a distinct habitat and food resource for waterbirds and fish as well as having inherent biodiversity values. Species that have been noted at the lakes include *Triglochin*, *Chara* and *Myriophilum*. In 1958, Beauglehole and Wood described three species of charophytes (freshwater macroalgae) from the Bridgewater Lakes, one species of *Nitella* and two of *Chara* (M. Casanova, pers, comm.).

The extent and diversity of submerged macrophytes within the site remains a knowledge gap.

Figure 39: Lake bed vegetation at Bridgewater Lakes, November 2015 (R. Butcher).

Figure 40: Lake bed vegetation at Swan Lake, November 2015 (R. Butcher).

3.4.3 Fish diversity and abundance

There have been relatively few surveys of fish undertaken within the Ramsar site, with most work either being undertaken in the Glenelg River upstream of the site, or more recently in Long Swamp in association with a hydrological restoration project (see Bachmann et al. 2013, Veale 2014, 2016). Records for the Malseed wetland complex and Bridgewater Lakes are very sparse. There are records of 53 native fish species from 29 families from the site. This includes a large number (23) of marine opportunist or marine straggler species (see Appendix F). Of the 53 native species, 28 species are considered to be regularly supported (Table 15).

Table 15: Fish species regularly supported within the Ramsar site (additional marine stragglers are listed in Appendix F). GRE = Glenelg Estuary, OL= Oxbow Lake, EC = Eel Creek, LS = Long Swamp, LMO = Lake Moniboeng, LMA = Lake Malseed, SL = Swan Lake, BWL = Bridgewater Lakes. Data from Glenelg Hopkins CMA unpublished data, DPI data cited in Bovill 2006; Halliday et al. 2015; Hammer et al. 2007; Hughes et al. 2014; Bachmann et al. 2013; Coleman et al. 2013; Saddlier et al. 2013; Veale 2014, 2015..

Common name	Scientific name	GRE	OL	EC	LS	LMO	LMA	SL	BWL
Australian herring	*Arripis georgianus*								
Black bream	*Acanthopagrus butcheri*								
Bridled goby	*Arenigobius bifrenatus*								
Climbing galaxias	*Galaxias brevipinnis*								
Common galaxias	*Galaxias maculatus*								
Little galaxias	*Galaxiella toourtkoourt*								
Estuary perch	*Macquaria colonrum*								
Flat-headed gudgeon	*Philypnodon grandiceps*								
Lagoon goby	*Tasmanogobius lasti*								
Large mouth goby	*Redigobius macrostoma*								
Mullaway	*Argyrosomus japonicus*								
Pouched lamprey	*Geotria australis*								
Prickly toadfish	*Contusus brevicaudus*								
River blackfish	*Gadopsis marmoratus*								
Sandy sprat	*Hyperlophus vittatus*								
Sea mullet	*Mugil cephalus*								
Short-finned eel	*Anguilla australis*								
Short-headed lamprey	*Mordacia mordax*								
Small-mouthed hardy head	*Atherinosoma microstoma*								
Smooth toadfish	*Tetractenos glaber*								
Southern pygmy perch	*Nannoperca australis*								
Spotted galaxias	*Galaxias truttaceus*								
Southern smelt	*Retropinna* spp.								
Tamar river goby	*Afurcagobius tamarensis*								
Tupong	*Pseudaphritis urvillii*								
Yarra pygmy perch	*Nannoperca obscura*								
Yellow eye mullet	*Aldrichetta forsteri*								
Western blue-spotted goby	*Pseudogobius* sp 9								

A comprehensive understanding of the fish diversity and abundance across all wetland types within the site is considered a knowledge gap, but there is some recent data on fish species in some of the wetlands associated with the Glenelg Estuary and Discovery Ramsar Site. Surveys in autumn 2014 – 2016 associated with the Long Swamp restoration project are illustrated in Figure 41. Data indicate that Oxbow Lake is dominated by estuarine and marine species, with the most common fish species in both years being small-mouthed hardy-head followed by black bream. In Long Swamp, the fish community is dominated by freshwater species with southern pygmy perch the most common species in recent surveys. Further east, at Lake Moniboeng, while the fish community is still largely comprised of freshwater species, there are some estuarine fish present and the most common taxa is common galaxias (Veale 2014, 2016).

Population distribution data was analysed for common species (Veale 2016) and indicates that common galaxias occur across all size and age ranges, consistent with the site providing a self-sustaining breeding population. Other species such as black bream and Yarra pygmy perch displayed multiple cohorts and recruits, indicative of movement between different parts of the site at different stages in their life-cycles.

There is a good understanding of the spawning and recruitment of black bream in the Glenelg Estuary, with stratification and freshwater inflows important for success. Bream egg buoyance means that they will accumulate near the halocline in a stratified water column and without stratification, hatching and recruitment can be impaired (Jenkins et al. 2010).

Spawning and recruitment of other fish species within the site remans a knowledge gap.

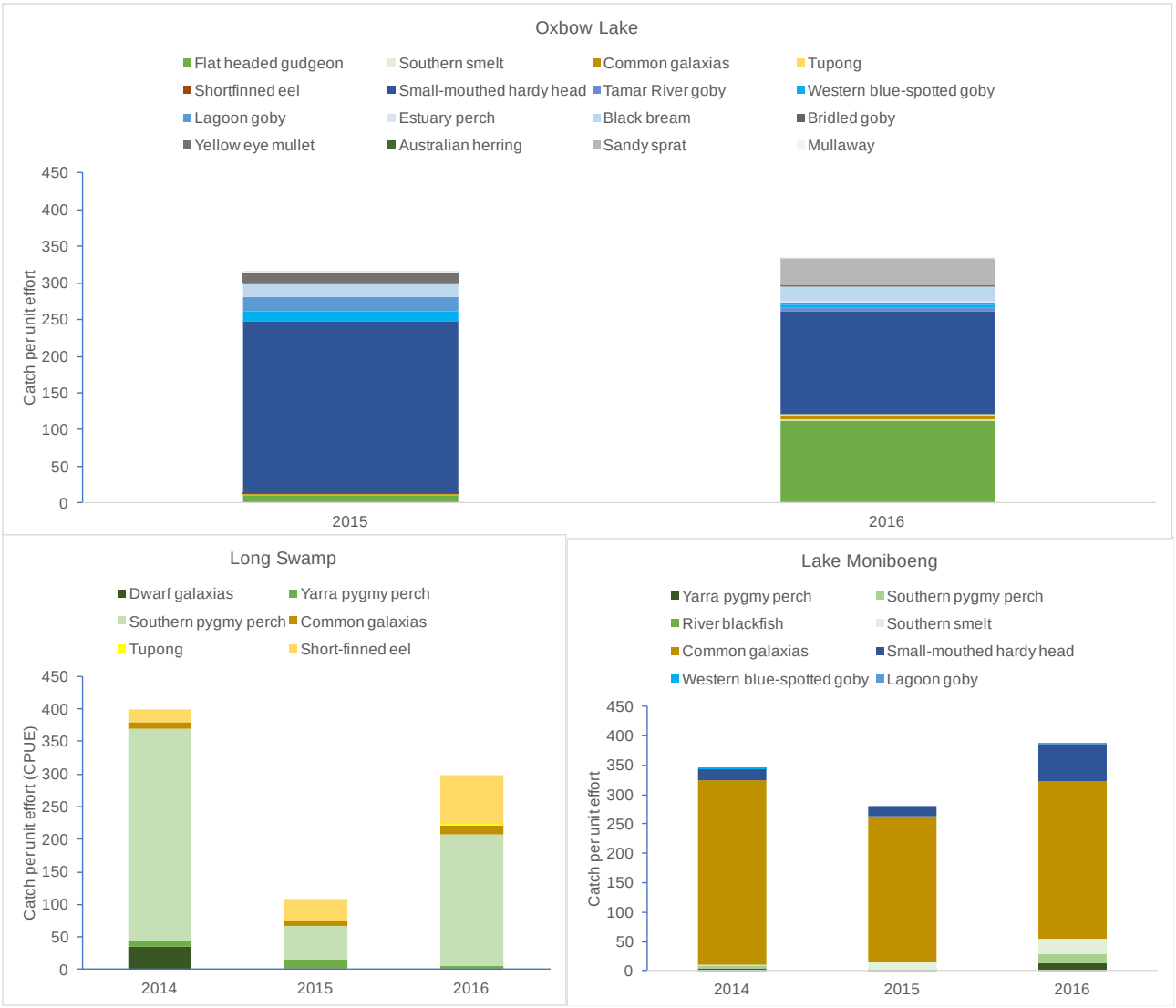

Figure 41: Fish abundance (Catch per Unit Effort; CPUE) from autumn surveys in Oxbow Lake, Long Swamp and Lake Moniboeng (data from Veale 2014, 2015). Note that survey method in 2014 varied slightly and results may not be directly comparable. Freshwater species shaded green, diadromous in yellow/brown, estuarine in blue and marine in grey.

3.4.4 Waterbird diversity and abundance

A total of 95 species have been recorded within the Ramsar site (Table 16), noting that this list excludes vagrants and species for which the site does not provide core habitat (e.g. pelagic seabirds and penguins). Twenty four species are listed under international migratory agreements: CAMBA (24), JAMBA (24), ROKAMBA (21) and the Bonn Convention on Migratory Species (21), although only 20 species are true international migrants with the remaining species resident within their Australian range. An additional 34

Australian species are listed as marine under the *EPBC Act* 1999. A full list of waterbirds recorded at the site is presented in Appendix E.

Waterbird abundance records for the site are limited and do not cover all habitat types. There are no complete counts for the entire site. Shorebirds 2020 data is available from 2007 to 2013, but not all areas were counted each year, making trend analysis or quantifying average conditions impossible. Complete summer counts of the beaches and shorebird habitats in 2008 and 2009, indicated 707 and 448 shorebirds, respectively (Shorebirds 2020 data). In addition, there are moderate numbers of birds in winter; with data from 2008 and 2009, indicating 362 and 155 shorebirds respectively. These winter counts would include juvenile birds from populations that breed in the northern hemisphere that over winter in Australia, Double-banded Plovers which winter in Australia and resident Australian shorebirds.

Table 16: Number of waterbird species recorded from within the Glenelg Estuary and Discovery Bay Ramsar Site.

Functional group	Description	Number
Ducks and small grebes	Ducks and small grebes that typically are omnivorous and shallow or open water foragers.	16
Herbivores	Black swans, hens and coots that have a vegetation diet	5
Fish eating species	Gulls, terns, cormorants and grebes with a diet mainly of fish	19
Australian shorebirds	Australian resident shorebird species that feed in shallow inland waters or mud and sand flats mainly on invertebrates.	14
International shorebirds	Palaearctic shorebird species that breed in the northern hemisphere and migrate to the southern hemisphere to feed.	20
Large wading birds	Long-legged wading birds with large bills, feeding mainly in shallow water and mudflats.	16
Other	Other birds that are wetland dependent such as birds of prey (white-bellied sea eagle, swamp harrier), reed warblers and the orange-bellied parrot.	5
Total		**95**

Data on abundance of individual species is also inconsistent. There are counts above the one per cent population threshold (220) for sanderling (*Calidris alba*), but inconsistent and incomplete counts make trend analysis difficult. Available data indicate (Birdlife Australia unpublished data):

- 1981 = 232
- 1983 = 560
- 2005 = 610
- 2008 = 500
- 2009 = 350

There are also some count data for the nationally threatened (vulnerable) hooded plover (*Thinornis rubricollis*), which do not exceed the one percent threshold (abundance ranges from 3 to 51 individuals), however the site is considered significant for this species (Mead et al. 2012). Counts from beaches in both summer and winter indicate the species is a permanent resident, but there are no breeding records and only a single observation of a juvenile from the site, suggesting that the species does not breed within the site boundary (Mead et al. 2012).

Two other threatened birds species have been recorded within the site: the Australasian bittern (*Botaurus poiciloptilus*), listed as endangered and the fairy tern (*Sternula nereis nereis*), listed as vulnerable. Records for these species are sparse, but observations from the BirdLife Australia atlas indicate that they are observed at the site regularly. Recently a single bittern with a radio tracker has been recorded using the site, having originated from NSW (Bitterns in rice project - see http://www.bitternsinrice.com.au/).

Waterbird breeding within the Ramsar site is a significant knowledge gap with respect to species numbers and important locations and habitats. There are breeding records of nine waterbird species from within the site, from incidental observations (BirdLife Australia, unpublished data):

- Australian pied oystercatcher (*Haematopus longirostris*)
- Black swan (*Cygnus atratus*)
- Chestnut teal (*Anas castanea*)
- Fairy tern (*Sterna nereis nereis*)
- Great cormorant (*Phalacrocorax carbo*)
- Great crested grebe (*Podiceps cristatus*)
- Little tern (*Sternula albifrons*)
- Pacific gull (*Larus pacificus*)
- Red-capped plover (*Charadrius ruficapillus*)

Little tern used the estuary regularly as a breeding colony in the past, with the first nesting being observed in 1988 and yearly from 2000 to 2004 (Smith and Smith 2001, Smith and Smith 2002, Campbell and Christie 2009). In 2003/04 both little and fairy terns were observed nesting together. Little terns typically breed in small colonies of up to 50 individuals; however, the colonies established at the Glenelg Estuary were small with typically 6-8 breeding pairs. Fairy tern also breed within the site as indicated by records at the estuary and on the Discovery Bay beach (Figure 42).

Figure 42: Fairy tern nesting on Discovery Bay beach, December 2014 (© Marcel Hoog Antink).

3.5 Critical processes

A single critical process has been identified for the Glenelg Estuary and Discovery Bay Ramsar Site: stratification of the Glenelg Estuary, which is important for nutrient cycling and other ecosystem functions and essential for successful recruitment of estuarine fish species such as black bream (Jenkins et al. 2010).

3.5.1 Stratification

The Glenelg Estuary can be described as a seasonally closed salt-wedge estuary (Glenelg Hopkins CMA 2006a). The interaction of fresh river flow and saline marine tides creates a salt wedge within the estuary, comprising three distinct layers (Barton and Sherwood 2004):

- Upper layer of fresh, river water constantly flowing downstream,
- Lower layer of denser saline water, moving upstream on the flood tide and downstream on the ebb tide, and

- A middle mixed layer of intermediate density that moves downstream with the freshwater layer, gradually thickening until the freshwater layer disappears.

The position and behaviour of this salt wedge is affected by river flow volume and tidal cycles. As illustrated in Figure 43, under an ebb tide, when the estuary is open, river water extends further downstream in a thick layer over the more saline seawater. In a flood tide, the pressure exerted by the tide pushes the salt wedge further up the estuary. When the estuary is closed and tidal exchange does not occur, the stratification (layers of fresh and saline water) becomes more stable forming a distinct halocline. This prevents the mixing of bottom water layers with the surface water (and air) and results in a decline in dissolved oxygen in bottom waters. It is not unusual for dissolved oxygen concentrations of less than two milligrams per litre (less than 10 percent saturation) to be recorded in the bottom waters during these times (Glenelg Hopkins CMA unpublished data).

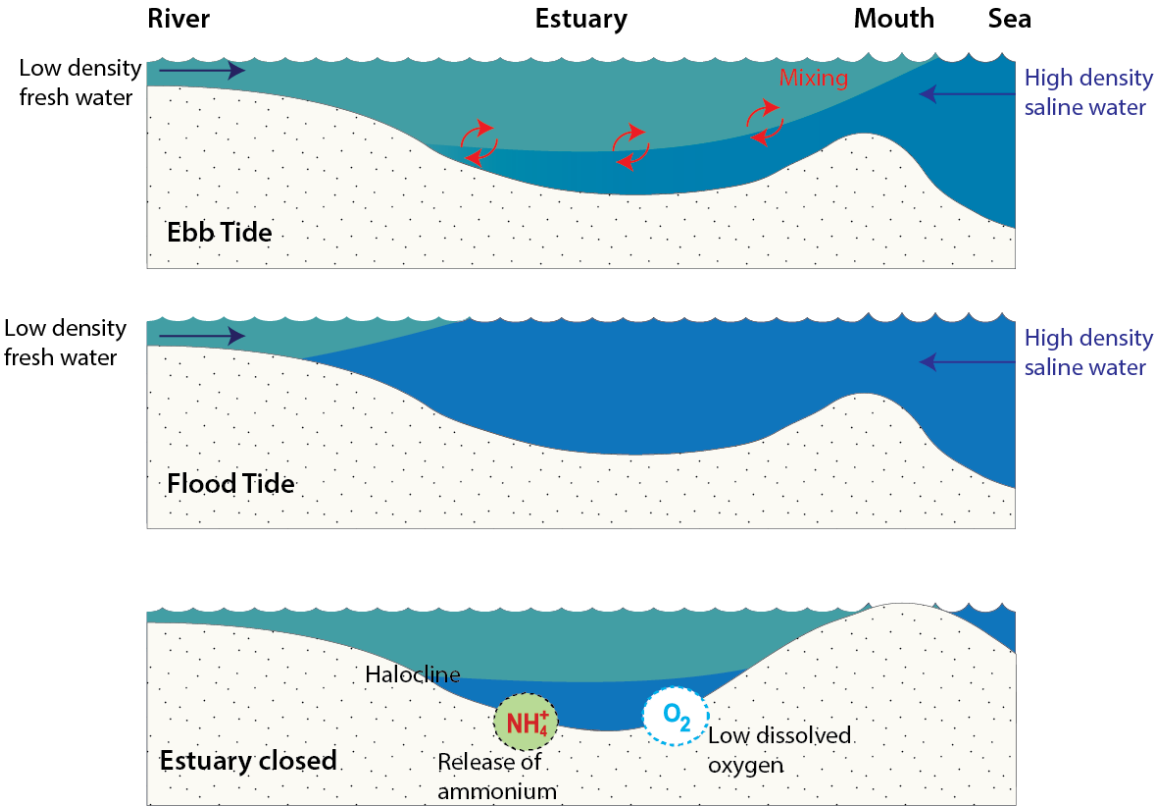

*Figure 43: Position of the salt wedge under different hydrological conditions (adapted from **Glenelg Hopkins CMA 2006a).***

The seasonal nature of freshwater inflows and opening of the estuary creates a cycle of salinity and dissolved oxygen in the estuary (Figure 44). During winter, the water column is well mixed and most often fresh to brackish. Although data are limited, salinity in winter is typically less than one part per thousand on ebb tide and two to four parts per thousand on flood tide. At this time, the water column remains well oxygenated with dissolved oxygen concentrations near 100 percent saturation and 8 to 12 milligrams per litre (Glenelg Hopkins CMA unpublished data). The graph for winter in Figure 44 shows depth profiles for salinity and dissolved oxygen in June 2011 during an ebb tide.

In spring, as freshwater inflows drop, the salt wedge becomes more established and water in the surface layer remains fresh to brackish, but in bottom-waters may be as high as seawater (35 parts per thousand). At this time, stratification is not permanent and dissolved oxygen in bottom waters remains high. Data in Figure 44 shows the depth profiles for salinity and dissolved oxygen from October 2010.

During summer and autumn, stratification becomes more stable, freshwater inflows are low and there is a distinct halocline. Data in Figure 44 are from March 2009, and show the position of the halocline at two metres, with a mixing zone to a depth of three metres. Water above the halocline is moderately saline with salinity at or above 20 parts per thousand; below the halocline salinity is 10 parts per thousand higher.

Dissolved oxygen in surface water remains high (over 100 percent saturation) but drops to near zero in bottom waters (Glenelg Hopkins CMA unpublished data).

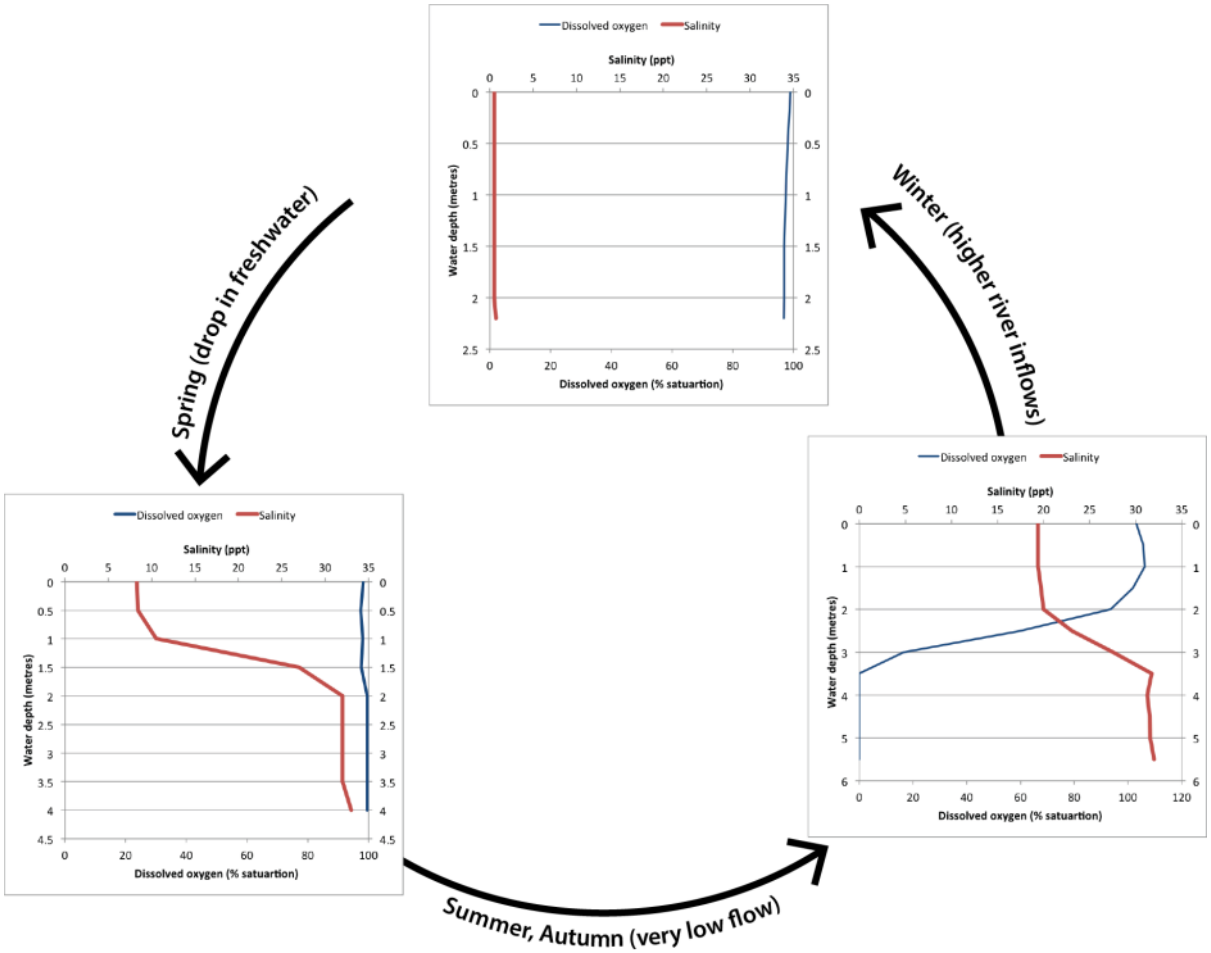

Figure 44: Salinity and dissolved oxygen cycles in the Lower Glenelg Estuary (schematic adapted from Barton and Sherwood 2004; data from Glenelg Hopkins CMA unpublished).

In addition to the seasonal cycles and tidal cycles described above, dissolved oxygen concentrations vary diurnally, generally being lower at night, when respiration exceeds photosynthesis and higher on sunny days, when photosynthesis of algae and submerged plants releases oxygen into the water column. Data however are too limited to determine trends in dissolved oxygen, with respect to primary productivity in the Glenelg Estuary.

Salinity also follows a gradient from the lower to the upper estuary. The salt wedge extends up the entire length of the estuary, with bottom water salinity often close to seawater and only occasional differences between the lower and upper estuaries. Salinity in the upper layers is higher in the lower estuary (i.e. at Nelson), which is closer to the mouth and marine waters, and fresher in the upper portions of the estuary (above Pritchard's landing), where water in the surface layers is fresher (Figure 45). The monthly data from 2003 to 2012 also show occasional periods (e.g. September 2004 and on a number of occasions in late 2010 and early 2011) where the water column became well mixed and entirely fresh. This coincides with periods of higher freshwater flows such as occurred at the breaking of the drought in late 2010.

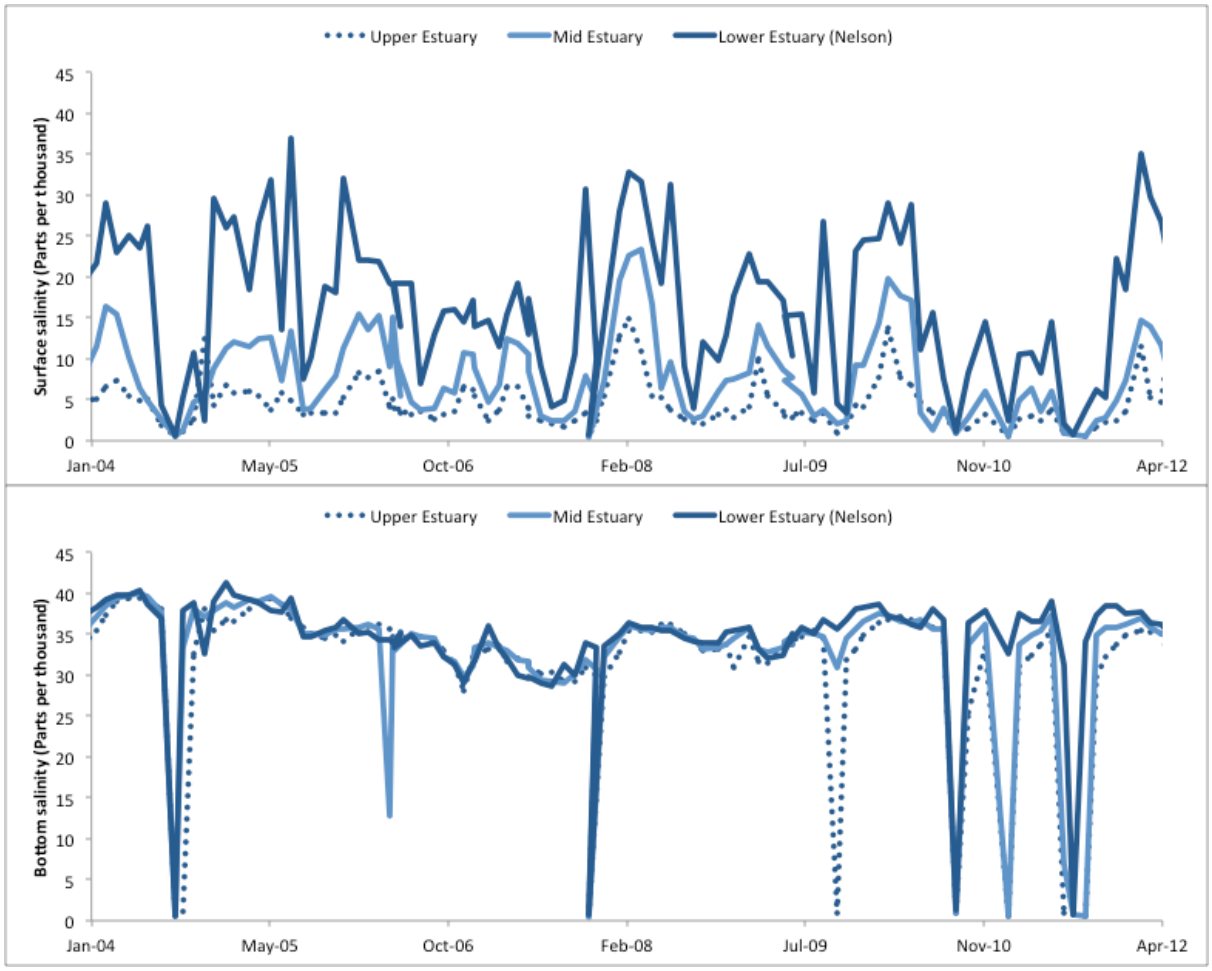

Figure 45: Salinity (parts per thousand) in surface water (top graph) and bottom waters (bottom graph) at three sites in the Glenelg Estuary (data provided by Glenelg Hopkins CMA).

3.6 Cultural services

3.6.1 Gunditj Mirring Traditional Owners Statement of Continuing Connection and Commitment

The authors of this report acknowledge the Gunditj Mirring TOAC as one of the primary guardians, keepers and knowledge holders of Aboriginal cultural heritage for the area being nominated for Ramsar listing as a Wetland of International Importance. As such, guidance and collaboration was sought to strengthen the case for nominating the site through recognition of Country. The Gunditj Mirring TOAC provided the following statement in support of the nomination of part of Country as a Ramsar site.

Creation	• At the start of the Yakinitj, Prenheal sent bolitabolita Creation Beings muyuban tungatt, woorrowarook, bocara and koonang.
Continuing Connection	• For Gunditjmara people, 'Country' includes all living things–none better than the other but equal in its importance in forming this diverse natural landscape that is Gunditjmara Country. • Country means people, plants and animals alike. It embraces the seasons, stories and spirits of the creation. • This flowing, connected cultural landscape possesses its own sacred places, languages, ceremonies, totems, art, clan groupings and law. • These features are seen as inseparable and make up what is known as Country.

	• Our Country is a place of belonging and pride that comes with this belonging.
Impact	• Gunditjmara, other people and climate change have impacted on the profile and ecology of the Bocara Estuary and Koonang Gunditj. • The original sequence of river flow, pools and wetlands are now severely affected and the habitat and refuge provided for birds and their ecology being reduced along the Bocara Estuary and Koonang Gunditj.
Understanding Ramsar	• To help protect and conserve wetlands that provide important habitats, Gunditjmara people understand the Convention on Wetlands, called the Ramsar Convention, as an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
Supporting Ramsar	• Gunditjmara people welcome a Ramsar listing for the areas identified in the Bocara Estuary and Koonang Gunditj to exist alongside our continued connection to Gunditj identified by the Ramsar nomination and our rights and interests recognised in 1997 and 2007 by Commonwealth and Victorian legislation.
Continuing Connection	• We all have a right and responsibility to care for Country, working together with respectful conversations to achieve our aspirations for Country. • We recognise the connections between people and Country; between communities and Country – past, present and future. Forever. • We will work together to restore and improve ecosystems so that they are intact and resilient.

3.6.2 South East Aboriginal Focus Group – Statement of Connection

The authors of this report acknowledge the Traditional Owner family clan groups that fall within the South East Natural Resource Management boundary of South Australia. These Traditional Owner family clan groups are Bunganditj people. The South East Aboriginal Focus Group (SEAFG) is representative of the following Bunganditj Traditional Owner family clan groups:

- Meintangk
- Potaruwutij
- Bunganditj
- Tatiara/ Ngarkat
- Tanganekald (Southern Clans)

The Bunganditj share a boundary with the Gunditj Mirring Traditional Owners and support their statement of the continuing connection and commitment in support of the nomination of part of this country as a Ramsar site.

The Bunganditj acknowledge the Country of Gunditjmara and recognise their long and continuing relationship with Bocara estuary and Koonang Gunditj. Our wish is to strengthen the relationship by respecting the country of Gunditjmara whilst acknowledging our shared history.

The Bunganditj welcomes a Ramsar listing and the connections between place and people. We will work with Gunditjmara and other recognised bodies to restore and improve the ecosystems so they remain intact and resilient. We are fully supportive of Gunditj Mirring Traditional Owners Statement of Continuing Connection and Commitment.

3.6.3 Recreation and tourism

The Ramsar site is located within the 'Green Triangle' of southwest Victoria and southeast South Australia that includes the cities of Warrnambool, Portland and Mt Gambier, as well as small townships such as Nelson and Dartmoor. Visitors are attracted to the area by a range of features, mostly natural or historical (DCE 1991). Visitor numbers to the area, including the Lower Glenelg National Park and Discovery Bay Coastal Park can exceed 100,000 annually, while visitor numbers at townships such as Nelson can exceed 20,000 annually (Glenelg Shire Council 2005, Parks Victoria 2006, DCE 1991). Tourism contributes over $37 Million to the local economy annually (http://www.economicprofile.com.au/glenelg/tourism/value-added) and is a significant with respect to local employment.

The Lower Glenelg National Park is a particularly important recreational area, as it contains large, relatively unmodified areas including unique environmental settings with relatively easy access. These include features such as the Glenelg River gorge and the Princess Margaret Rose Caves within a setting that is highly valued for recreational activities such as sightseeing, boating, canoeing, picnicking, angling and camping. The National Park (and the Ramsar site) are also connected to the Great South West Walk, a 250 km walking loop linking most of the natural areas between Portland and Nelson and which is another important tourism feature of the region (Parks Victoria 2006).

The importance of recreation and tourism, as well as the continued pursuit of adjacent agriculture, is consistent with the wise-use concept promoted by the Ramsar convention.

3.7 Critical supporting services

Supporting services are those which are considered essential 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. A summary of the critical supporting services of the site is provided in Table 17.

Table 17: Summary of critical services within the Glenelg Estuary and Discovery Bay Ramsar Site.

Critical ecosystem service	Description
Diversity of wetland types	The site comprises a network of interconnected wetland types including freshwater permanent wetlands, intermittently inundated marshes, estuarine waters and intertidal sandy beaches.
Special geomorphic features	The site is significant for a number of geological and geomorphic features; in particular the dune slack system is rare, if not unique, within the bioregion.
Provides physical habitat (for waterbirds)	The site provides a network of habitats for waterbird feeding, roosting and breeding. Species that are supported by the site represent a wide range of functional groups (e.g. fishers, waders, ducks) each with different habitat requirements.
Threatened wetland species and ecosystems	One nationally listed ecological community and eight nationally or internationally listed species of conservation significance are supported by the site.
Ecological connectivity	The Ramsar site has a range of distinct wetland types which are both hydrologically and ecologically connected. The connection between the marine, estuarine and freshwater components is significant for fish migration and reproduction.

3.7.1 Supports a diversity of wetland types

As described in section 2.3.4, the Glenelg Estuary and Discovery Bay Ramsar Site contains 10 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 a key driver 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 model in Figure 46. More detailed conceptual models of the wetlands in each of the broad systems (freshwater wetlands, Glenelg Estuary and beach habitat and dune fields are provided in Appendix C).

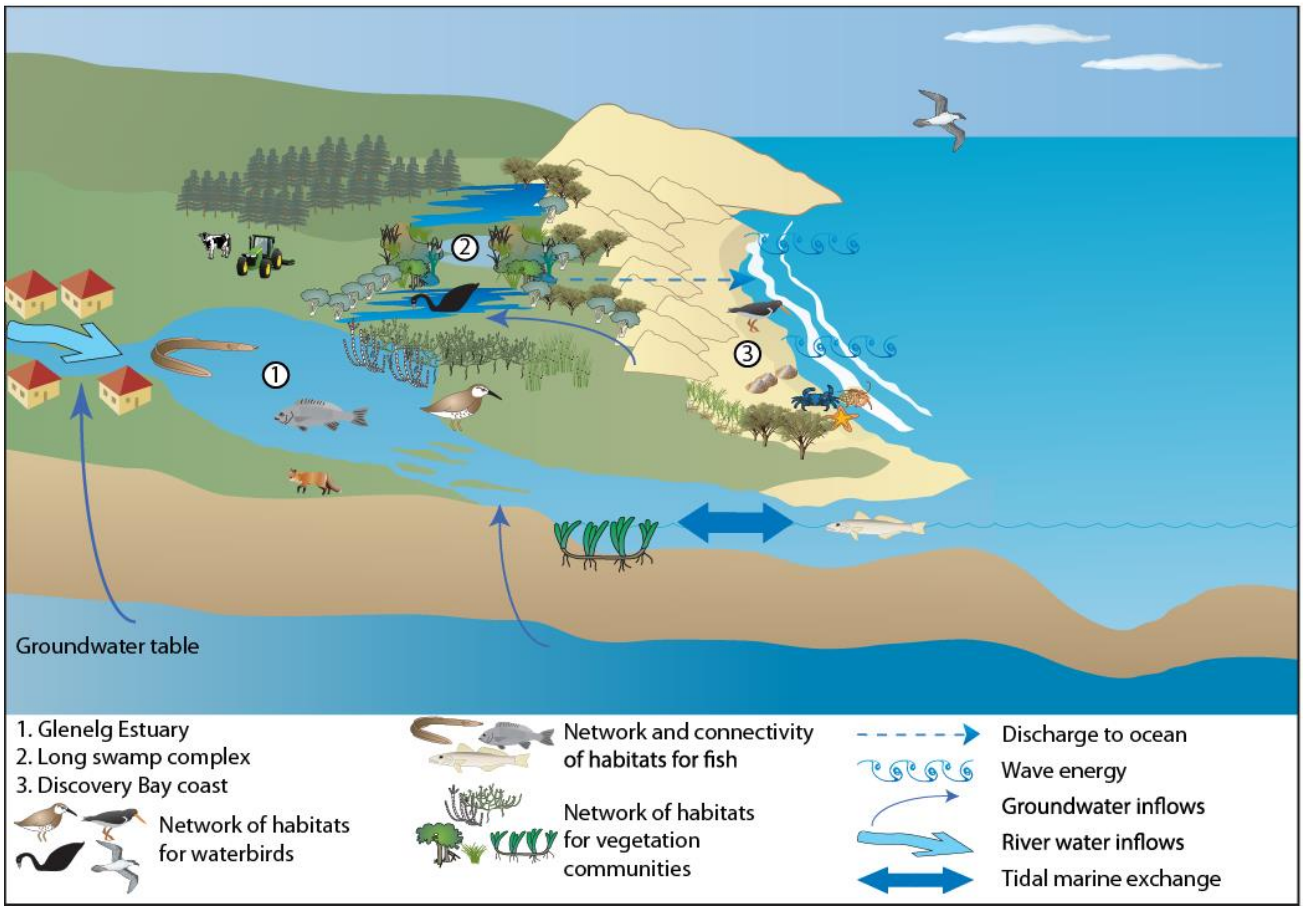

Figure 46: Stylised conceptual model of Ramsar site showing the lower estuary below Nelson and dune, beach and Long Swamp complex

3.7.2 Special features (dune slacks)

The Special Features ecosystem service is defined by DEWHA (2008) as supporting special ecological features, generally uncommon in the landscape, that arise from a combination of features such as uncommon species, habitat, geomorphic features or ecological functions (including acting as refuge in terms of drought, supporting species at a vulnerable or particular stages of their life cycle, or supporting high productivity). Within the Glenelg Estuary and Discovery Bay Ramsar Site the key geomorphic feature is the presence of a dune slack system in the dune fields. The process by which many of the wetland habitats are formed within the Ramsar site make it unusual within the bioregion with the dune system being a key characteristic, albeit largely terrestrial, feature of the site.

Dune slacks are the damp or wet hollows within a coastal dune terrain, where the groundwater level is seasonally at or near the surface. As such, dune slacks are distinct from wetlands associated with swales in other dune systems such as desert linear dunes (Semeniuk and Semeniuk 2011). A second key feature of dune slacks are that they are subject to seasonal inundation or waterlogging and that the water levels are maintained by groundwater. Also the chemistry of the dune slack water should be fresh or evolving from brackish (i.e. recently marine derived) to fresh (Semeniuk and Semeniuk 2011) and typically be low in nutrients.

The water regime of a dune slack is determined by the hydrology of the dune system and its location within it, with local variation in the water table meaning some areas of a slack may be seasonally inundated and

others permanently inundated. Dune slacks are largely fed by infiltration of rain water and are characterised by a pattern of pronounced annual fluctuation of the water table, related to the landform of the dune system as well as climate and the nature of the underlying sediment (JNCC 2007). Variations in the extent and duration of flooding of the dune surface are very important in determining the vegetation and influence the breeding of aquatic species. Hydrological change is an inherent dune slack characteristic; with shallow lakes becoming shallower seasonally inundated basins and eventually seasonally waterlogged basins.

A change in the water table within an existing dune slack can be attributed to a number of factors which can occur at a regional, local or intra-basinal scale. These could include a rise or fall in the dune slack water table (from Semeniuk and Semeniuk 2011):

- As part of a regional response to cyclic changes in rainfall patterns, progradation or erosion of the beach, or a changing sea level; or
- Due to a set of environmental conditions within a local area such as impounding of groundwater, local seepage, or the barring of a valley tract; or
- A response to intra-basinal conditions.

3.7.3 Provides physical habitat for waterbirds

The Glenelg Estuary and Discovery Bay Ramsar Site provides a variety of habitats for waterbirds. Although waterbird usage of the site is largely unknown, the different wetland types and structural habitats of the site provide a mosaic for waterbirds:

- Beach – sandy shores for breeding of Australian resident shorebirds such as red-capped plover, little terns, hooded plover and pied oystercatcher. Intertidal areas provide feeding habitat for shorebirds that also utilise the fore dunes for roosting.
- Saltmarsh can also be used by several bird species for nesting, and although not recorded breeding in the site, bird species that have been observed in the site that also breed in saltmarsh include brolgas and ibis.
- Freshwater wetlands - open water areas provide loafing habitat for ducks and swans, and protection during moult of primary flight feathers. The vegetated freshwater marshes are the preferred habit of the Australasian bittern and a number of large Australian waders such as herons. Black swans build nest mounds in emergent vegetation as do a number of other species, with important habitats ranging from tree hollows to large trees over water and dense reed beds.

The feeding 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 18.

Table 18: Habitat requirements of select waterbird species from the Glenelg Estuary and Discovery Bay Ramsar Site

Function group	Example species	Habitat characteristics
Fish eating waterbirds	Pied Cormorant	Mainly marine in eastern 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.
	Crested Tern	Mainly coastal on beaches, bays, estuaries and lagoons. Roost on bare flat sand areas Diet mainly fish caught from the surface to or shallow waters mainly in inshore areas.
	Australasian Gannet	Pelagic, spending the majority of the year at sea and using land only for breeding. Diet consists mainly of fish, which are caught by plunge diving.
Ducks	Blue-billed Duck	Prefer deep, large permanent open water. Roost – nocturnally usually on open water. Diet – seeds and leaves of aquatic plants and invertebrates (chironomids, caddis flies, dragonflies). Foraging – Deep diving.

Function group	Example species	Habitat characteristics
	Freckled Duck	Shallow productive inland wetlands. Roost – by day on banks. Diet – plants and animals. Foraging – filter feed at night in soft mud or shallow water.
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. Foraging – grazers.
Shorebirds	Black-fronted dotterel	Prefer inland freshwater marshes. Diet – feed mainly on small molluscs but also aquatic insects and crustaceans. Foraging – wade in shallow water and seize prey at or near the surface, but occasionally taking sub-surface prey.
	Pied oyster catcher	Prefer coastal environments with soft sediments. Diet – predominantly bivalve molluscs for which their bill is specifically adapted. Foraging – predominantly for surface prey (by sight), but also probing mudflats.
	Red-capped plover	Prefer saline and brackish wetlands. Diet – mainly molluscs and small crustaceans, but also vegetation. Foraging – wading in shallow water / wet mud and saltmarsh.
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.

3.7.4 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 community and key threatened taxa are shown in Table 19, with further detail specific to the site and listed items presented in Appendix D.

Table 19: Summary of listed species and communities regularly recorded in the Glenelg Estuary and Discovery Bay Ramsar Site.

Listed Species or Community
Subtropical and temperate coastal saltmarsh
Coastal saltmarsh requires some form of ongoing connection to the tidal regime. This could occur via both surface and/or ground waters, occurring in either the intra or supratidal zones. Can also include areas that are cut off from the sea by natural barriers but subject to seepage from the sea.
Maroon leek-orchid (*Prasophyllum frenchii*)
Perennial terrestrial orchid that emerges annually from an underground tuber. Grows in variety of grassland or grassy woodland habitats. Plants grow in damp soil, which is usually well drained. At Long Swamp, the orchid grows in seasonally wet/inundated grassy-sedgelands.

Listed Species or Community
Flowers between late October and December. Produces a single slender flowering spike bearing 20-60 small flowers. Flower spike to 60 centimetres tall. Reverts to dormancy in late February as an underground tuber, when the life-cycle is complete. Seed capsules may be produced and can be seen for several more months.
Swamp greenhood (*Pterostylis tenuissima*)
Occurs exclusively in silky tea-tree (*Leptospermum lanigerum*) scrub. Habitat critical for the survival of this species is defined as all remaining areas of Silky Tea-tree Scrub (Dickson et al. 2012). Pollinated by small gnats and mosquitoes, thought to be attracted to the flowers by scent undetectable by humans (Jones 2006 cited in (Dickson et al. 2012). Likely to be some degree of dependence on mycorrhizae for nutrient exchange to promote germination (Dickson et al. 2012), but specifics are not known. Unlikely to respond or require fire to promote flowering as it predominantly occurs in wet habitats.
Australasian bittern (*Botaurus poiciloptilus*)
Inhabits inland wetlands, and occasionally, estuarine wetlands, generally where there is permanent water. Prefers wetlands with dense vegetation, including sedges, rushes and reeds. Freshwater is generally preferred, although saltmarsh vegetation in estuaries and flooded grasslands are also used by the species. Little information available regarding breeding. Breed from October to February. Nests built approximately 30 centimetres above water level from reeds or rushes.
Curlew sandpiper (*Calidris ferruginea*)
Typically found on intertidal mudflats in sheltered coastal areas, such as estuaries, bays, inlets and lagoons, and also around non-tidal swamps, lakes and lagoons near the coast. Species doesn't breed in Australia.
Fairy tern (*Sterna nereis nereis*)
Secure nesting sites within close proximity to abundant food resources (i.e. fish). Low breeding success has meant that the adult population is typically 10 to 12 years old. Threats to the species include predation by silver gulls, foxes, increased human disturbance of nesting areas and inappropriate water resource management.
Hooded plover (*Thinornis rubricollis*)
Secure nesting sites within close proximity to abundant food resources. Can live up to 16 years, although the average longevity is less. Most birds begin breeding in the second season after hatching, but some commence breeding in either the first or third seasons after hatching. Typically lay 1–3 eggs from August to March. Anthropogenic nest disturbance and egg and chick predation by foxes is common. Loss of nesting habitat through invasive species such as sea spurge (*Euphorbia parallias*).
Yarra pygmy perch (*Nannoperca obscura*)
Obligate freshwater species, most often associated with large amounts of aquatic vegetation (particularly emergent vegetation) in fresh to slightly brackish water. Inhabits slow flowing streams of still waters and often associated with large amounts of woody debris (Kuiter et al. 1996). It breeds in spring, at water temperatures between 16 and 24 degrees Celsius. Completes entire lifecycle in freshwater and like other pygmy perches is presumed to spawn large demersal eggs amongst aquatic vegetation (Bray and Thompson 2011).
Growling grass frog (*Litoria raniformis*)
Critical habitat varies across the range of distribution, but the species utilises both permanent and temporary waters with submergent and fringing vegetation. Preference is for permanent freshwater but non-breeding refugia and habitat along dispersal / recolonisation routes are also important for maintaining the species (Clemann and Gillespie 2012). Breeds in summer and spring, but may not be reliant on flows to trigger breeding (Clemann and Gillespie 2012). Adults can overwinter alongside wetlands; tadpoles hide amongst vegetation in the shallower edges of wetlands, with the aquatic period lasting 2 – 15 months. Preferred breeding habitat is typically shallow, up to 1.5 m, where there is complex vegetation structure.
Ancient greenling (*Hemiphlebia mirablis*)

Listed Species or Community
At Long Swamp the high densities of the species were in areas with 20–40 cm of water dominated by *Baumea* (Cordero-Rivera 2015). They are poor dispersers, only flying very short distances, typical of some other small damselflies. Lifespan is estimated to be in the order of three weeks (Cordero-Rivera 2015).

3.7.5 Ecological connectivity

Ecological connectivity can relate to water mediated movement of biota, energy and materials through the landscape (Pringle 2001, 2003) and is a well-established principle in the maintenance of spatially structured populations. Aspects of ecological connectivity considered critical to the character of the Glenelg Estuary and Discovery Bay Ramsar Site include pathways for migratory fish, particularly for diadromous fish, and interconnected habitat for waterbirds.

Fish

Fish that migrate from their home range usually do so as part of feeding or breeding strategies. Fish that display these traits are defined as (Potter et al. 2015):

- **Diadromous,** which includes**:**
  - **Anadromous:** diadromous fish that live mostly in the sea but migrate to fresh water to breed,
  - **Catadromous:** diadromous fish that live mostly in fresh water and migrate to the sea to breed,
  - **Amphidromous:** diadromous fish that spawn in fresh water, with the larvae flushed out to sea, where feeding occurs, followed by a migration back into fresh water, where most somatic growth and spawning occurs.
- **Potamodromous:** fish that migrate within freshwater habitats only, and
- **Oceanodromous:** fish that migrate within marine environments only.

While only one percent of the world's fish are diadromous (Arai and Chino 2012), they are usually well represented in estuarine environments, such as at the Ramsar site (Appendix F). Diadromy was thought to involve regular, physiologically mediated movements which occur at predictable life history phases in each diadromous species, they involve most members of a species' populations, and they are usually obligatory (McDowall 1997). Recent investigations, however, have indicated variable patterns of migration are possible (e.g. short fin eels completing whole life cycle in marine environment (Arai and Chino 2012)). The importance of migration within the lifecycle of migratory fish means that activities such as river regulation and the instalment of barriers to migration have resulted in diadromous fish being amongst the most threatened vertebrate species in many parts of the world (Angermeier 1995, Jonsson 1999 cited in Miles et al. 2013, Baumgartner et al. 2014).

Examples of fish species recorded at the Ramsar site that display different forms of migration (Drew et al. 2008) are listed in Table 20, with the common pattern of migrations illustrated in Figure 47. The number of species with different migratory strategies contributes to the biodiversity value of the site, and is also important in supporting fisheries elsewhere in the catchment.

Table 20: Migratory strategies for fish species recorded as occurring in the site (adapted from Cook et al. 2007, Crook et al. 2008, Drew et al. 2008).

Migration strategy	Species name	Common name
Anadromous	*Atherinosoma microstoma*	Smallmouth hardyhead
	Geotria australis	Pouched lamprey
	Mordacia mordax	Short-headed lamprey
Catadromous	*Acanthopagrus butcheri*	Black bream
	Anguilla australis	Short-finned eel
	Aldrichetta forsteri	Yellow-eye mullet

	Galaxias maculatus	Common galaxias
	Macquaria colonorum	Estuary perch
	Mugil cephalus	Sea mullet
	Pseudaphritis urvillii	Tupong
Amphidromous	*Galaxias brevipennis*	Climbing galaxias
	Galaxias truttaceus	Spotted galaxias
	Redigobius macrostoma	Large mouth goby
Potamodromous	*Nannoperca australis*	Southern pygmy perch (very limited)
	Retropinna species	Southern smelt

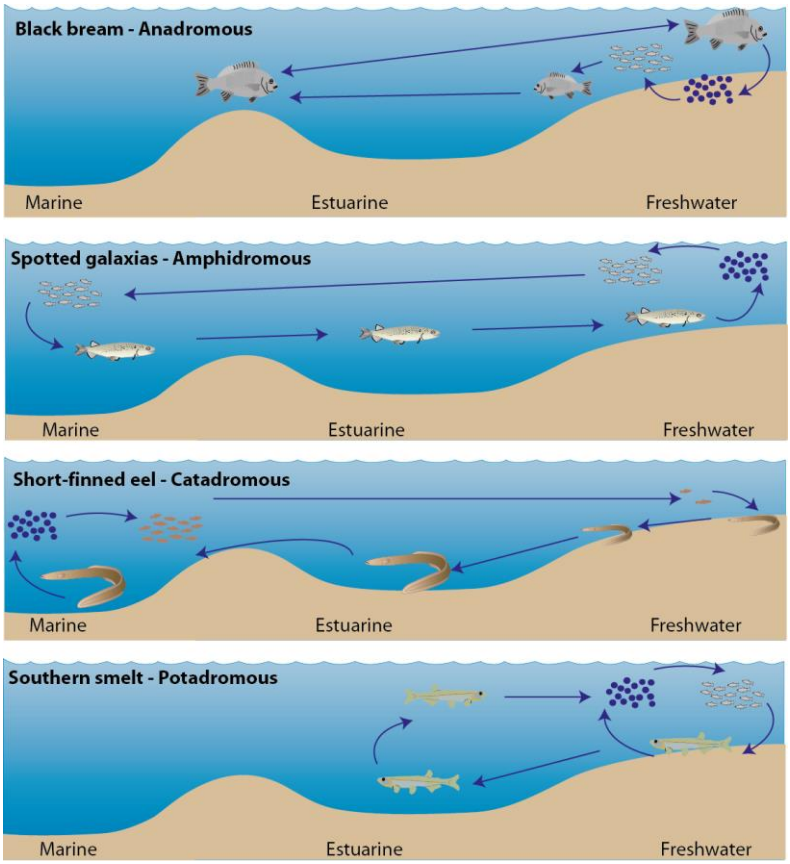

Figure 47: Simple conceptual model of fish migration strategies representing species from the Ramsar site (adapted from Potter and Hyndes 1999).

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. As described in sections 3.7.1 and 3.7.3. 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 10,000 kilometres twice in a single year (Figure 48).

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 (March 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 bird’s 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.

The exception to this lifecycle pattern is the double-banded plover, which is the only species in the East Asian-Australasian Flyway that breeds in the southern hemisphere. This species breeds in New Zealand from September to December and then spends the winter in Australia (May to August). There are moderate numbers of double-banded plover recorded in the site during winter predominantly in the vicinity of the Glenelg River mouth and Oxbow Lake (BirdLife Australia unpublished data).

Figure 48: East Asian-Australasian Flyway (Bamford et al. 2008)

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 49). 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.

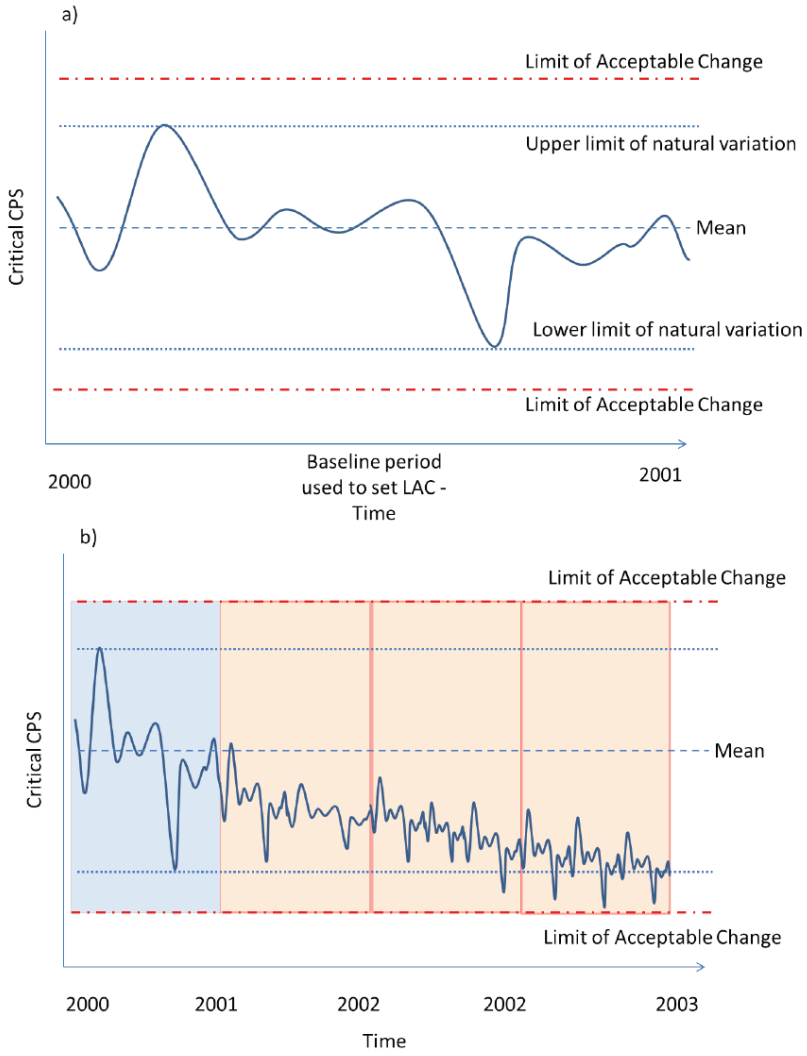

Figure 49: Issue of setting LAC only on upper and lower limit of natural variability. A) represents upper and lower limit of natural variation and b) which shows a changed temporal pattern as well as a declining trend, which would not be detected as it would not trigger the LAC.

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 Glenelg Estuary and Discovery Bay Ramsar Site

LAC have been set for the Glenelg Estuary and Discovery Bay Ramsar Site to represent current conditions. Where possible, site specific information has been used to statistically determine LAC, however, there is relatively little data on which to set quantitative LAC. In the absence of sufficient site specific data, LAC are based on recognised standards or information in the scientific literature that is relevant to the site. In all cases, the source of the information upon which the LAC has been determined is provided.

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 21: Limits of Acceptable Change for the Glenelg Estuary and Discovery Bay Ramsar Site.

Critical CPS	Baseline / supporting evidence	Limit of Acceptable Change	Confidence
Hydrology	With the exception of the Glenelg Estuary, quantitative information on the hydrological regimes of most of the wetlands in the Ramsar site is lacking. For the inland wetlands, a change in permanence (e.g. permanent to intermittent) would be considered a change in character. Permanent wetlands within the site comprise: Bridgewater Lakes, Lake Moniboeng, Swan Lake, Malseed Lake and Cain Flat Swamp. There is insufficient data to derive a hydrological LAC for the other wetlands in the site. The Glenelg Estuary is seasonally closed estuary that is characterised by periods of closure averaging 40 days, but sometimes spanning a year. A sustained change to become permanently open or closed would represent a potential change in character.	Bridgewater Lakes, Lake Moniboeng, Swan Lake, Malseed Lake and Cain Flat Swamp will not dry. The Glenelg Estuary will not remain closed for three consecutive years or open for greater than five years.	Moderate
Water quality: salinity and dissolved oxygen	The Glenelg Estuary is a seasonally closed salt-wedge estuary with three distinct layers that vary under different tidal and freshwater inflow conditions. Maintaining this variability in salinity and dissolved oxygen regimes is important for many biological and chemical functions and processes. The variability is maintained by the opening and closing of the estuary mouth.	See LAC for hydrology (Glenelg Estuary)	Moderate
Vegetation type and extent	Two broad vegetation types in the site were mapped in detail in 2008 (Sinclair and Sutter 2008): • Coastal saltmarsh - 26 hectares • Freshwater sedges and tall marsh - 939 hectares A LAC has been set based on a 50% change in extent (consistent with LAC for other Victorian Ramsar sites). Lake bed macrophytes are also a critical component of the ecological character of the site, but remain a knowledge gap with insufficient information to derive a LAC for this community.	Vegetation extent will not fall below the following: • Coastal saltmarsh - 13 hectares • Freshwater sedges and tall marsh - 470 hectares, with at least 270 hectares of *Baumea* sedgelands.	Moderate
Fish diversity and abundance	There is a lack of underlying knowledge of variability in fish species richness for the site, with incomplete inventory of several of the freshwater wetlands. Current species lists put the number of species found at the site at 45 across four life history strategies (i.e. freshwater, estuarine, diadromous and marine – based on Potter et al. (2015). The LAC has been developed based on expert opinion and due to the limited data focuses on the loss of a guild as representing a potential change in character.	Native fish within the Ramsar site will represent each of the following life history strategies: estuarine dependent, estuarine opportunists, marine migrants, diadromous and obligate freshwater species.	Moderate

Critical CPS	Baseline / supporting evidence	Limit of Acceptable Change	Confidence
Waterbird diversity and abundance	The site supports a diversity of waterbirds with a total of 95 wetland dependent species recorded from the site. Consistent count data are not available, but BirdLife Australia records indicate that 32 species across several waterbird guilds are regularly recorded (> two thirds of years) in the site: • Ducks, swans and grebes • Fishers • Large wading birds • Australian waders • International waders • Gulls and terns In addition, the site supports 1.4% of the population of sanderling (*Calidris alba*). The LAC is based on representative waterbird guilds and a 50% decline in the Sanderling.	Absence of the following waterbird guilds in any three out of five years: • Ducks, swans and grebes • Fishers • Large wading birds • Australian waders • International waders • Gulls and terns • Sanderling abundance falls below 0.7% of the global population in three out of five years.	Moderate
Diversity of wetland types	The Glenelg Estuary Ramsar site supports a range of wetland types. Wetland type is a product of hydrology and vegetation. This criteria service is covered by the LACs for those respective components and processes.	See LAC for vegetation type and extent and hydrology.	Moderate
Special geomorphic features: dune slack	The formation of dune slack wetlands is a critical feature of the site and contributes to meeting criterion 1 however this service does not lend itself to having a threshold of change as it operates on geological time scales.	No LAC. The formation of dune slack wetlands is a critical feature of the site and contributes to meeting criterion 1. This service, however, does not lend itself to having a threshold of change as it operates on geological time scales.	
Physical habitat for waterbirds	This critical service is linked to changes in the frequency and duration of wetland inundation as well as changes in extent and condition of vegetation.	See LAC for vegetation type and extent and hydrology.	Moderate
Threatened species: plants	Two nationally threatened plant species have been recorded on a semi-regular basis from the site. Insufficient data to derive a quantitative LAC, LAC based on continued presence.	Absence of maroon leek-orchid (*Prasophyllum frenchii*) and or swamp greenhood (*Pterostylis tenuissima*) in three consecutive targeted surveys.	Low
Threatened species: fish	One nationally threatened fish species have been recorded on a semi-regular basis from the site. Insufficient data to derive a quantitative LAC, LAC based on continued presence.	Absence of Yarra pygmy perch (*Nannoperca obscura*) in any three out of five targeted surveys	Low

Critical CPS	Baseline / supporting evidence	Limit of Acceptable Change	Confidence
Threatened species: birds	Hooded plover are recorded at the site in over 80% of years. There is insufficient count data, however, to derive a quantitative LAC. LAC based on continued presence.	Absence of hooded plover (*Thinornis rubricollis*) in three out of five years.	Low
Threatened species: growling grass frog	Growling grass frog are regularly recorded at the site, but there is insufficient data to derive a quantitative LAC. LAC is based on continued presence.	Absence of growling grass frog (*Litoria raniformis*) in any three out of five targeted surveys at 50% of known (recent) locations within the Ramsar site (see Bachmann et al. 2013).	Low
Threatened species: ancient greenling	The Ramsar site supports at least 5 % of the total population of the ancient greenling. LAC was derived based on expert opinion, and critical habitat (50% loss of critical habitat).	See LAC for vegetation type and extent.	Low
Ecological connectivity	Ecological Connectivity is related to estuary opening.	See LAC for hydrology (Glenelg Estuary) and fish (continued presence of diadromous fish).	Moderate

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 2008) 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 CPS 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.

There are a number of potential and actual threats that may impact on the ecological character of the Ramsar site, as illustrated in Figure 50. These threats have been identified in various management strategies and plans relevant to the Ramsar site (e.g. Parks Victoria 2015), as well as in consultation with local stakeholders. For this ECD, the IUCN threat classification scheme (IUCN 2012b) has been applied to the threats identified at the Ramsar site.

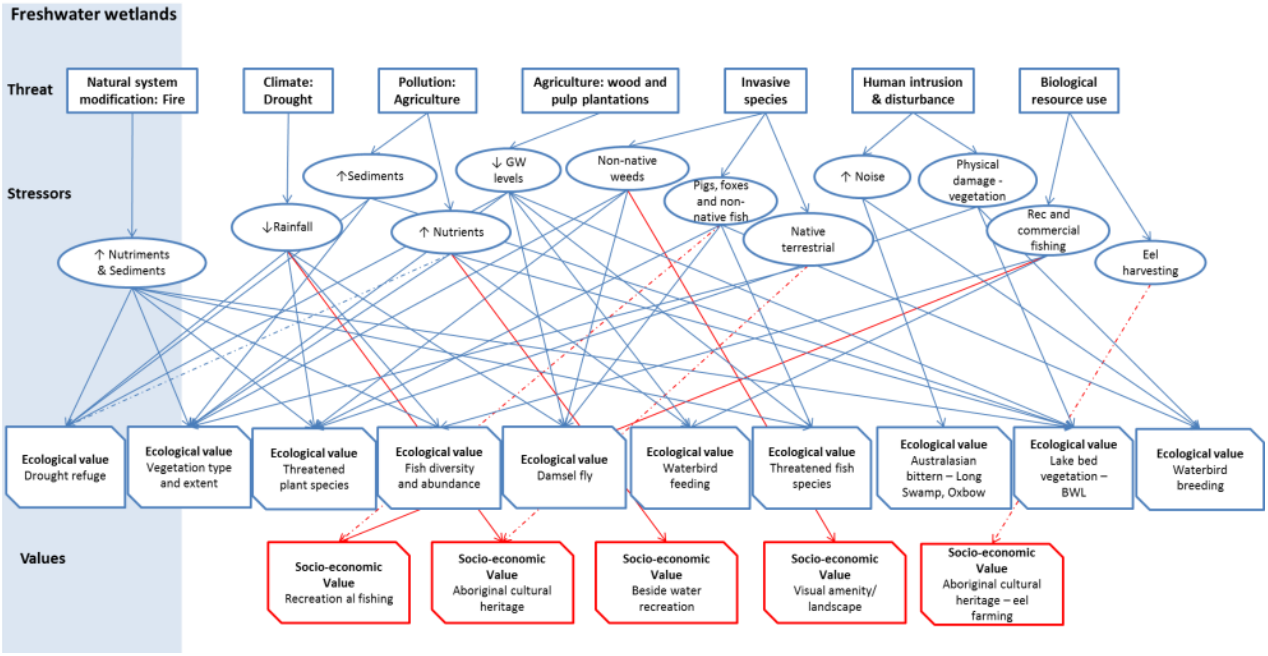

Figure 50: Simple stressor model for the freshwater wetlands management unit of the Ramsar site. Red and blue dashed arrows indicate a likely relationship, but are currently a knowledge gap for the site.

5.1 Agriculture and aquaculture

5.1.1 Wood and pulp plantations

The growth of trees in plantations can lead to changes to the interception of rainfall and groundwater recharge. Rates of evapotranspiration can vary over the life of a crop, which can in turn affect water yield and groundwater levels (e.g. Adelana et al. 2015, Benyon et al. 2008). For example, there is likely to be less evapotranspiration and interception of rainfall and groundwater early in the production cycle when trees are planted and establish, compared with the increased interception and evapotranspiration (decreased water yield) that can occur as trees grow to maturity.

Many of the wetlands within the Ramsar Site are connected to the local groundwater table, and have remained so whilst nearby agricultural land has supported the production of plantation timber over many decades. In this context, the existing timber plantations contribute to the conditions surrounding the Ramsar site at the time of listing. The risk associated with decreased groundwater levels affecting critical components, processes and services, such as vegetation type and extent, and habitat for waterbirds, as well as threatened invertebrates and native fish, would occur should the area of timber plantation in land adjacent to the Ramsar site be increased substantially from that occurring at the time of listing.

5.2 Energy production and mining

5.2.1 Oil and gas drilling

Petroleum Exploration Licences (PEPs) 150 and 151 cover the Discovery Bay Coastal Park and surrounding areas (Figure 51, http://www.bridgeport.net.au/otway.html). Work conducted under the PEPs by Bridgeport Energy includes seismic processing, interpretation and mapping, and has confirmed the existence of drilling prospects. Potential unconventional gas mining "plays" have been identified, most likely involving fracking.

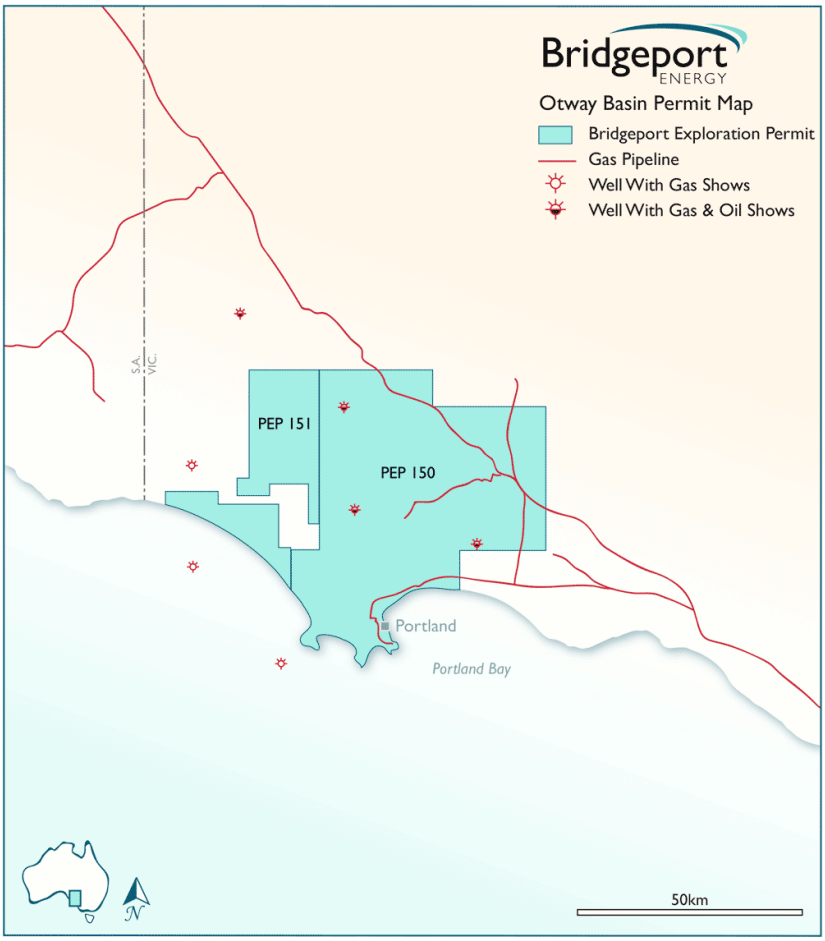

Figure 51:Location of PEP 150 and 151. Source: Bridgeport Energy, accessed September 2015, ***http://www.bridgeport.net.au/otway.html****.*

Fracking involves stimulating fractures in a rock layer in order to increase the flow of gas, oil or other substances, such as geothermal fluids (http://www.appea.com.au/oil-gas-explained/operation/hydraulic-fracturing-fraccing/). Fluid (often a mixture of water and sand and other chemicals to reduce friction and control microbes) is pumped down the well at high pressure to produce tiny cracks in the target rock reservoir. "Proppants", such as sand or tiny ceramic beads, are included in the fluid to hold the fissures open and improve the flow of gas or oil. While the proppants

remain behind in the rock formation, most of the injected fluid flows back to the surface where it is recovered for storage, treatment, disposal or reuse.

Victoria has had a moratorium on the issuing of new licences and fracking since 2012 (Parliament of Victoria 2013); and in March 2017 the *Resources Legislation Amendment (Fracking Ban) Bill 2016* was passed in parliament putting a permanent ban on fracking and extending a moratorium on conventional onshore gas exploration to 2020. The moratorium and subsequent ban was in response to a number of potential issues with the production of coal seam gas that may have negative environmental and social impacts. These issues include:

- The large amount and management/disposal of 'produced water' pumped from coal seams to release the gas and the potential associated impacts this may cause. Produced water is often saline and can contain other chemicals that either occur naturally or are used in the fracking process.
- The potential environmental implications of fracking should this increase the risk of creating new fractures in the rock that intersect adjacent aquifers and contaminate water resources.
- The leakage of methane as 'fugitive emissions'.
- Potential seismic activity and land subsidence.
- Potential restrictions on access to, or management of agricultural land.

This threat would only be realised were the ban to be overturned by a future government.

5.3 Biological resource use

Excessive biological resource use has the potential to affect critical CPS via recreational or commercial harvesting that reduces food resources that help maintain waterbird diversity and abundance. Excessive biological resource use can also affect the provision of aquatic foods for human consumption.

Recreational fishing is a popular activity, particularly in the Lower Glenelg Estuary and Bridgewater Lakes. In addition, the Glenelg region has a commercial eel fishing industry that collects eels from most lakes and wetlands in the region (Glenelg Hopkins CMA 2006), and this may extend to the aquatic ecosystems within the Ramsar site boundary. However, there is no documented evidence of any impact of recreational or commercial fishing on fish diversity and abundance within the Ramsar site.

Pipis (*Donax (Plebidonax) deltoides*) are bivalve molluscs found in the sands of high-energy beaches in eastern Australia (Early et al. 2013). They are harvested commercially and recreationally from the Discovery Bay Coastal Park (Parks Victoria 2006). There is concern that this is unsustainable and impacting not only on populations of pipis, but on waterbird species such as the pied oyster catcher that feed on the small molluscs (VPNA 2015). There is little information on the extent of the pipi population within the Ramsar site or the effect of recreational and commercial catches.

Fisheries Victoria has commenced a process to develop a fishery management plan for the Victorian Pipi Fishery (DEDJTR 2016). A Steering Committee has been formed to provide recommendations and expert advice in relation to the development of Victorian Pipi Fishery Management Plan (FMP) and to ensure that the FMP conforms to requirements of the Fisheries Act 2009 and Ministerial Guidelines.

5.4 Human intrusion and disturbance

5.4.1 Recreational activities

Recreation activities have the potential to affect CPS via noise disturbing waterbirds and physical damage that can affect wetland vegetation and other physical habitat. Threatened species, such as such as the maroon leek-orchid (*Prasophyllum frenchii*) and the swamp greenhood (*Pterostylis tenuissima*), can also be put at risk from physical damage.

Recreational activities such as four wheel driving, trail bike riding horse riding and dune buggying have all been identified as a risk to dune and foreshore stability, with increased erosion and damage to vegetation and habitat being direct consequences (Parks Victoria 2006). Saltmarsh is particularly

vulnerable to these types of disturbance and is slow to recover (Boon et al. 2011). Recreational activities near feeding and roosting shorebirds and nesting seabirds can cause several impacts. Disturbance of shorebirds has shown to reduce condition and place birds at risk on the northward migration to breed (Glover et al. 2011). Disturbance of beach nesting birds can reduce recruitment and cause nest abandonment (Weston et al. 2012).

Bridgewater Lakes are popular for boating activities such as jet-skiing, motor boating and water-skiing. These have the potential to disturb fauna as well as cause damage to foreshore and littoral vegetation from backwash and erosion. For example, a recent assessment of lake habitat quality undertaken by the Victorian EPA indicated a high score at Lake Moniboeng, which was considered representative of a relatively unmodified lake located within a national park (EPA Victoria 2010). However, the lake habitat modification score rated moderate and indicated threats due to human activities, possibly including recreational activities such as camping and boating, and also moderately intensive land uses within the catchment, including forestry (EPA Victoria 2010). Lake Bridgewater was also assessed as part of the EPA Victoria; water quality was found to be good but the lake habitat quality was rated as moderate, while lake habitat modification rated as poor. A number of in-lake threats were noted as possible contributors to the low biological scores, including boating and water sports, as well as surrounding landuse threats such as livestock grazing (EPA Victoria 2010).

5.5 Natural systems modifications

5.5.1 Fire and fire suppression

Wildfire has the potential to affect CPS through impacts on vegetation type and extent, and water quality (e.g. increased sediment, turbidity and pollutant load), and poses a risk to threatened species and communities. Fire management is covered by local plans (e.g. management plans for the National Park and Coastal Park, Parks Victoria 1991 and 2006), regional fire management strategies (DELWP 2015b) and regional management plans (e.g. Parks Victoria 2015). These plans recognise that days of extreme fire danger occur during summer in the Lower Glenelg area in most years and that fires may threaten life, property and natural values.

Fire is a natural part of the environment and is important for regenerating and maintaining the health of many species and ecosystems. However, large, intense fires pose a risk to ecosystem values by affecting vegetation diversity, type and extent and may result in vegetation communities are overly dominated by fire-tolerant species. It can also put at risk threatened species that occur at the Ramsar site, such as the maroon leek-orchid (*Prasophyllum frenchii*) (Duncan 2010). This risk posed by fires is likely to increase under climate change, as fires are expected to be more frequent and intense and fire seasons expected to start earlier and end later.

Fire management is carried out according to regional fire management codes of practice and operational plans (e.g. DES 2012, Government of Victoria 2014), which aim to decrease the incidence, spread and severity of wildfire. In the area of the Ramsar site, special consideration is given to protecting pine plantations, National Park and Coastal Park values and the township of Nelson. Wildfire is considered to be of lower strategic significance for fire management in the Coastal Park than the National Park section of the Ramsar site due to proximity to the coast and presence of coastal vegetation communities. Fires generally enter the Coastal Park when the prevailing winds are northerly and pose less of a risk to freehold land than fires in the National Park (Parks Victoria 2006).

In addition to fire prevention, fire suppression also needs to be carefully managed to avoid loss or damage to environmental and cultural values through such things as soil erosion, weed invasion, increased water turbidity, fragmentation of habitats and loss of species (terrestrial and aquatic).

An improved understanding of the role of fire management in maintaining ecosystem health and cultural values is now being built into regional management strategies (e.g. EPA Victoria 2011, Parks Victoria 2015). This includes planned burning based on the needs and features of the landscape. Key factors that are considered include the presence of species that require fire (e.g. for recruitment) and the frequency of fire that can be tolerated by the species that make up a vegetation communities in the area. Many wetland dependent vegetation communities are not reliant on fire to regenerate and recover slowly after fire (e.g. saltmarsh). In addition, cultural burning of wetlands and dune scrub in the indigenous protected areas may be appropriate in order to support traditional practices.

5.5.2 Dams and water management

Both regional and local water management activities have the potential to threaten ecological values, through impacts on river, wetland and estuary water regimes (hydrological processes), ecological connectivity and thus processes such as fish migration and reproduction.

Hydrological alteration of the Glenelg River

The construction and operation of Rocklands Reservoir since 1953 and the resultant regulation of flows below the dam has altered the natural hydrological regime in the Glenelg River, particularly in the reach below the dam. It has been estimated that the operation of Rocklands Reservoir has reduced mean annual streamflow in the Glenelg River from approximately 113 GL to approximately 43 GL (SKM 2003). In particular, the regulated flow regime has resulted in a large decrease in the frequency of large flow events (e.g. bankfull flows and floods) and connection of the river channel with its riparian zone and floodplain. The operation of the dam has also altered the seasonality of flows along the river, although this effect declines with distance downstream from the dam due to tributary inputs. While the index of stream condition (DEPI 2015) indicated that much of the Glenelg River remains in moderate condition, however the hydrology sub index indicated poor to very poor condition. Other studies have also noted the degradation of the physical form, water quality and overall health of the river that has resulted from previous land use practices (e.g. land clearing, removal of snags) and changed hydrology (e.g. Glenelg Hopkins CMA 2002, Erskine 1994).

In 2003 an environmental flow study (SKM 2003) was conducted to develop flow recommendations to achieve river health objectives. The flow recommendations are now refined and implemented as part of seasonal watering plans for the river (see VEWH 2014), using water held under an environmental water entitlement (Wimmera CMA and Glenelg Hopkins CMA 2011). While management and delivery of the environmental water reserve will contribute (along with other river management initiatives) to improvements in the condition and ecosystem function of the Glenelg River the influence of environmental water delivery on the condition and ecological objectives for the estuary is not clear. Flow recommendations for the estuary are currently being investigated.

Hydrological alteration of the Long Swamp complex

In the late 20th Century, two channels were cut through the coastal dune at White Sands and Nobles Rocks, which are narrow, low points in the dune system, to increase the land available for agriculture (Reynolds 2007). The effect of this was to reduce the duration, extent and frequency of inundation within the complex. During the Millennium drought, the channel at White Sands naturally closed, and in 2014, works were completed to close the channel at Noble Rocks. Early observations indicate increased duration, depth and extent of inundation and restored connectivity between the chain of wetlands that comprise the Long Swamp complex and potentially the Glenelg Estuary (Bachmann unpublished) (see section 3.4.1).

DEPI (2014) states there is evidence that groundwater levels in the area have declined from pre-European times. If the water table were to decline further this would further reduce the water supply of the wetland. A decline could be caused by a drier climate, higher levels of direct extraction or recharge interception in areas in the groundwater recharge zone outside the proposed Ramsar site. Higher recharge interception could happen if the cleared area to the north of the swamp was used for new forestry plantations, as this would intercept runoff that would otherwise replenish the groundwater. New forestry developments are subject to local planning considerations and potential impact to Matters of National Environmental Significance. Reynolds (2007) stated that plantations on the cleared northern dunes inland of Long Swamp have been present since the 1950s, with major harvesting and replanting occurring in the 1980s.

5.5.3 Other ecosystem modification - estuary opening

Seasonal closure of the Glenelg Estuary occurs naturally during periods of low river flow, when sand builds up across the estuary mouth. Although the system can open naturally, artificial opening (by mechanical means) can be carried out to alleviate flooding. The potential effects of artificial openings include (Glenelg Hopkins CMA 2006a):

- Reduced sand bar scour when the mouth is opened at lower water levels, leading to more rapid mouth closure.

- Disruption to the natural patterns of variation in water quality and biotic distribution and abundance.
- Disruption of aquatic faunal migration and reproductive cycles.

Entrance opening is now managed using the Estuary Entrance Management Support System (EEMS), which is designed to minimise adverse impacts of the artificial opening of estuaries (Arundel 2006).

Under the *Water Act* 1989 any works in, on or over a designated waterway require a Works on Waterways Permit from the responsible catchment management authority. The permit process aims to avoid adverse impacts on the health of the waterway (e.g. damage to vegetation and river banks). The Glenelg Hopkins CMA issues a Works on Waterways Permit for the opening of the Glenelg Estuary mouth. There are no permits in the area of the proposed site for sand or gravel extraction.

Figure 52: Closed Glenelg Estuary mouth, October 2015 (© Marcel Hoog Antink).

5.6 Invasive and other problematic species and genes

Invasive species can affect CPS either directly or via their effect on habitat availability or by reducing food resources. Wetland vegetation extent and diversity, as well as native fish and waterbird diversity and abundance are all threatened by invasive species, including both non-native and problematic native species. While a number of invasive species have been recorded within the Ramsar site, the extent of these species is largely unknown.

5.6.1 Invasive non-native plants and animals

A number of terrestrial weed species have been noted as threatening the Ramsar values of the site (Australis Biological 2012). These include radiata pine (*Pinus radiata*), blackberry (*Rubus fruticosus* agg.), bridal creeper (*Asparagus asparagoides*), boxthorn (*Lycium ferocissimum*), Italian buckthorn (*Rhamnus alaternus*), myrtle-leaf milkwort (*Polygala myrtifolia*) and sea-lavender (*Limonium hyblaeum*). While these species may affect terrestrial vegetation within the Ramsar site, including

threatened species such as the maroon leek-orchid (Duncan 2010), they are less likely to pose a significant threat to the aquatic ecosystems and associated biota of the Ramsar site. Of more concern is the potential for the introduction of cord grass (*Spartina* spp.). Although not yet recorded in the Glenelg region, the species is known from eastern Victoria and South Australia, and the intertidal and saltmarsh habitats of the Ramsar site would be vulnerable to invasion by this species. It is tolerant of inundation and salinity, is resistant to many herbicides and can rapidly outcompete native vegetation (Boon et al. 2011).

Introduced mammals are present within the Ramsar site, with damage to soil and vegetation by rabbits, goats, pigs, deer and sheep identified as a significant threat for the Discovery Bay Coastal Park (Parks Victoria 2006) and an important area of management in the river forest and sea country in the South West area (Parks Victoria 2015). In addition, foxes and feral cats pose a threat to nesting, feeding and roosting shorebirds and seabirds.

Eastern gambusia (*Gambusia holbrooki*) has been recorded in the Long Swamp complex (Veale 2014) and redfin (*Perca fluviatilis*) and tench (*Tinca tinca*) are known from the Bridgewater Lakes (Glenelg Hopkins CMA 2006b). Bridgewater Lakes were stocked with brown trout (*Salmo trutta*) as early as the 1940s (Border Watch 1948), but the practice no longer occurs and trout are no longer present in the lake. Carp (*Cyprinus carpio*) have not been recorded in any of the estuaries or wetlands within the Ramsar site, but they are present in the Glenelg River, and there is suitable habitat in the freshwater systems (Veale 2014).

5.6.2 Problematic native species (plants and animals)

A number of problematic native plant species are known to occur in both the Lower Glenelg National Park and Discovery Bay Coastal Park areas in areas included in the Ramsar site. While native species, they are problematic because of their vigorous growth and ability to displace other native plants, thus reducing vegetation diversity. Problematic species include coast wattle (*Acacia longifolia var. sophorae* (Emeny et al. 2006; Emeny 2009) spiny rush (*Juncus acutus*) and beach daisy (*Arctotheca populifolia*) (Parks Victoria 2006).

Coastal wattle has become a seriously invasive species in the last two decades, invading new habitats having a profound effect on coastal heath. In south west Victoria it is now thought to infest an estimated 10 000 hectares of indigenous vegetation (Emeny 2009). It has the potential to threaten most of the coastal dune, heathland and woodland vegetation in the Portland area, as well as populations of rare plant and animal species. For example, the endangered Mellblom's spider orchid (*Caladenia hastata*) and the endangered heath rat (*Pseudomys shortrigdei*) are both thought to be under threat. Its invasion of the Bats Ridge Wildlife Reserve, also in south-western Victoria, is threatening the remaining populations of the spider orchid known as limestone caladenia (*Caladenia calcicola*). It has also been shown to reduce the diversity of two ant populations in infested areas. Studies have shown that the change is progressive, and that areas that had been invaded for a longer period of time were more greatly affected. Dense infestations could often cause up to 75% of indigenous species to be lost from the vegetation, and at worst all indigenous species may be eliminated.

5.7 Pollution

Pollution has the potential to affect CPS through its effect on water quality (nutrients and sediments) and estuary stratification, which in turn can affect fish and associated services such as food production, as well as threatened species via degradation of habitat.

5.7.1 Agricultural and forestry effluents (nutrients and sediments)

Land clearing and subsequent runoff and erosion in the Glenelg River catchment has resulted in large amounts of sediments moving into the river. It is estimated that between 10,000 and 50,000 cubic metres of sand has been deposited per kilometre of channel (Rutherfurd and Budahazy 1996), causing significant sand slugs and bars upstream of the Ramsar site. Unless management actions can prevent the downstream movement of this sediment, the sand will eventually reach the lower Glenelg Estuary (Glenelg Hopkins CMA 2006a). It is expected that sand deposition could alter the morphology and habitat of the estuary, impacting on associated biota (Glenelg Hopkins CMA 2006a).

The predominantly agricultural landscape of the Glenelg River catchment also contributes large loads of nutrients into the system, increasing the potential for algal blooms (Ierodiaconou et al. 2005). Although nutrient concentrations in the Lower Glenelg River are not well understood, it is likely that nutrients are entering from upstream and particularly when the system is closed, and could lead to excessive algal growth and low dissolved oxygen concentrations. This would impact on seagrass and aquatic fauna within the estuary system.

5.7.2 Industrial and military effluents

In June 2015, Iluka Resources Ltd applied to the EPA Victoria for a Works Approval to dispose an estimated 2,200,000 tonnes of waste from its Douglas Mine site over the next 15 to 20 years (Kismet Forward 2015). The mine site is located a considerable distance upstream from the proposed Ramsar site at the catchment boundary with the adjacent Wimmera River. The waste will be predominantly by-products from its Hamilton Mineral Separation Plant (MSP), as well as concrete and steel from other Victorian Iluka mine sites that is contaminated with Naturally Occurring Radioactive Materials (NORM). It is proposed that the waste by-products, including NORM wastes, would be covered with a 5m thick cap of clean fill. In response to community concerns, a community conference was held to explore the issues surrounding the application, information in relation to the issues, and proposed mitigation measures to safeguard community and environmental health.

In terms of the current Ramsar project, the potential risk from management of wastes at the Douglas Mine would be contamination of groundwater with waste products (including heavy metals and NORM), which may then make its way back into the Glenelg River and the Glenelg Estuary. As part of its assessment of the Works Approval application, EPA Victoria has recently (September 2015) requested additional information from Iluka Resources, including details of existing or proposed surface and groundwater monitoring and best-practice management methods. The application process continues at the time of writing this report.

5.7.3 Garbage and solid waste

Plastics and other pollutants have the potential to affect waterbirds foraging and feeding along the beaches of the site. Waterbirds and fish can die following ingestion of litter, or coming into contacts with marine pollutants (e.g. oil and other toxicants) and pollutants from the catchment. In addition, pollution can affect the aesthetic and recreational values associated with the beaches.

5.8 Climate change

Climate change has the potential to affect CPS by changes in temperature, rainfall, evaporation, sea levels and ocean pH. These changes can affect wetland vegetation diversity and extent, fish and waterbird populations and estuary stratification, which in turn can affect fish and associated services such as food production, as well as threatened species via loss or degradation of habitat.

Recent climate change modelling for Australia has resulted in projections for a number of key variables that are important to the ecological character of the Ramsar site (Table 22). The potential effects of climate change on Victorian marine environments, estuaries and wetlands are well studied (e.g. (EPA Victoria 2011,DSE 2013,Klemke and Arundle 2013) and are summarised in the following sections.

Table 22: Climate change projection summaries for the southern slopes Victoria west sub-cluster (Grose et al. 2015).

Climate variable	Predicted change (relative to 1986-2005)		Confidence in predictions
	2030	2090	
Air temperature (degrees Celsius)	0.4 to 1.1	1.1 to 4.0	Very high
Sea surface temperature (degrees Celsius)	0.5	0.6 to 2.2	Very high

Rainfall	Decrease	Decrease by 25% (winter) and 45% in summer	High
Evaporation	Increase	Increase	High
Sea level rise (m)	0.08 to 0.18	0.29 to 0.64	Very high
Ocean pH	-0.07 to -0.08	-0.07 to -0.3	Medium

5.8.1 Habitat shifting and alteration (sea level rise)

Predicted increases in sea level have the potential to reduce habitat availability for feeding shorebirds and nesting seabirds along the coast and estuary beaches (EPA Victoria 2011). Storm surge could result in the intrusion of seawater into the low lying freshwater wetland systems that are located close to the ocean and estuaries (DSE 2013). In addition, any increase in water height in the Glenelg Estuary due to sea level rise could result in the loss of littoral vegetation, unless it has the capacity to migrate inland (Glenelg Hopkins CMA 2006a).

5.8.2 Droughts

Reduced rainfall coupled with higher temperatures (and higher rates of evaporation) is likely to result in a decrease in inundation frequency and duration in wetland systems (DSE 2013). It may also result in decreased periods that systems like the lower Glenelg Estuary are open to the ocean (EPA Victoria 2011). The freshwater systems of the Ramsar site are vulnerable to prolonged decrease in inflows from surface and groundwater sources that are likely under climate change

Decreased rainfall could also lead to increased salinity in wetlands and the estuary. Aquatic biota have an optimum salinity range and a threshold of tolerance. If the balance is shifted towards a more saline or brackish system, then freshwater taxa will be replaced by more salt tolerant species and communities.

5.8.3 Temperature extremes

Air and surface water temperatures are predicted to increase and this will affect the solubility of dissolved oxygen, reducing dissolved oxygen concentrations in many waters (EPA Victoria 2011), particularly those that are deep and/or stratified, such as the Glenelg Estuary when it is closed. This can affect obligate aquatic species such as fish and macroinvertebrates and lead to a higher incidence of fish deaths.

Many biological processes are linked to temperature. An increase in temperature may stimulate the growth of phytoplankton and result in higher biomass leading to algal blooms. The vulnerability of Victorian marine and estuarine fish species to changed temperature under climate change was considered to be moderate (Hirst and Hamer 2013) and seagrass and soft sediment habitats to be variable (Morris 2013). Changes in reproductive timing, time to maturity and range extensions for northern species, were all considered to be likely outcomes from increased temperatures.

5.8.4 Storms and flooding

An increase in extreme weather events such as storms could see destabilisation of dune vegetation leading to blowouts. Blowouts occur when dune vegetation is removed and wind erosion prevents reestablishment of vegetation. Blowouts are a natural process, but can be exacerbated by climate change impacts.

5.9 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 23.

Table 23: Summary of threats to the Ramsar site.

Threat or potential threat	Impact	Likelihood[1]	Timing
Agriculture and aquaculture	• Altered groundwater hydrology (decreased groundwater levels)	Certain	Immediate
Biological resource use	• Reduced food resources, reduced waterbird abundance	Certain	Immediate
Human intrusion and disturbance	• Disturbance of waterbirds • Damage to flora and waterbird habitat	Certain	Immediate
Natural systems modification – fire and fire suppression	• Impact on flora and fauna processes • Impact on habitat condition • Sediment deposition, increased turbidity and nutrient enrichment	Moderate	Immediate-Long term
Natural systems modification – dams and water management	• Altered hydrological regimes (timing, magnitude and frequency of flows) • Changes to water depth • Changes to habitat availability from changes in area, frequency and flooding • Impacts on flora and fauna (e.g. breeding events, vegetation distribution)	Certain	Immediate
Natural systems modification – estuary opening	• Altered natural patterns of variation in water quality and biotic distribution and abundance • Disruption of aquatic faunal migration and reproductive cycles	Low-Moderate	Medium-Long term
Invasive and other problematic species	• Reduced habitat (e.g. changes in vegetation structure) • Competition with native flora and fauna • Loss of native species	Certain-Moderate	Immediate-Long term
Pollution	• Sediment deposition and increased turbidity • Nutrient enrichment • Reduced habitat quality	Certain-Moderate	Immediate-Long term
Climate change	• Altered hydrological regimes • Reduced water depth • Impacts on flora and fauna (e.g. breeding • events, vegetation distribution) • Impacts on habitat condition and availability • Increased erosion and habitat destruction, possible blowouts and destabilisation of dunes	Moderate	Medium-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.

6 Changes since designation

This ECD sets the benchmark for the time of listing as current condition, represented as at 2015. As such there is no assessment of change in ecological character in this version of the ECD.

7 Knowledge gaps

There are a substantial number of knowledge gaps that need to be addressed in order to fully describe the ecological character of this site and enable rigorous and defensible LAC to be set and are listed in Table 24. Recommended actions aim to develop indicators of ecological character that could fill knowledge gaps and help in the design of ongoing monitoring.

Table 24: Summary of knowledge gaps and recommended actions.

Component / process	Knowledge Gap	Recommended Action/ Justification
Fish	Baseline survey data for Malseed and Swan Lakes.	Inventory assessment required to inform LAC.
	Investigation on fish breeding and nursery habitats across freshwater lakes and estuary.	Surveillance assessment required to strengthen case for criterion 4.
Waterbirds	Baseline records for breeding.	Surveillance assessment required to strengthen criterion 4.
	Relative importance and use of interconnected habitat for waterbirds.	Surveillance survey to confirm use of inter-connected habitats by waterbirds.
Vegetation	Baseline survey data for emergent and submergent vegetation at Bridgewater Lakes, Lake Malseed and Swan Lake – likely to be a critical component, but there is currently no data.	Inventory assessment required to inform LAC.
Invertebrates	Macroinvertebrate community composition across all habitat types in the lower Glenelg Estuary, Oxbow Lake, and freshwater wetlands.	Base line surveys be undertaken to establish community composition and linkages between current and future hydrological regimes at Long Swamp.
	Conditions and habitat required for oviposition by ancient greenling.	Investigate conditions required for oviposition.
	The relative importance of fish predation and potential changes associated with the restoration of hydrology in Long Swamp on ancient greenling.	Surveillance monitoring of ancient greenling.
	Understanding of the microinvertebrate community	Inventory assessment across the site.
Amphibians	Baseline data on abundance and distribution lacking at Bridgewater Lakes, Malseed and Swan Lake, upper reaches of the Glenelg Estuary.	Inventory assessment across whole of site.
Reptiles	Baseline data on the Swamp skink (*Lissolepis conventryi*).	Inventory assessment across whole of site.
Mammals	Limited data on the importance of the site for Southern bent-wing bat, which is an important element of the site biodiversity (but not considered a critical CPS). No information on the importance of the site for other mammals, including the swamp antechinus and water rat.	Inventory assessment across whole of site.
Phytoplankton	No data was sourced on algae (including benthic algae) and phytoplankton.	Undertake baseline surveys of phytoplankton across the site.
Hydrology	Understanding of the hydrology of the whole Ramsar site. The relative influence of the Kanawinka Fault to the east of the Ramsar site on the local hydrology.	Confirmation of the hydrology (including groundwater-surface water interactions) across the site is required to inform LAC.

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 *Environment Protection and Biodiversity Conservation Act 1999* a person must not take an action that has, will have or is likely to have a significant impact on the ecological character of a listed Ramsar wetland. While there is no explicit requirement for monitoring of the site, in order to ascertain if the ecological character of the wetland site is being protected a monitoring program is required.

A comprehensive monitoring program is beyond the scope of an ECD, but an important component of a management plan. What is provided here is an identification of monitoring needs required to set baselines for critical components and processes and to assess against LAC. 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. The ECD monitoring is not 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 in the management plan for the site.

The recommended monitoring to meet the obligations under Ramsar and the *EPBC Act* (1999) with respect to the site are provided in Table 25.

Table 25: Summary of monitoring needs.

Component /Process	Purpose	Indicator	Locations	Frequency	Priority
Hydrology	Address knowledge gap and confirm baseline – depth to groundwater table at freshwater wetlands	Depth to groundwater	Freshwater wetlands	Seasonal to establish baseline over several years, then less frequently	High, to set baseline
Hydrology	Assess against LAC	Estuary opening / closing	Estuary mouth	Weekly	Medium
Vegetation (freshwater)	Assess against LAC and establishment of baseline for lake bed vegetation	Extent by community type and baseline composition and cover	All habitats for community extent. Freshwater Lakes for baseline of lake bed vegetation (Swan, Malseed, Bridgewater and Moniboeng)	Establish baseline by quarterly monitoring over two years, then repeat annually every three to five years	High
Vegetation (saltmarsh)	Assess against LAC	Extent	Glenelg Estuary and Oxbow Lake	Every five years	Medium
Fish	Assess against LAC	Species and abundance	Key locations in freshwater wetlands and Glenelg Estuary	Annual	Medium
Waterbirds (abundance)	Address knowledge gap related use of habitats within the site Assess against LAC	Species and abundance	Key locations in freshwater wetlands, Glenelg Estuary and Discovery Bay beach	Bi-annual	High
Waterbird breeding	Address knowledge gap	Evidence of breeding (nests, breeding plumage, juveniles)	Key locations in freshwater wetlands, Glenelg Estuary and Discovery Bay beach	Annual (matched to known breeding timings)	Medium
Threatened species: Maroon leek-orchid, swamp greenhood	Assess against LAC	Targeted surveys for abundance	Known locations	Annual	Medium
Threatened species: Australasian bittern	Assess against LAC	Calls	Emergent freshwater vegetation	Annual	Medium
Threatened species: Hooded plover, Australian	Assess against LAC	Would be covered by the program for waterbird abundance (see above)			

Component /Process	Purpose	Indicator	Locations	Frequency	Priority
fairy tern, curlew sandpiper					
Threatened species: Yarra pygmy perch	Assess against LAC	Would be covered by the program for fish abundance (see above)			
Threatened species: Growling grass frog	Assess against LAC	Calls, tadpoles	Freshwater wetlands	Annual	Medium
Threatened species: Ancient greenling	Address knowledge gap	Abundance	Freshwater wetlands	Annual	High
Migratory species: fish and waterbirds	Assess against LAC	Would be covered by the programs for fish and waterbird abundance (see above)			

9 Communication and Education Messages

A comprehensive CEPA program for an individual Ramsar site is beyond the scope of an ECD, but key communication messages and CEPA actions, such as a community education program, can be used as a component of a management plan. A number of key communication messages were identified in consultation with stakeholders associated with the Ramsar site, and should be promoted. These include:

- The Glenelg Estuary and Discovery Bay Ramsar Site is listed as a wetland of international importance under the Ramsar Convention, meeting six of the nine criteria.
- The site supports unique aesthetic and recreational values. Includes the Great South West Walk, as well as boating and fishing in the estuary. It is an excellent example of wise use of wetlands.
- Nomination of the Ramsar site was undertaken with funds from the Australian River Prize (International River Foundation) awarded to GH CMA for work on the Glenelg River.
- The Ramsar site provides ecological connectivity to the Picaninnie Ponds Ramsar site across the South Australian border – this increases protection of values associated with a national biodiversity hotspot.
- The Ramsar site is important for supporting threatened wetland dependent species and communities.
- The Ramsar site contains a diversity of wetland types, several of which are considered regionally rare.

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Appendix A: Justification for critical components, processes and services

Components and processes

The identified critical components and processes (section 3) were assessed against the four criteria given in the National guidelines, and the scoring system described in Table 26, with the justification for each being critical presented in Table 27.

The annex to Resolution VI.1 (Ramsar 2014) notes that there is a need to increase the value of the information collected for describing and assessing the ecological character of listed sites, and it urges that emphasis should be given to:

- establishing a baseline by describing the ecological character of the site "from which derive the ecosystem services of international importance" (necessary because the existing Ramsar Criteria do not cover the full range of wetland benefits and values that should be considered when assessing the possible impact of changes at a site); and
- providing information on human-induced factors that have affected or could significantly affect the benefits and "values of international importance".

Table 26: Key to scoring assigned to CPS (modified from Butcher and Cottingham 2015).

Criteria	Score		
	+	++	+++
Criterion 1 - CPS is an important determinant of the site's unique character	CPS is thought to be important based on inferred data from other sites, but may be lacking evidence from the site. Reasonable expectation by community that CPS would be present at the site.	Site specific evidence of the significance of the CPS in determining the sites character. High expectation by community that CPS would be present at the site.	Considered an ecological driver or controlling variable. Strong support in literature with clear relationship between CPS and character of the site.
Criterion 2 – important for supporting the Ramsar or DIWA criteria under which the site was listed	Indirect, or limited, relationship between CPS and listing criteria, for example may be a service or benefit which is reliant on other critical CPS directly related to the listing criteria.		Strong, direct relationship between CPS and listing criteria.
Criterion 3 – of a nature for which change is reasonably likely to occur over short or medium time scales (<100 years)	Possible: Could occur but not expected.	Likely: Will probably occur in most circumstances.	Almost certain: Is expected to occur in most circumstances.
Criterion 4 – of a nature that will cause significant negative consequences if change occurs	Change likely to cause relatively slow but significant declines/deterioration in other critical CPS (for species/ populations <20% loss over 10 years or three generations; whichever is the longer). Affects minority of the CPS (<50%) and a possible change in ecological character.	Change likely to cause rapid declines/ deterioration in other critical CPS (for species/ populations 20–30% over 10 years or three generations; whichever is the longer). Affects the majority of the CPS (50-90%), likely change in ecological character but may be short lived.	Change likely to cause very rapid declines/deterioration in critical CPS (for species/ populations >30% over 10 years or three generations; whichever is the longer). Affects the vast majority of CPS (>90%), and definite sustained change in ecological character.

Table 27: Justification for critical components and processes against criteria listed in DEWHA (2008).

Component / process	Criterion 1 – important determinants	Criterion 2 – support listing criteria	Criterion 3 – change is likely <100 years	Criterion 4 – will cause significant negative consequences
Hydrology	+++ The site is a significant groundwater dependent ecosystem strongly influenced by hydrology.	+++ Ramsar criterion 1 – wetland type and hydrology (i.e. groundwater dependent ecosystem).	++ Drought and water resource use are likely to continue to impact on the hydrology of the site. Both surface water and groundwater impacts are possible.	++ Linked to the opening and closing of the estuary mouth and also the depth and extent of wetland habitat.
Vegetation – type and extent	++ Characteristic types are associated with the freshwater wetlands, fens, dunes and estuary. Provides habitat and breeding areas for biota.	+++ Ramsar criterion 1, 2 and 4. Threatened plant communities and species. Provision of habitat for waterbird feeding.	+++ Invasive species, fire and recreational impacts are all likely to cause changes to vegetation type and extent.	+++ Invasive species, particularly in the dune scrub habitat is likely to lead to significant loss of diversity.
Fish – diversity and abundance	++ Threatened and obligate freshwater species in a groundwater dependent ecosystem, and diadromous species.	+++ Ramsar criterion 2, 4 – supports two threatened fish species, and important regional populations of obligate freshwater species.	++ Changes to regional and local groundwater could lead to a loss of threatened and obligate freshwater species from some of the site (i.e. Long Swamp).	+++ Species specific - loss of some species could represent regional extinctions.
Waterbirds – diversity and abundance	++ Threatened, migratory, cryptic species and 1% of Sanderling flyway population are regularly present as part of a diverse waterbirds community.	+++ Ramsar criterion 2, 4 and 6	++ Declines in shorebirds have been reported at a number of Victorian coastal Ramsar sites (e.g. Minton et al. 2012, Hansen et al. 2015), and these declines are predicted to continue.	++ Part of the Discovery Bay beach area contributes to a significant bird area – with any substantial losses in diversity and abundance likely to reflect broader patterns of decline in the flyway (migratory species).
Water quality stratification	++ The estuary mouth naturally opens and closes, dictating connectivity both hydrologically and ecologically.	+ Ramsar criterion 1 – contributes to maintaining good water quality (Ramsar Convention 2009)	+ Extended periods of mouth closure could lead to increased periods of stratification.	++ Increased periods of stratification could fundamentally change the ecology of the lower estuary.

Services and benefits

Fisher et al. (2008) redefined the MEA “ecosystem services” as including: benefits, intermediate and final ecosystem services. They also redefine the MEA “benefits people obtain from ecosystems” as the aspects of ecosystems utilised (passively or actively) to produce human wellbeing. This redefinition is illustrated in Figure 53 and was derived to avoid problems of double counting in environmental-economic accounts of ecosystem services. Fisher et al. (2008) define intermediate and final ecosystem services as follows:

- **Intermediate ecosystem services** as those that form part of a ‘cascade of services’ that support one another and underpin final services, and
- **Final ecosystem services** as those that are directly used by people to provide benefits.

The MEA is one of the most widely accepted categorisation (i.e. provisioning, regulating, cultural and supporting services) and was originally developed to promote the general acceptance of the concept of ecosystem services (Reid-Piko et al. 2010). The ecosystems services classification used in this ECD follows the terminology of the National Guidelines for developing ECD (DEWHA 2008), but also adopts the separation of services and benefits as described by Fisher et al. (2008).

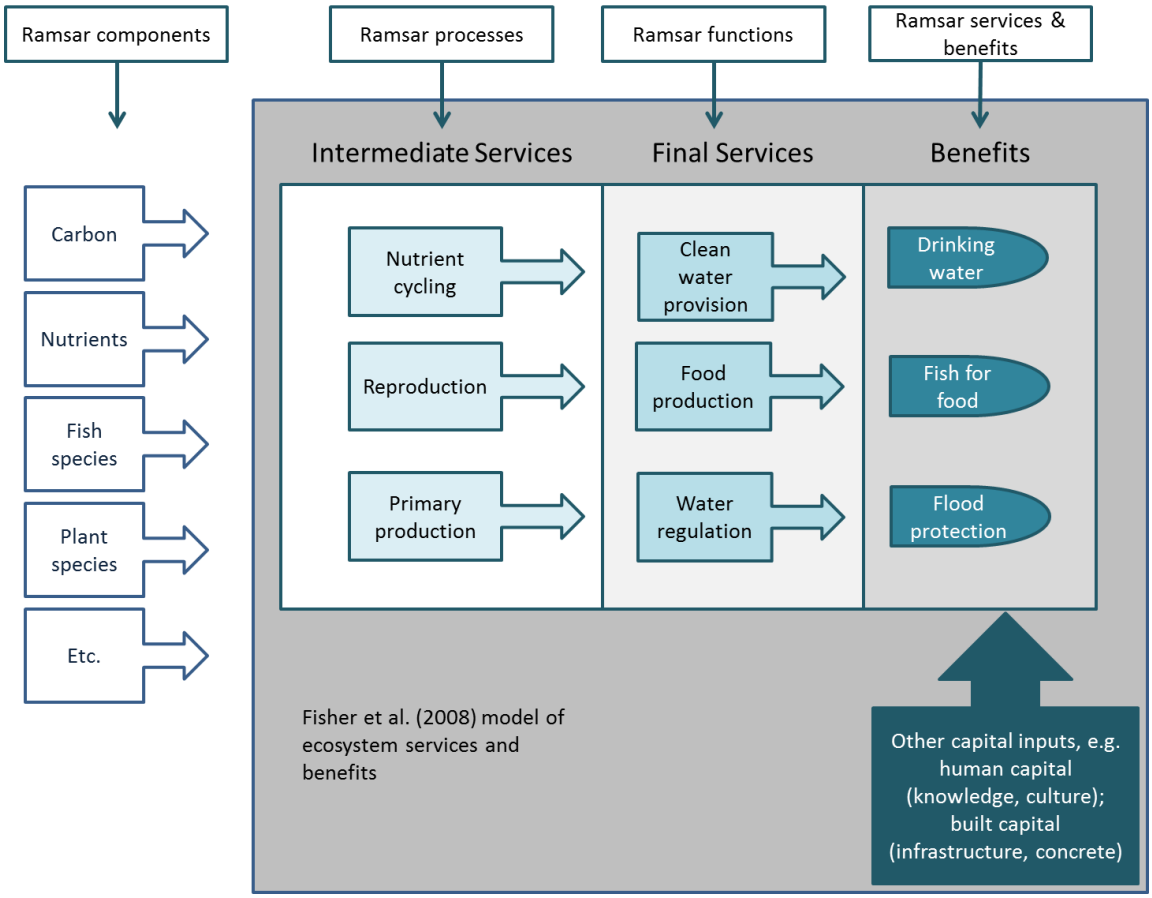


Figure 53: Modified Fisher et al. (2008) model of ecosystem services and benefits (all in shaded blue box) with the Ramsar definition of processes and functions added (modified from Butcher 2014).

The services and benefits which occur at the Ramsar site are summarised in Table 28 and justification for critical services and benefits are presented in Table 29.

Table 28: Ecosystem services and benefits provided by the Glenelg Estuary and Discovery Bay Ramsar Site using Fisher et al. (2008) type (those critical to the ecological character of the site are shaded; see section 3).

Category/service	Description	Fisher et al. (2008) type
Provisioning		
Provision of aquatic foods for human consumption	The site supports recreational fisheries with the main species including mulloway, black bream, and pipi. These fisheries are considered critical to the character of the site and incorporate aspects of cultural services (i.e. recreation) as well. Gundijtmara have a long established history of fishing in the region, particularly for the short fin eel and of molluscs and crustaceans.	Benefit
Genetic resources	This service is about the role the site potentially plays in preserving a natural reservoir for biological diversity and providing genetic resources that can support colonisation, contribute to maintaining intra-species diversity, and allow for research and development such as selective breeding. Includes the provision of genetic resources for resistance to pathogens, or tolerance to environmental conditions, and the development of new medicines. This service does not relate to maintaining populations of threatened species *per se*, which are covered under supporting services. This is not considered a critical service provided by the site.	Final service
Regulating		
Maintenance and regulation of hydrological cycles and regimes	Oxbow Lake is the terminal wetland complex on the Glenelg River and plays an important role in influencing groundwater–surface water balances through local recharge and discharge processes although this is poorly understood at the site. Not considered a critical service.	Final service
Coastal shoreline stabilisation and storm protection	Occurs at the site and may be critical to the character of the site over long time spans, however not considered critical within this ECD.	Final service
Natural hazard reduction – reduced risk of wildfire	Presence of surface water may provide a reduced risk of fire. Not a critical service.	Benefit
Cultural		
Cultural heritage and identity/ Spiritual and inspirational	At the start of the Yakinitj, Prenheal sent bolitabolita Creation Beings muyuban tungatt, woorrowarook, bocara and koonang. For Gunditjmara people, 'Country' includes all living things–none better than the other but equal in its importance in forming this diverse natural landscape that is Gunditjmara Country. Country means people, plants and animals alike. It embraces the seasons, stories and spirits of the creation. This flowing, connected cultural landscape possesses its own sacred places, languages, ceremonies, totems, art, clan groupings and law. These features are seen as inseparable and make up what is known as Country. Our Country is a place of belonging and pride that comes with this belonging. Statement provided by Gunditj Marra TOAC.	Benefit
Science and education	The site is one of the more significant coastal dune lake systems in the bioregion having different limnological characteristics than other south eastern Australian coastal dunes (e.g. Timms 1977, Head 1987, Head 1988). Recent investigations are contributing to the understanding of the national biodiversity hotspot – i.e. regional, cross border. Not considered a critical service.	Benefit
Aesthetic amenity	Not critical, but occurs at the site. Includes unique waterscapes such as the estuary mouth, river gorge sections of the Glenelg River, and	Benefit

Category/service	Description	Fisher et al. (2008) type
	beachscapes along Discovery Bay. Closely linked to recreational activities.	
Recreation	Considered a critical benefit relating to the character of the site. Bridgewater Lakes is used for a range of recreational activities including boating, fishing, swimming, and water skiing. Other lakes including Lake Moniboeng are also used for canoeing, small yacht sailing and swimming (Parks Victoria 2006). The Glenelg River as part of the Lower Glenelg River National Park supports a large number of recreation activities as does the Discovery Bay section of the site (i.e. the Great South West Walk).	Benefit
Tourism	Occurs at the site but is not considered a critical service relating to the character of the site.	Benefit
Supporting		
Diversity of wetland types	The site supports the cyclic movement of water through the surface, subsurface, and atmospheric compartments associated with a wetland, and the resultant variation of the spatial and temporal distribution supports a diverse array of wetland types considered critical to the character of the site.	Intermediate service
Special ecological, physical or geomorphic features	The site is significant for a number of geological and geomorphic features; in particular the dune slack system is rare, if not unique within the bioregion. Considered a critical service.	Final service
Provides physical habitat (for waterbirds)	Ninety-five species of wetland bird have been recorded within the Ramsar site. A number of different environments are found within the Ramsar site which supports a range of waterbirds including feeding and breeding areas. Considered a critical service at the site.	Final service
Threatened wetland species, habitats and ecosystems	One nationally listed ecological community and 10 nationally or internationally listed species of conservation significance, nine of which are considered to be regularly supported at the site, or for which the wetlands of the site represent core habitat. Considered a critical service.	Final service
Priority wetland species and ecosystems	The site supports a number of migratory waterbirds listed under international treaties. Numbers and diversity are low, compared to comparable sites and so this is not considered a critical service.	Final service
Nutrient cycling	Not critical to the character of the site, but is believed to play an important role in biogeochemical process, although this remains a knowledge gap for parts of the site.	Intermediate service
Primary production	Not critical to the character of the site, but plays an important role as a supporting service, underpinning food webs within the system.	Intermediate service
Ecological connectivity	The Ramsar site has a range of distinct wetland types which are both hydrologically and ecologically connected. Connectivity is critical for the maintenance of biodiversity values. The connection between the marine, estuarine and freshwater components is significant for fish migration and reproduction. Considered a critical service for fish migration.	Intermediate service
Food webs	The food webs of the Ramsar site are not well understood and whilst considered important in supporting the character of the site, at this point in time, none are considered critical. Not a critical service.	Final service

Table 29: Justification for critical services against criteria listed in DEWHA (2008). See Table 26 above for scoring system.

Service/ benefit	Guideline 1 – important determinants	Guideline 2 – support listing criteria	Guideline 3 – change is likely <100 years	Guideline 4 – will cause significant negative consequences
Diversity of wetland types	+++	+++ (C1)	++	+++
Special ecological, physical or geomorphic features	+++	+++ (C1) dune slack system	++	+++
Provides physical habitat (for waterbirds)	+++	+++ (C1, 2, 4)	++	++ Loss of habitat identified as key off site impact on populations, potential for loss of habitat on site (i.e. nesting habitat, feeding habitat) could increase rate of decline.
Threatened wetland species, habitats and ecosystems	++	+++ (C1, 2) – supports globally threatened fen peatlands, grassy wetlands, dune slack, threatened plant communities and a number of listed species.	+	++
Ecological connectivity	++	+ (C4, 7 and 8)	+	+

Appendix B: Other biota within the site

Invertebrates

Invertebrate data is limited for the Ramsar site and constitutes a knowledge gap. (Bovill 2006) sampled macroinvertebrates from four permanent wetlands within the Ramsar site, including Lake Moniboeng, Cain Hut swamp, and Lake Bridgewater north, middle and south (three disjunct basins) in early winter 2006. In total 90 taxa were identified (not all aquatic) with the results indicating the wetlands were significantly different for taxon richness. Species richness is scale dependent with all richness measures being affected by sample size, abundance and effort (Hurlbert 1971, Hammond 1994, Gaston 1996, Gotelli and Colwell 2001, Butcher 2003). Variation in sampling effort can result in widely variable result. Even for what are considered as exhaustive samples estimates of species richness are often largely dependent on the effectiveness of the sampling method and its ability to successfully detect all species present (Butcher 2003).

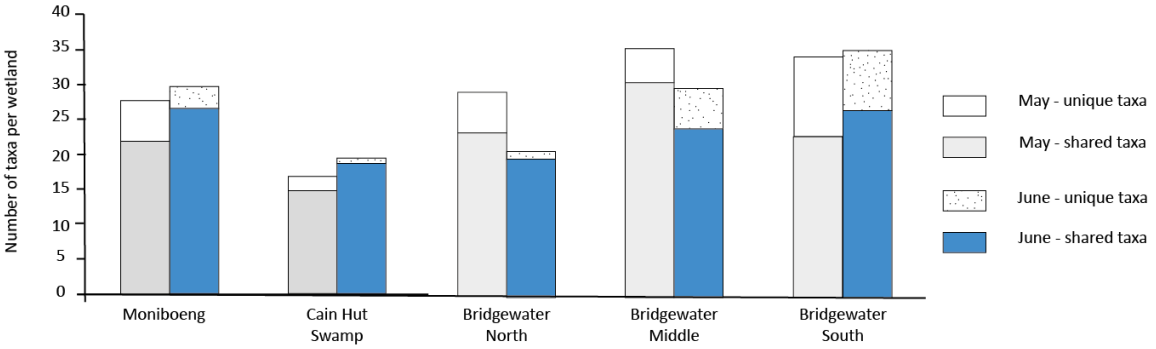


Figure 54: Total macroinvertebrate taxon richness of individual wetlands (pooled samples) in May and June 2006, including counts of taxa unique to particular wetlands (modified from (Bovill 2006)

Bovill (2006) suggested that the macroinvertebrate fauna of the wetlands assessed is different to other wetlands in the region and also other coastal wetlands; however, the timing and amount of sampling is not comparable to many other inventory projects which typically collect data in early spring to summer and autumn. The fauna collected by Boville (2006) is characteristic of permanent waters (i.e. trichopterans, crustaceans, mayflies); however, there are insufficient data to determine if the fauna is in fact different to other coastal systems. For example, the Victorian EPA undertook a snapshot assessment of macroinvertebrates across a number of Victorian lakes whilst developing a lakes assessment protocol that included Lake Moniboeng and Bridgewater Lakes. The macroinvertebrate diversity was high at Lake Moniboeng and comparable to sand dune lakes elsewhere in the bioregion (the same study) such as Lake Barracouta and Dock Inlet. However Lake Bridgewater recorded a very low number of macroinvertebrate families, only seven (EPA Victoria 2010). It is not possible to make a comparison to the Boville (2006) data as it is not included as count data by site, only a taxon list, and as stated above the assessment methods varied between the studies.

Invertebrate fauna in the temporary wetlands within the system and the estuarine components would be expected to be different again to that of the permanent systems. Overall the invertebrate communities are anticipated to be diverse and potentially unusual reflecting the isolation, heterogeneity of habitat, and groundwater dependent hydrological regimes. The relative importance of fish predation and potential changes associated with the restoration of hydrology in Long Swamp is a knowledge gap.

Microinvertebrate investigations at the site are lacking, other than early work undertaken by Ian Bayly and Brian Timms in the 1960s and 1970s (Timms 1977). These early investigations identified some interesting zooplankton with marine affinities, however their persistence within the site has not been assessed and an understanding of the microinvertebrate community is another knowledge gap.

Amphibians and reptiles

Data for amphibians in the Ramsar site are limited. Early survey work indicates that Lake Malseed supported large numbers of frogs however recent surveys by the Nature Glenelg Trust have only recorded low numbers of individuals. This recent survey work has been largely limited to the Long Swamp complex. Seven species have been recorded including the nationally listed growling grass frog (*Litoria raniformis*) (see Table 30). The

relatively low numbers of frogs within the Ramsar site recorded to date may reflect a lack of permanent water in the areas surveyed, although further surveys of the permanent waterbodies and nearby wetlands may show a different pattern of use and abundances. Alternatively, low numbers of frogs in the area may also reflect a loss of ecological connectivity between inland wetlands and the coastal system through alienation of dispersal routes.

Three other species occur in the south west of Victoria for which there are no records at the site. The two spadefoot toads (*Neobatrachus sudelli*, *N. pictus*) are more likely to be found further inland, than in the coastal dune system. The spotted marsh frog (*Limnodynastes tasmaniensis*) is a common species and may be present at the site.

The wetland dependent swamp skink (*Lissolepis conventryi*) has been recorded from Long Swamp (VBA extract 2015), and glossy grass skink (*Pseudemoia rawlinsoni*), also a wetland dependent species may also be present at the site (G. Peterson, DELWP, pers. comm.). Data on numbers and distribution within the site are a knowledge gap.

Table 30: Amphibians recorded from Glenelg Estuary and Discovery Bay Ramsar Site. Data provided by GH CMA (unpublished), (Bachmann et al. 2013) and G. Peterson, DELWP, pers. comm.

Species	Common name	Location
Crinia signifera	Common froglet	White Sands outlet Long Swamp, Long Swamp, Lake Moniboeng, Swan Lake.
Geocrinia laevis	Southern smooth froglet	Long Swamp.
Limnodynastes dumerilii	Southern bullfrog (ssp. unknown)	Lake Moniboeng.
Limnodynastes peronii	Striped marsh frog	No location specified in VBA.
Litoria ewingii	Southern brown tree frog	Swan Lake.
Litoria raniformis	Growling grass frog	Lake Moniboeng, Swan Lake, Long Swamp.
Pseudophryne semimarmorata	Southern toadlet	Glenelg National Park

Mammals

Southern bent-wing bat

The Southern bent-wing bat (*Miniopterus schreibersii bassanii*) is one of only five Australian mammals that are federally listed as critically endangered under the *EPBC Act*. Whilst not considered strictly wetland dependent (advice from DELWP), it does utilise wetland environments as one of its two preferred foraging habitats, and as such is included here.

It is an obligate cave-dwelling bat with a restricted distribution, occurring only in south-east South Australia and south-west Victoria (Figure 55, Lumsden and Jemisen 2015). Whilst it is distributed across this region during the non-breeding season, during the breeding season the majority of individuals congregate in just two regularly-used breeding caves, located at Naracoorte in South Australia and Warrnambool in Victoria.

The population size of the bat has declined dramatically in recent decades, falling from an estimated 100,000 – 200,000 individuals in the 1950s and 1960s at the Naracoorte maternity site to approximately 20,000 individuals in 2009. The numbers in the Warrnambool maternity site declined from approximately 15,000 to 10,000 individuals over the same time period (Lumsden and Jemison 2015). The severity of this decline led to listing of the Southern bent-wing bat as critically endangered under the *EPBC Act* in 2007. The National Recovery Plan for the Southern bent-wing bat (Lumsden and Jemison 2015) identified numerous threats (individually and in combination) that may have led to the decline in numbers, including:

- Loss and modification of roosting and foraging habitat,
- Human disturbance,
- Pesticides,

- Disease, and
- Drought and climate change affecting food availability.

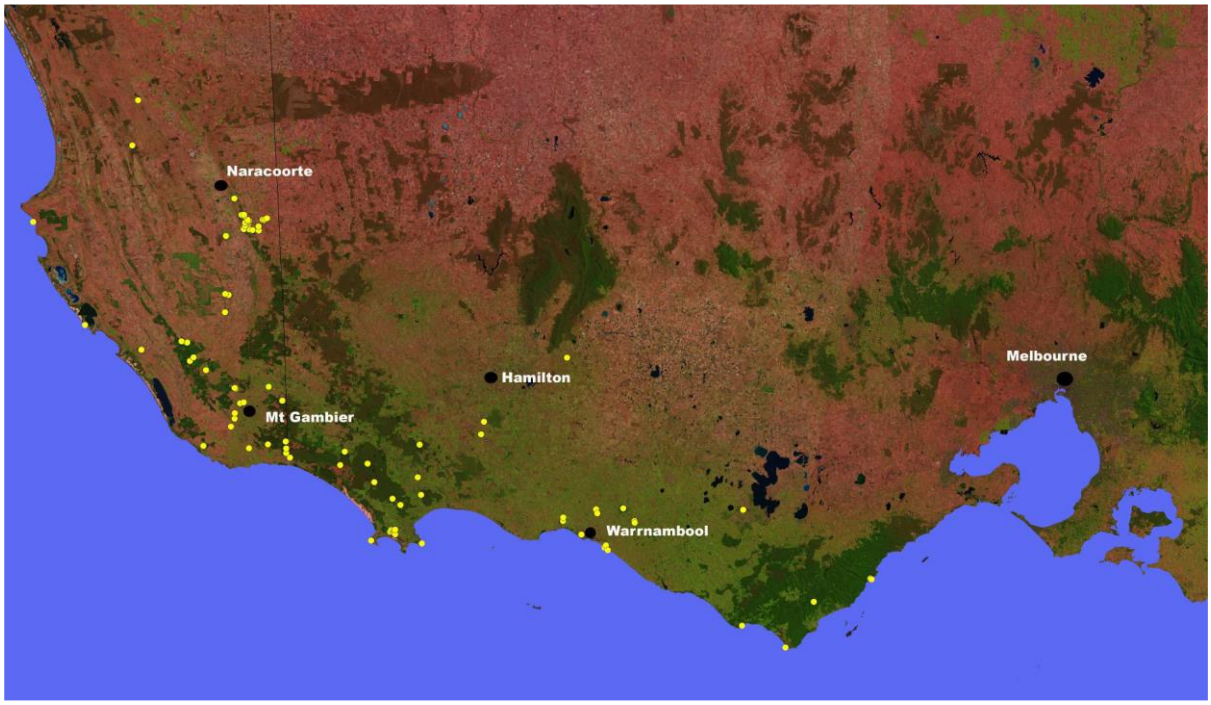


Figure 55: Distribution of the Southern bent-wing bat (from Lumsden and Jemisen 2015).

However, the National Recovery Plan noted that there is little empirical evidence to clearly identify the main cause/s of the current decline; filling this knowledge gap was considered a management priority, along with protecting breeding and foraging habitat. Limited information is available on foraging habitat used by the species; radio-tracking suggests it occurs predominantly along forested ridgelines and around wetlands and swamps containing aquatic vegetation and fringed by terrestrial vegetation (Stratman 2005 cited in Lumsden and Jemisen 2015). All swamp sites used by the bat provided open areas for flight and most were prone to seasonal inundation (Stratman 2005).

This species whilst not considered a critical CPS, does contribute to the biodiversity value of the site and as such further data on this species should be collected. The caves in the Lower Glenelg Estuary are roosting sites, however recent surveys of these sites are lacking and the population size using the site is a knowledge gap.

Other mammals

Two other wetland dependent mammal species present in the site include the water rat (*Hydromys chrysogaster*), and swamp antechinus (*Antechinus minimus maritimus*) (G. Peterson, DELWP, pers. comm.). Swamp antechinus is being considered for listing as vulnerable under the *EPBC Act* (Department of Environment 2015a), however the outcome of the nomination has not yet been determined. The species in Victoria and South Australia is believed to be a distinct subspecies to that found more commonly in Tasmania. The distribution and abundance of these species within the Ramsar site are a knowledge gap.

Appendix C: Conceptual models

Three conceptual models have been developed to show how critical and supporting CPS interact. The models are:

- **Estuarine habitat** (Figure 56) showing lower section of Glenelg estuary in open and closed state.
- **Beach habitat and dune fields** (Figure 57) illustrates beach, dune and dune slack in area of Long Swamp.
- **Freshwater habitat** (Figure 58) represented by a model of Bridgewater Lakes.

Within the estuary the critical CPS which are illustrated in Figure 56 include provision of habitat to support waterbird feeding (critical supporting service - hydrological processes, wetland diversity), ecological connectivity allowing freshwater fish to move downstream and marine species to move into the estuary. Roosting habitats in the lower sections of the estuary are important for waterbirds, both waders and waterfowl. Fish reproduction also occurs in the estuary providing stocks for recreational fishing and food for piscivorous birds. The closing and opening of the estuary mouth has a strong influence on the water quality within the area of the estuary, below Nelson in particular, but the extent of influence is a knowledge gap.

The upper reaches of the estuary are not shown in the estuary model however, this section of the estuary is characterised by high levels of groundwater inflows, surface water inflows from the upper catchment and the presence of a salt wedge. The river/estuary is largely constrained lying within an area of limestone, with high cliffs and numerous karst features (none fully aquatic).

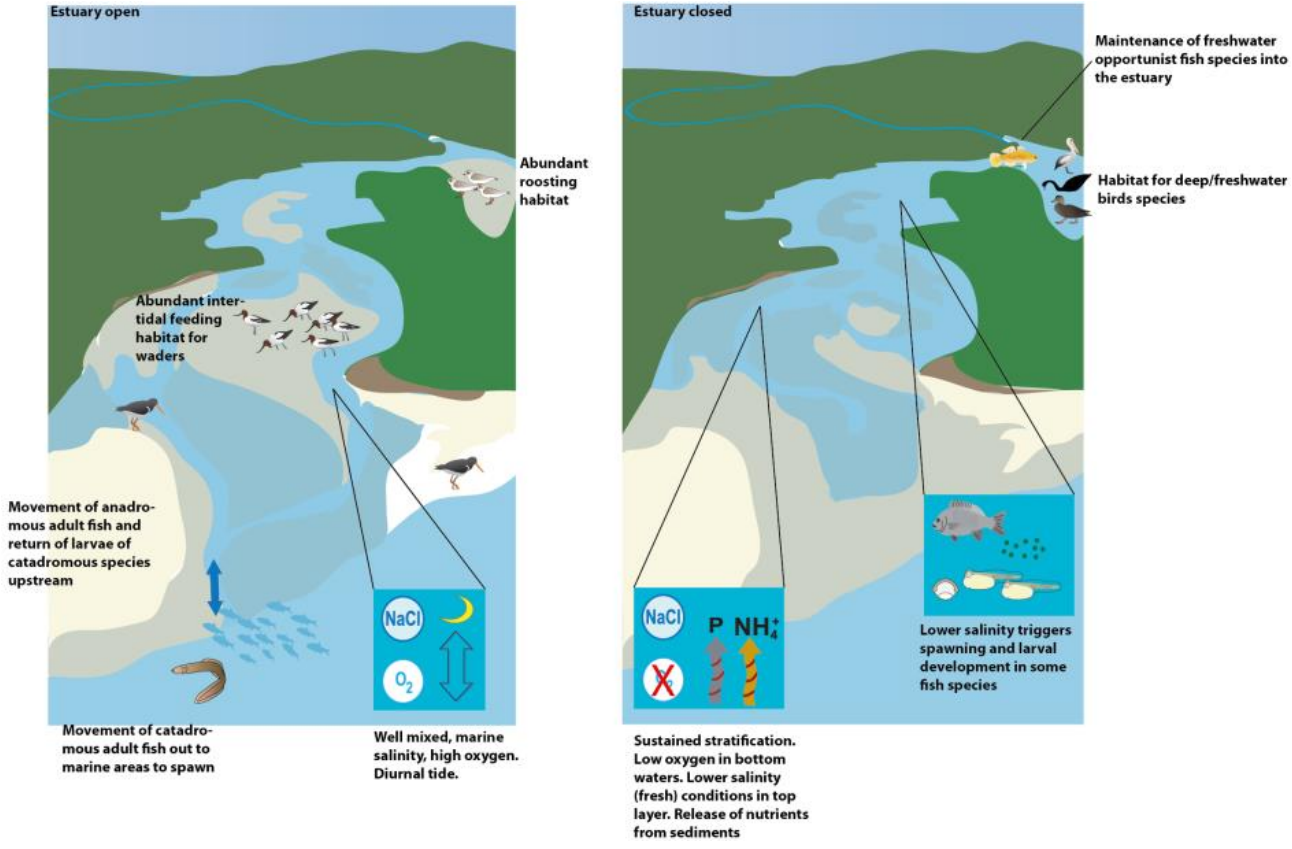


Figure 56: Conceptual model of opened and closed estuary.

The beach and dune management units are relatively poorly surveyed and there are very limited data available. This area of the site is considered important for migratory shorebirds and waterbird breeding. The trophic relationships between near shore environments and the species supported by the Ramsar site are a knowledge gap. The beach environment is one of the most active in Victoria with strong consistent winds shifting significant amounts of sand, constantly contributing to and reshaping the dune system. Within the western end of the Discovery Bay system the dune field supports dune slacks, a particular type of wetland reliant on groundwater likely derived from the dune system rather than deeper tertiary aquifer. The actual wetlands within the dune system are included in the freshwater management unit. The dune vegetation stabilises the system, however in the middle section of the dune field (towards the eastern end of the Ramsar site) the vegetation is sparse and blowouts have occurred leading to mobile dunes.

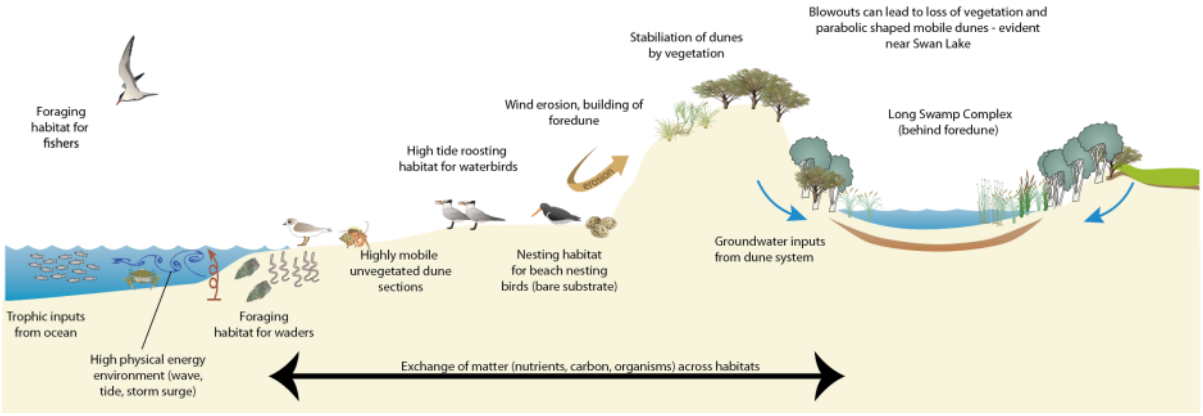
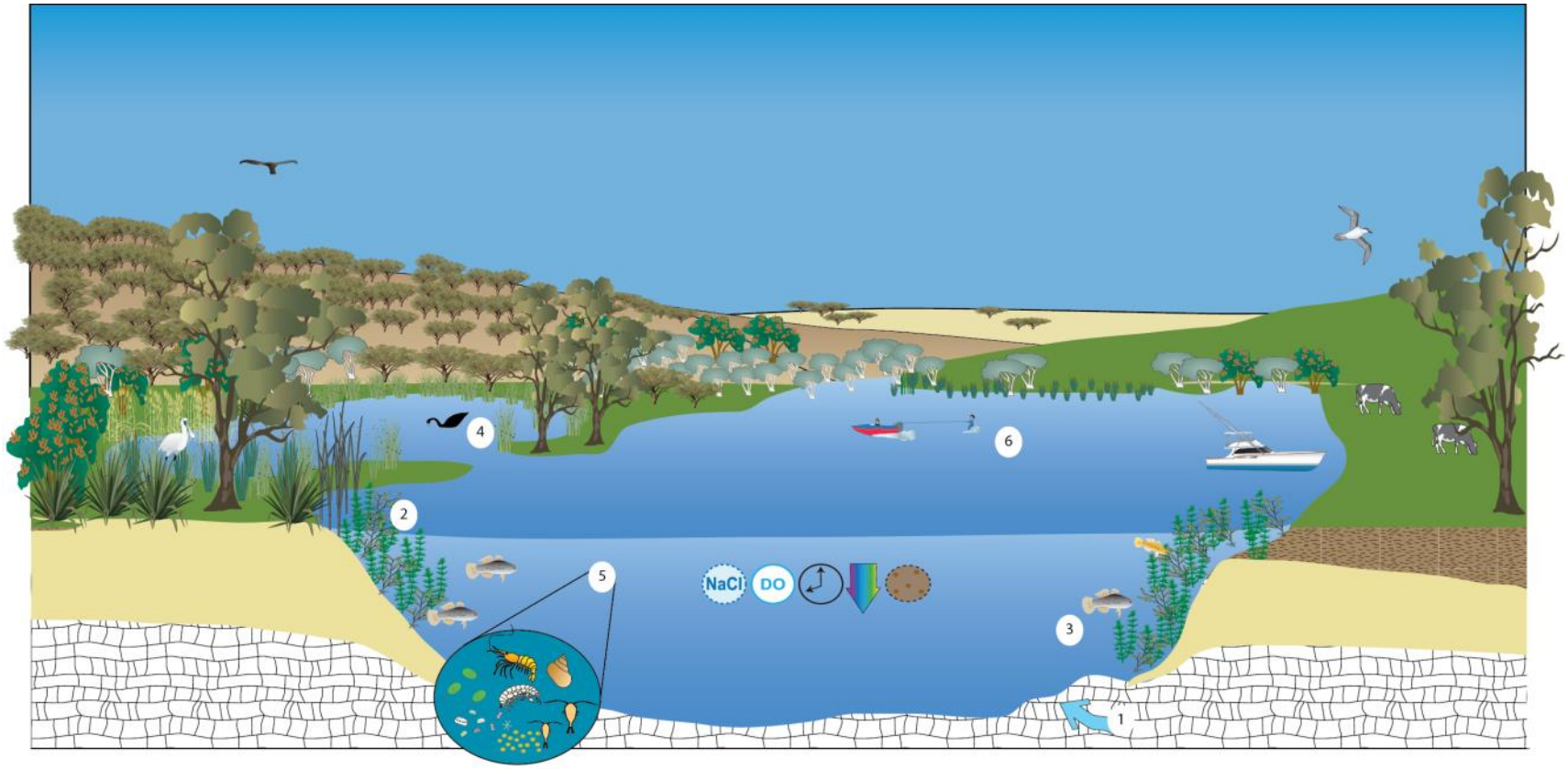


Figure 57: Conceptual model of near shore, beach and dune system in vicinity of Long Swamp.

The characteristics of each of the freshwater wetlands differ in relation to dominant groundwater source, depth and size. The Long Swamp complex is relatively shallow and has a connection with the ocean via Oxbow Lake on the western end of the wetland. Two artificial drainage points have been recently closed and the wetland is returning to a more 'natural' hydrology. Data on Lake Moniboeng, the Malseed and Swan Lake wetlands and Bridgewater lakes is scarce. Water quality in all of these lakes are good and the submergent and emergent aquatic vegetation appears to be both diverse and abundant, however there are no data on the lake bed aquatic vegetation other than broad estimates of extent. These wetlands provide critical habitat to obligate freshwater species and support a range of waterbirds and fish.



1 Deep groundwater dependent lakes (Bridgewater Lakes) connected to tertiary limestone aquifer. Discharge into lakes is a knowledge gap. Some groundwater from dunes would also enter the system.

2 Lake bed vegetation extensive due to water clarity. Extent and composition is a knowledge gap for the Bridgewater Lakes and Malseed complex.

3 4 Fish and waterbird diversity and abundance is a knowledge gap for the deeper lakes within the Ramsar site. Waterbirds likely to be dominated by waterfowl as there is limited shorebird habitat.

5 Phytoplankton, microinvertebrates and macroinvertebrate communities are a knowledge gap for the deeper freshwater systems but expected to be a detrital based food web.

6 Recreational activites at the lakes include water skining, jet boat use, canoeing, walking and swimming. High recreational value to local community.

NaCl DO

Water quality is high, with low salinity, high disolved oxygen due to mixing and plant growth, high residence time for water, high level of light penetration due to water clarity and low sediment/turbidity.

Figure 58: Conceptual model of groundwater dependent Bridgewater Lakes.

Appendix D: Threatened species and communities

Coastal saltmarsh

The Subtropical and Temperate Coastal Saltmarsh ecological community was listed as vulnerable under the EPBC Act in 2013 (TSSC 2013). It commonly occurs in the upper intertidal zone of estuaries and includes the assemblage of plants, animals and micro-organisms associated with intertidal saltmarsh vegetation. The seaward extent of the Coastal Saltmarsh ecological community is determined by the depth, duration and periodicity of tidal submergence, and the landward extent is typically determined by the penetration of the highest tide (TSSC 2013).

This definition can be problematic as saltmarsh vegetation often extends landward beyond tidal influences and intergrades with other vegetation types (Boon et al. 2011). For the purposes of this ECD the mapped extent of saltmarsh patches that are known to be predominantly influenced by tides are assessed against the listing advice for the community. The listed coastal saltmarsh community includes marshes that may become intermittently disconnected from tidal influence (e.g. when the mouth of the estuary becomes closed by sand bars) and supratidal saltmarshes that have groundwater connectivity to tidal groundwater flows (TSSC 2013). All the coastal saltmarsh within the site fits these two categories. The saltmarsh fringing the estuary is isolated from tidal influence when the shallow mouth of the Glenelg River is closes seasonally through the deposition of a barrier bar and supratidal saltmarshes fringe several saline depressions located between the river channel and western shore of Oxbow Lake. These are presumably also cut off from tidal influence when the river mouth closes.

At the state level, the listed community includes two Victorian Ecological Vegetation Classes (EVC): coastal saltmarsh (EVC9) and estuarine wetland (EVC 10) (DELWP 2015a).

Maroon leek-orchid - *Prasophyllum frenchii*

The maroon leek-orchid prefers open sedge, wet grassland and wet heathland generally bordering wetland areas. Typography is general flat and the species typically only occurs in low altitude locations. Often found in association with kangaroo grass (T*hemeda* spp.), wallaby grass (*Rytidosperma* spp.), twig-rush (*Baumea* spp.) and sword-sedge (*Lepidosperma* spp.) and sometimes with saw-sedge (*Gahnia* spp.), tussock grass (*Poa* spp.) and speargrass (*Austrostipa* spp.). Associated taller stratum species include Woolly Teatree (*Leptospermum lanigerum*), Swamp Paperbark (*Melaleuca ericifolia*) and Scented Paperbark (*Melaleuca squarrosa*) (Department of Environment 2015b) .

The orchid was formerly more widespread in much of south-eastern Australia, but has undergone declines in both range and abundance (Duncan 2010). A number of threats have potentially contributed to the decline of the species. Altered fire regimes may be one such factor, with fires likely to reduce competition. Altered hydrology and reduced soil moisture are also threats to the species (Duncan 2010). Detailed information on the community at Long Swamp is lacking and is a knowledge gap for the site.

Swamp greenhood - *Pterostylis tenuissima*

Pterostylis tenuissima is a perennial terrestrial greenhood orchid which appears as a rosette in the non-reproductive stage, however, the rosette is absent when in flowering form. The flowering form has up to five stem-sheathing leaves (10-30 mm long) along its flower stem. The stem reaches up to 300 mm in length and supports a single, nodding flower (Dickson et al. 2012) (Figure 59). *Pterostylis tenuissima* colonises very moist soils under dense silky tea-tree (*Leptospermum lanigerum*), in close proximity to the groundwater table. Threats within the Ramsar site could include invasion of habitat by Coastal wattle which has been shown to have significant impacts on groundcover species (Dickson et al. 2012).

Figure 59: Swamp greenhood, Pterostylis tenuissima. (© Laura Weedon).

Australasian bittern - *Botaurus poiciloptilus*

The Australasian bittern (*Botaurus poiciloptilus*) is a shy and cryptic wading species of wetland bird, typically solitary in nature, but sometimes occurring in pairs or dispersed aggregations of up to 12 birds. The breeding ecology of the species is poorly known but is believed to breed in solitary, territorial pairs. The bitterns tend to be residents, or sedentary, in suitable permanent habitat, but can undertake regular short distance movements in winter (Marchant and Higgins 1990). This has been recently supported by the Bitterns in Rice project, which suggests bitterns have altered their movement and breeding patterns to adapt to using rice

crops as habitat (Herring et al. 2014). It may also account for the regular coastal influxes of birds in winter around Melbourne and Geelong (BirdLife Australia, Atlas database) which may be post-breeding birds originating from the rice fields in NSW (Herring et al. 2014).

Preferred habitat includes permanent wetlands with tall dense vegetation (e.g. *Phragmites, Cyperus, Eleocharis, Juncus, Typha, Baumea, Bolboschoenus*) or cutting grass (*Gahnia*) growing over a muddy or peaty substrate, with still, shallow water up to 0.3 metres deep (Marchant and Higgins 1990; TSSC 2011a). The birds are often found in the littoral zone, or on platforms or mats of vegetation over deep water (TSSC 2011a).

In 2010, the total population of the Australasian bittern in Australia was estimated to be between 250 and 800 individuals (Birds Australia, unpublished data, 2010 cited in (TSSC 2011a).

Figure 60: Australasian bittern (Botaurus poiciloptilus) (© Ian Montgomery, Birdway).

Curlew sandpiper - *Calidris ferruginea*

In Victoria, curlew sandpiper were widespread in coastal bays and inlets. Despite recent declines these are still their Victorian strongholds; they are widespread in near-coastal wetlands, and they occur intermittently on inland wetlands (e.g. in the Kerang area, Mildura, and western districts). A generation time of 7.6 years (BirdLife International, 2014) is derived from an age at first breeding of 2.0 years, an annual survival of adults of 79% and a maximum longevity of 14.8 years, all extrapolated from congeners (Garnett et al., 2011). Estimates of apparent and true survival rate respectively for curlew sandpipers in Victoria are 73.1% and 80.5% (Rogers and Gosbell 2006). Rogers and Gosbell (2005) demonstrated that long-term decline in Victorian curlew sandpipers, although influenced by consecutive years of low breeding success, has been driven by reduced adult survival.

Figure 61: Curlew sandpiper (Calidris ferruginea) (© Ian Montgomery, Birdway).

Fairy tern – *Sterna nereis nereis*

Fairy tern (*Sternula nereis nereis*) was listed in 2011 under the EPBC Act as a vulnerable threatened species, and is also listed as vulnerable under the IUCN Red List (IUCN 2015). The total number of mature birds is limited, and estimated to range between 3000 to 9000 individuals (Baling et al. 2009 cited in TSSC 2011b). The listing advice for the species suggests a decline in the population of approximately 24 percent over the past three generations (1974–2007), and anticipate this decline to continue over the next three generations or 33 years as there is no evidence that the threats affecting this subspecies are abating (TSSC 2011b).

Fairy terns are single prey item, central-place foragers (Orians and Pearson 1979), and as such their foraging locations are restricted by the location of their nest site, being the central place they return to consume their prey. As a small bird, fairy terns are also limited in the size of the prey and this is thought to constrain the location of nesting sites to a close reliable source of suitable-sized fish (Paton and Rogers 2009). Fairy terns were recorded breeding within the site, near the mouth of the estuary, alongside little terns in 2003/2004. Breeding is also occurring elsewhere within the site, along Discovery Bay beach as evidence by photograph taken in December 2014 (see Figure 42 above).

Threats to the species include predation by silver gulls, foxes, increased human disturbance of nesting areas and Inappropriate water resource management (Baker-Gabb and Manning 2011, DENR 2012).

Hooded plover - *Thinornis rubricollis rubicollis* (eastern)

Hooded plover (*Thinornis rubricollis*) listed as vulnerable on the IUCN Red List (IUCN 2012b) and EPBC Act (TSSC 2014), occurs on ocean beaches, typically above the high water mark and also at coastal lakes across southern Australia (Buick and Paton 1989, Weston and Elgar 2005). Buick and Paton (1989) reported that densities along ocean beaches are typically less than one per kilometre. More recent data collected under the biennial counts indicates that densities of hooded plover have varied considerably within the

Ramsar site, with densities of 0.47 birds per kilometre in 2008, 0.36 in 2010 and 1.15 birds per kilometre in 2012 (Mead et al. 2012).

The adults forage across the beaches preying on insects, sandhoppers (*Orchestia* sp.), small bivalves and soldier crabs (*Mictyris platycheles*). Nests are shallow scrapes in the sand or fine gravel and may be encircled or lined with pebbles, seaweed and other beach debris. One to two eggs hatch approximately 30 days after laying with the young leaving the nest shortly afterwards. Chicks rely heavily on fore-dunes and dunes as their main site of concealment from potential predators (Weston and Elgar 2005, Baker-Gabb and Weston 2006).

Figure 62: Hooded plover (Thinornis rubricollis) (© Ian Montgomery, Birdway).

Within the Ramsar site, the birds nest on the ocean beach above high tide mark and close to the base of the dunes. Data from the 2012 biennial count indicated 41 birds present within the Ramsar site, however there was no evidence of breeding that year (no scrapes, nests, eggs or young) (Mead et al. 2012).

The presence of birds on a beach may indicate there is available food and nesting habitat, but it doesn't reflect the overall quality of the habitat. Hooded plovers are known to continue to breed at sites without success for six to nine years (Mead et al. 2012). This indicates that while there is physical habitat, it can be impacted by recreational use and predators so that the birds have repeated unsuccessful nesting attempts over time (Mead et al. 2012). Estimates of population size is also not a good indicator of the health of the population, as the birds are a long-lived species (up to 18 years, but typically 10-15 years once adulthood is reached – G. Maguire BirdLife, pers. comm. 2013) with high adult survival (greater than 90% G. Maguire BirdLife, pers. comm. 2013), populations are likely to remain stable for many years as the main impacts to the species are not on the adults (Mead et al. 2012). Limited breeding success over consecutive years will mean poor recruitment into the adult population and as they start to die off, then a crash may occur (Mead et al. 2012).

Yarra pygmy perch – *Nannoperca obscura*

The Yarra pygmy perch occurs in Victoria and South Australia and is listed as vulnerable under the EPBC Act. Declines in populations have been attributed to habitat changes to rivers, creeks and shallow freshwater wetlands (particularly wetland drainage) (Saddlier and Hammer 2010). Yarra pygmy perch typically occur in slow flowing waters which have abundant aquatic vegetation, in particular emergent vegetation. Most often found in small numbers, occasionally co-occurring with Southern pygmy perch (Saddlier and Hammer 2010).

The ecological requirements of Yarra pygmy perch are poorly understood but assumed to have similar requirements to that of the southern pygmy perch (Humphries 1995 cited in Saddlier et al. 2013). Yarra pygmy perch is an obligate freshwater species completing its life cycle in freshwater, and is most often associated with large amounts of aquatic vegetation (particularly emergent vegetation) in fresh to slightly brackish water (e.g. (Woodward and Malone 2002; Bice and Ye 2006 cited in Saddlier et al. 2013). Yarra pygmy perch is believed to live between 1-5 year, spawns in spring (September–November) at water temperatures of 16–24°C (Saddlier et al. 2013).

Current total population status is not known as comprehensive surveys have not been undertaken from the known locations (Figure 63) post the Millenium drought (Saddlier et al. 2013). Within the Ramsar site, local population size is not known, however Veale (2014) reported a slight decrease in the number of Yarra pygmy perch caught in 2014 compared to 2012. The data are too limited however to establish if there is a declining trend, but Veale (2014) reported length frequency data which suggested recruitment was occurring. Also, there are other habitats within the Ramsar site which should be surveyed to establish the presence of the species across the whole site. The major threats to Yarra pygmy perch include wetland drainage, habitat damage through grazing and lack of regeneration, altered hydrology and introduced fish (Saddlier et al. 2013).

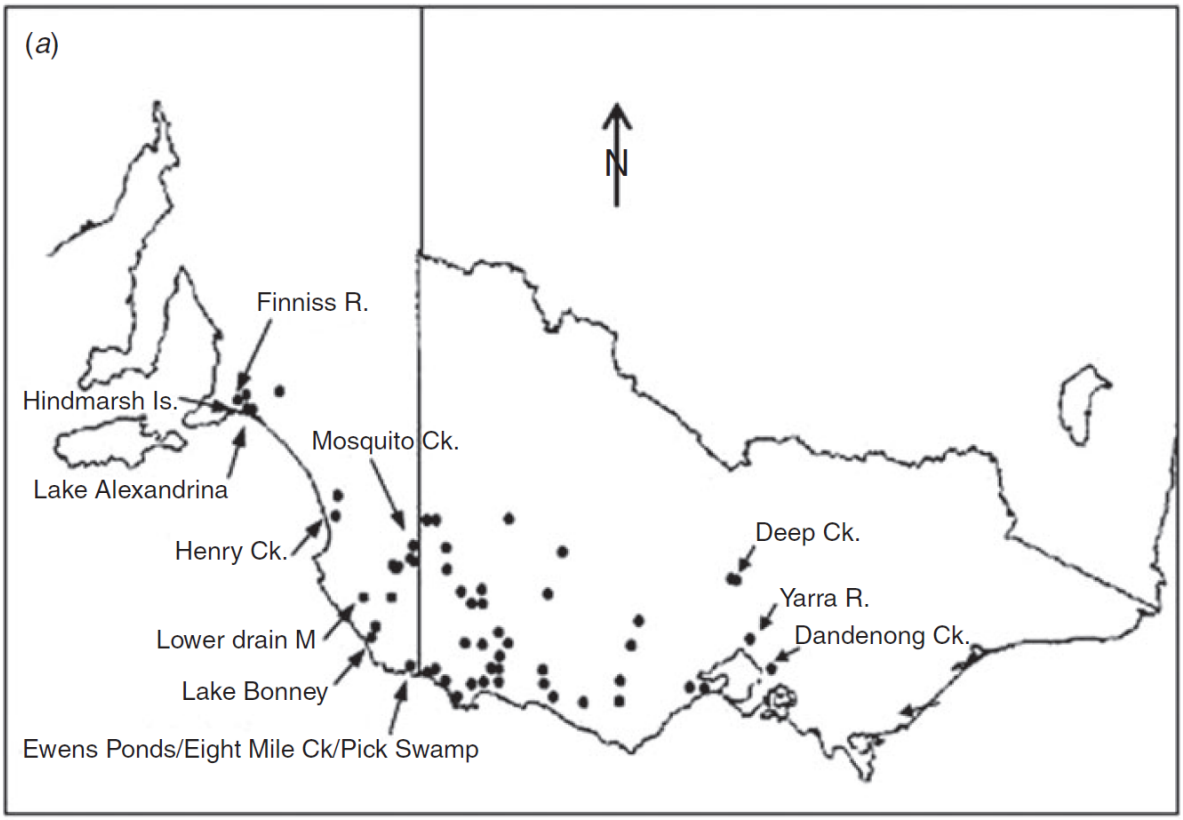


Figure 63: Distribution of Yarra pygmy perch (Nannoperca obscura) in Victoria and South Australia (from Saddlier et al. 2013).

Growling grass frog - *Litoria raniformis*

The growling grass frog (*Litoria raniformis*) is listed under the EPBC Act as vulnerable, and endangered under the IUCN Red List. The species occurs across the south-eastern States, and whilst it can be locally common, it is in decline in many areas of its range. Adults are typically found near water or in wet areas in woodlands, shrubland or open and disturbed areas, but prefer still waters. Tadpoles hide amongst vegetation in the shallower edges of wetlands, with the aquatic period lasting 2 – 15 months, in which time they grow to 110 mm and, in the later stages of development, have a characteristic green to yellowish dorsal colouration (Anstis 2002 cited in Clemann and Gillespie 2012). They will occupy both permanent and temporary wetland habitats, actively moving onto recently flooded areas and using permanent wetlands as refuges in dry periods (Bannerman 2005). Refuge habitat could include soil cracks in dry wetland beds, fallen timber, debris and dense vegetation on low frequently inundated floodplains (Bannerman 2005).

Adult frogs have a varied diet and will eat terrestrial invertebrates, small reptiles, other frogs and even small fish. They are sit-and-wait predators, and predominantly nocturnal. Breeding typically occurs between November and March (Bannerman 2005) following rises in water levels, from rain events or flooding. In the southern part of its range the species often has a long larval phase, so permanent waterbodies, or those in close proximity to permanent water, can be favoured by the species (Clemann and Gillespie 2012). Adult frogs overwinter beneath thick vegetation, logs, rocks and other ground debris, sometimes at considerable distances from waterbodies (P. Robertson, Wildlife Profiles pers. comm. cited in Clemann and Gillespie 2012).

The Chytrid fungus *Batrachochytrium dendrobatidis* causes the disease chytridiomycosis, which has been implicated in the declines of amphibians throughout the world including Australia (Berger et al. 1999 cited in Clemann and Gillespie 2012). Chytrid fungus is known to infect growling grass frogs and is considered a significant threat to the species. The National Recovery Plan identified the following additional processes that have potentially caused declines and/or are still operating as threats to growling grass frog populations (from Clemann and Gillespie 2012), many of which have the potential to act in concert:

- Loss and degradation of habitat
- Barriers to movement (may be important at the Ramsar site)
- Disease (see above)
- Predation
- Biocides
- Ultra-violet B radiation

The relative importance of these threats within the Ramsar site are a knowledge gap.

Ancient greenling - *Hemiphlebia mirabilis*

Recent investigations suggest an extremely large population of ancient greenling damsel fly (*Hemiphlebia mirabilis*) exists at Long Swamp, estimated to be more than one million specimens per season (Cordero Rivera 2014). The species has been found in the Grampians and also at nearby Piccaninnie Ponds Karst Wetland Ramsar site and other sites in South Australia (Haywood and Richter 2013) (Figure 64). This species is listed under the FFG Act and is on the IUCN Red List as endangered (IUCN 2015). The species has been considered at risk of global extinction, given its small population size, its localised distribution, and the fact that it is a 'living fossil', described as the oldest extant damselfly, however several authors suggest it is not critically endangered (Cordero-Rivera 2015).

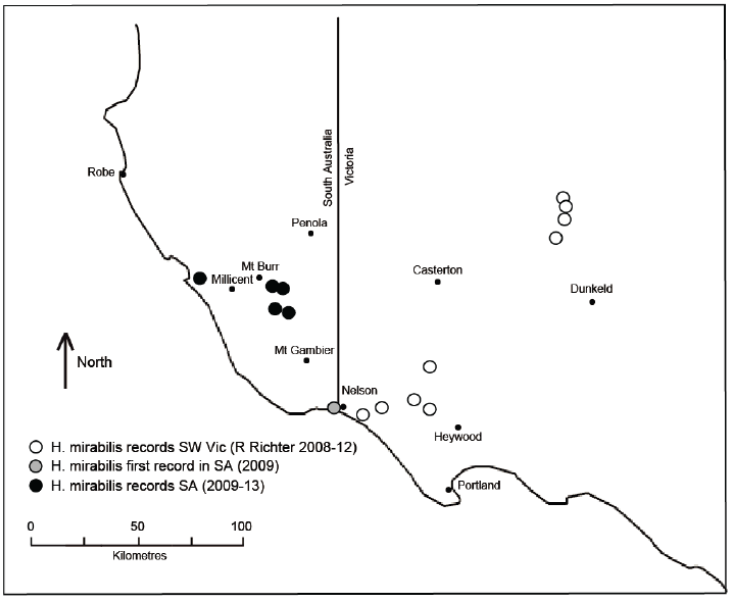


Figure 64: Locations of Hemiphlebia mirabilis in South West Victoria and South Australia (Haywood and Richter 2013).

The area of favourable habitat for *H. mirabilis* at Long Swamp is difficult to estimate, but that maximum density was observed at areas with 20-40 centimetres of water, which probably dry up in summer. This supports habitat preferences listed for other populations with water depth listed as < 50 centimetres (Crowther 2011). Preferred habitat in Long Swamp included dense stands of bare-twig sedge, *Baumea juncea*. This vegetation is found mainly associated with the fen peatlands Ramsar type U (Figure 65).

The greenling has been observed to be a weak flier, spending the majority of its time perched, (New 1993 cited in Cordero Rivera 2014) and possibly has weak dispersal abilities. This could make populations vulnerable to local extinction events. The expected longevity for males was calculated as 7.3 days and for females 4.4 days as adults (excluding the teneral phase), with mean observed lifespan for individuals recaptured at least once being 4.7±0.27 (168) for males and 4.4±0.47 (46) for females (Cordero Rivera 2014).

Mating frequency observed at Long Swamp was considered to be surprisingly low, and there were no data collected on oviposition and this remains a significant knowledge gap for the species.

Figure 65: Preferred reed habitat within Long Swamp (image taken from Cordero Rivera 2014).

Appendix E: Wetland birds recorded at the Glenelg Estuary and Discovery Bay Ramsar Site

EPBC Act listing: M = Listed as migratory or marine under the *EPBC Act*; J = JAMBA; C= CAMBA; R = ROKAMBA, B = BONN; CE = critically endangered internationally, Vu = vulnerable, En = endangered. Breeding: Limited = one or two records of breeding, usually with low counts, Regular = less than annual, Annual = breeding occurs annually with strong data record.

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty
Accipitriformes - Accipitridae			
Swamp harrier	*Circus approximans*		M
White-bellied sea eagle	*Haliaeetus leucogaster*		M, C
Anseriformes - Anatidae			
Australasian shoveler	*Anas rhynchotis*		M
Australian shelduck	*Tadorna tadornoides*		M
Australian wood duck	*Chenonetta jubata*		M
Black swan	*Cygnus atratus*	Yes	M
Blue-billed duck	*Oxyura australis*		M
Cape Barren goose	*Cereopsis novaehollandiae*		M
Chestnut teal	*Anas castanea*	Yes	M
Freckled duck	*Stictonetta naevosa*		M
Grey teal	*Anas gracilis*		M
Hardhead	*Aythya australis*		M
Musk duck	*Biziura lobata*		M
Mallard (introduced)	*Anas platyrhynchos*		
Pacific black duck	*Anas superciliosa*		M
Pink-eared duck	*Malacorhynchus membranaceus*		M
Anseriformes - Anseranatidae			
Magpie goose	*Anseranas semipalmata*		M
Charadiiformes - Charadriidae			
Banded lapwing	*Vanellus tricolor*		M
Black-fronted dotterel	*Elseyornis melanops*		
Double-banded plover	*Charadrius bicinctus*		M,C
Greater sand plover	*Charadrius leschenaultii*		M,B,C,J,R
Grey plover	*Pluvialis squatarola*		M,B,C,J,R
Hooded plover	*Thinornis rubricollis*		V (EPBC), M
Masked lapwing	*Vanellus miles*		
Oriental plover	*Charadrius veredus*		M,B,J,R
Pacific golden plover	*Pluvialis fulva*		M,B,C,J,R
Red-capped plover	*Charadrius ruficapillus*	Yes	

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty
Red-kneed dotterel	*Erythrogonys cinctus*		
Charadiiformes - Haematopodidae			
Australian pied oystercatcher	*Haematopus longirostris*	Yes	
Sooty oystercatcher	*Haematopus fuliginosus*		
Charadiiformes - Laridae			
Caspian tern	*Hydropogne (Sterna) caspia*		M,C, J
Crested tern	*Thalasseus bergii*	Yes	M
Fairy tern	*Sternula (Sterna) nereis*		V (EPBC), M
Gull-billed tern	*Gelochelidon nilotica*		M
Kelp gull	*Larus dominicanus*		M
Little tern	*Sternula (Sterna) albiforns*	Yes	M,B,C,J,R
Pacific gull	*Larus pacificus*	Yes	M
Silver gull	*Chroicocephalus novaehollandiae*		M
Whiskered tern	*Chlidonias hybrida*		M
White-fronted black tern	*Sterna striata*		
Charadiiformes - Recurvirostridae			
Banded stilt	*Cladorhynchus leucocephalus*		
Black-winged stilt	*Himantopus himantopus*		M
Red-necked avocet	*Recurvirostra novaehollandiae*		M
Charadiiformes - Scolopacidae			
Bar-tailed godwit	*Limosa lapponica*		M,B,C,J,R
Black-tailed godwit	*Limosa limosa*		M,B,C,J,R
Broad-billed sandpiper	*Limicola falcinellus*		M,B,C,J,R
Common greenshank	*Tringa nebularia*		M,B,C,J,R
Common sandpiper	*Actitis hypoleucos*		M,B,C,J,R
Curlew sandpiper	*Calidris ferruginea*		CE (EPBC), M,B,C,J,R
Eastern curlew	*Numernius madagascariensis*		CE (EPBC), M,B,C,J,R
Great knot	*Calidris tenuirostris*		M,C,J,R,B
Grey-tailed tattler	*Tringa (Heteroscelus) brevipes*		M,B,C,J,R
Latham's snipe	*Gallinago hardwickii*		M,B,C,J,R
Marsh sandpiper	*Tringa stagnatilis*		M,B,C,J,R
Red knot	*Calidis canutus*		M,B,C,J,R
Red-necked stint	*Calidris ruficollis*		M,B,C,J,R
Ruddy turnstone	*Arenaria interpres*		M,B, C,J,R
Sanderling	*Calidris alba*		M,B, C,J,R

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty
Sharp-tailed sandpiper	*Calidris acuminata*		M,B, C,J,R
Terek sandpiper	*Xenus cinereus*		M,B,C,J,R
Ciconiiformes - Pelecanidae			
Australian pelican	*Pelecanus conspicillatus*		M
Ciconiiformes - Ardeidae			
Australasian bittern	*Botaurus poiciloptilus*		CE (IUCN), En (EPBC)
Australian Little bittern	*Ixobrychus dubius*		
Cattle egret	*Ardea ibis*		M,C,J
Eastern great egret	*Ardea modesta*		M, C, J
Intermediate egret	*Ardea intermedia*		M
Little egret	*Egretta garzetta*		M
Nankeen night-heron	*Nycticorax caledonicus*		
White-faced heron	*Egretta novaehollandiae*		
White-necked heron	*Ardea pacifica*		
Ciconiiformes - Threskiornithidae			
Australian white ibis	*Threskiornis molucca*		M
Royal spoonbill	*Platalea regia*		
Straw-necked ibis	*Threskiornis spinicollis*		M
Yellow-billed spoonbill	*Platalea flavipes*		
Coraciiformes - Alcedinidae			
Azure kingfisher	*Alcedo azurea*		
Gruiformes - Rallidae			
Australian spotted crake	*Porzana fluminea*		M
Black-tailed native-hen	*Tribonyx ventralis*		
Brolga	*Grus rubicunda*		
Buff-banded rail	*Gallirallus philippensis*		
Dusky moorhen	*Gallinula tenebrosa*		
Eurasian coot	*Fulica atra*		
Lewin's rail	*Lewina (Rallus) pectoralis*		
Purple swamphen	*Porphyrio porphyrio*		
Spotless crake	*Porzana tabuensis*		M
Passeriformes - Acrocephalidae			
Australian reed warbler (Calamorous reed-warbler)	*Acrocephalus australis*		M
Phalacrocoraciformes - Phalacrocoracidae			
Australasian darter	*Anhinga novaehollandiae*		

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty
Black-faced cormorant	*Phalacrocorax fuscescens*		M
Great cormorant	*Phalacrocorax carbo*	Yes	
Little black cormorant	*Phalacrocorax sulcirostris*		
Little pied cormorant	*Microcarbo melanoleucos*		
Pied cormorant	*Phalacrocorax varius*		
Phalacrocoraciformes - Sulidae			
Australasian gannet	*Morus serrator*		M
Podicipediformes - Podicipedidae			
Australasian grebe	*Tachybaptus novaehollandiae*		
Great crested grebe	*Podiceps cristatus*	Yes	
Hoary-headed grebe	*Poliocephalus poliocephalus*		
Psittaciformes - Psittacidae			
Orange-bellied parrot	*Neopherma chrysogaster*		CE(EPBC),M,J

Appendix F: Fish species and ecology

Ecology and biological information sourced from FishBase (Froese and Pauly 2014), (Treadwell and Hardwick 2003), and Hammer (2001)(2002) and references therein, unless otherwise stated. Fish have been assigned to four categories and associated guilds based on the estuarine usage functional groups proposed by Potter et al. (2015):

- Marine category:
  - Marine straggler (MS),
  - Marine estuarine - opportunist (MO),
  - Marine estuarine - dependent (MD),
- Estuarine category:
  - Solely estuarine (SE),
  - Estuarine and marine (EM),
  - Estuarine and freshwater (EF),
  - Estuarine migrant (Emi),
- Diadromous category:
  - Anadromous (A),
  - Semi-anadromous (SA),
  - Catadromous (C),
  - Semi-catadromous (SC),
  - Amphidromous (Am),
- Freshwater category:
  - Freshwater straggler (FS),
  - Freshwater estuarine – opportunist (FO).

Table 31: List of fish recorded within the Ramsar site modified from unpublished data supplied by GH CMA, VBA data, and (Glenelg Hopkins CMA 2006a).

Family	Common name	Scientific name	Guild/ Functional group	Biology
Anguillidae	Short-finned eel	*Anguilla australis*	C	Benthopelagic; occurring in streams lakes and swamps. Feeds on fishes, invertebrates, aquatic plants, and terrestrial and aquatic insects. Long lived species which migrate to near the Coral sea to breed. Larval eels return as elvers (around 10 centimeters).

Family	Common name	Scientific name	Guild/ Functional group	Biology
Arripidae	Australian herring	*Arripis georgianus*	MO	Usually found inshore in bays and estuaries over seagrass beds or near areas of seaweed (e.g. kelp), on rocky reefs, and along ocean beaches. Juveniles are found in inshore coastal waters, bays and inlets. Feed on small fish and prawns.
	Australian salmon	*Arripis truttaceus*	MS or MO?	Inhabit continental shelf waters including estuaries, bays and inlets.
Atherinidae	Freshwater hardyhead	*Craterocephalus fulvus*	FO	Identified as *C. stercusmuscarum* in Parks Victoria (2006). Temperate, shoaling, inhabiting the margins of slow-flowing or still freshwater rivers and lakes, backwaters and billabongs with sand, gravel or mud substrates and aquatic vegetation.
	Marine hardyhead	*Atherinomorus vaigiensis*	MO	Identified as *Pranesus ogilbyi* in Parks Victoria (2006). Found in shallow coastal waters, including bays and estuaries; can tolerate salinity as low as 3 parts per thousand.
	Short-snout hardyhead	*Kestratherina brevirostris*	MS	Typically found in protected marine habitats with soft bottoms or seagrass beds. This species can be found in small aggregations below three m, however larger schools are found nearer the surface. This species has not been collected from the upper reaches of estuaries or lagoons (Pavlov et al. 1988 cited in IUCN 2015). Individuals exceeding three cm are planktivorous, feeding mainly on copepods. (IUCN 2015).
	Smallmouth hardyhead	*Atherinosoma microstoma*	A	Pelagic. Found in shallow coastal bays, estuaries and lakes ranging from pure fresh to salinities in excess of seawater. Occurs abundantly in estuaries around eel-grass thickets, occasionally penetrating the lower freshwater reaches of rivers. Feeds on tiny crustaceans and insects. Breeds in spring (September to October). An annual species (living for only one year), dying shortly after spawning. Estuarine resident.
	Tamar hardyhead	*Leptatherina presbyteroides*	EM	A schooling species found in inshore waters
Carangidae	Araara, blue trevally	*Pseudocaranx georgianus*	MS or MO?	Large mobile schools move in and out of estuaries, and often hang around jetties and piers.
Cheilodactylidae	Dusky morwong	*Dactylophora nigricans*	MS	A species of morwong native to the western and southern coastal reefs of Australia where it is found down to about 60 metres (200 ft) in depth.

Family	Common name	Scientific name	Guild/ Functional group	Biology
	Silver morwong	*Nemadactylus douglasii*	MS	A morwong of the genus *Nemadactylus*, found around south eastern Australia and the north eastern coast of the North Island of New Zealand at depths of about 10 to 100 metres, on sandy and rocky coasts.
Clupeidae	Sandy sprat	*Hyperlophus vittatus*	Am	Schools in large numbers in shallow sandy areas of bays and estuaries.
Eleotrididae	Flat-headed gudgeon	*Philypnodon grandiceps*	FO	Demersal. Found in still and flowing waters; often abundant in dams and lakes, usually among weeds or over mud bottoms. Occurs in reservoirs and brackish estuaries, less common in gently flowing streams). Feeds on invertebrates and other fishes and tadpoles. In breeding season (mainly spring to summer), males darken and display more vibrant fin markings. Females lay a clutch of eggs on a hard surface such as a rock or piece of wood. The male cares for the nest, chasing away intruders and fanning the eggs with his pectoral fins. Hatching occurs after 4-6 days.
	Carp gudgeon complex*	*Hypseleotris* spp.	FS	Normally lives around littoral vegetation and can be found in dams, lakes and canals as well as streams. Inhabits slow-flowing rivers or in still water like billabongs. It congregates in large schools below dams and weirs.
Engraulidae	Australian anchovy	*Engraulis australis*	MS	Found mostly inshore, in bays, inlets and estuaries, sometimes in low salinities. Older individuals tend to move out to sea in winter and back in the spring. Spawns in inlets, bays and also estuaries, probably throughout the year but mainly in late spring to early autumn and especially about November to February.
Gadopsidae	River blackfish	*Gadopsis marmoratus*	FS	Typically lives in clear, flowing streams with abundant cover. Prefers streams with gravel bottoms and abundant snags. Also occurs in lakes and reservoirs. Tolerant of slightly brackish conditions (10 p.p.t.) in the tidal reaches of rivers, and a temperature range of 5°-25°C. Home-ranging; remaining within about a 20-30 metre stretch of water throughout the life span. Feeds on insects, crustaceans and small fishes; also on molluscs. The spawning season runs from November to January. A popular angling species in the south, but large fish are rare. Highly susceptible to overfishing, due to its home-ranging behaviour and low fecundity.
Galaxidae	Climbing galaxias	*Galaxias brevipinnis*	Am	Normally in coastal streams but can survive in landlocked systems (Lintermans 2009). Larvae spend 5-6 months at sea before migrating back into freshwater and estuarine habitats. Inhabits mainly clear streams, often deeply shaded and relatively fast-flowing, although it sometimes occurs in lakes, particularly in Tasmania. The existence of a marine stage is regarded to be facultative rather than obligatory in Australia.

Family	Common name	Scientific name	Guild/ Functional group	Biology
	Common galaxias	*Galaxias maculatus*	C (marginally)	Benthopelagic, free swimming. Use a variety of habitat, but mostly prefer still or slow-flowing waters, mainly in streams, rivers and lakes within a short distance of the sea. Will also occur in landlocked wetlands. Feed on aquatic and terrestrial invertebrates. Adults typically migrate downstream into estuaries during high spring tides in autumn to spawn on fringing vegetation and also algal mats. Spawning does not occur beyond the river estuaries, making this species 'only marginally catadromous'. Many perish after spawning but some survive another year. Coastal populations have a marine juvenile stage.
	Spotted galaxias	*Galaxias truttaceus*	Am	Spawn in freshwater but larvae swept out to sea – only found in coastal systems. Occurs in still or slow-flowing waters at low elevations close to the sea; most abundant along shore margins in rocky areas.
	Little galaxias	*Galaxiella toourtkoourt*	FS	Frequently found among vegetation along the edge of still or slow-running waters like swamps, drainage ditches and backwaters of creeks. Adults live in both ephemeral and permanent habitats. A short-lived fish, reaching maturity in the first year of life and perishing shortly after spawning. Fish occupying ephemeral water possibly aestivate or shelter in crayfish burrows when surface water evaporates during summer.
Geotriidae	Pouched lamprey	*Geotria australis*	A	Demersal. Typically found in mud burrows in upper reaches of coastal streams for the first four years of life, and then they migrate back to the sea. Adults inhabit the sea for an undetermined period and are parasitic on other fishes. Migrate upstream which may last for 16 months and spawn in freshwater. Adults are often found below weirs and dams during their spawning migration which may take them considerable distances upstream of the coast. Migration mostly takes place in rainy nights when water levels are rising, with temperatures between 12-14.5°C and when there is extensive cloud cover or during the dark phase of the moon. Sometimes they exit the water by wriggling up the bank to bypass obstacles to migration. Adults stop feeding while in freshwater and die shortly after spawning.
Gobiidae	Blue-spot goby (eastern Australia)	*Pseudogobius* sp. 9	EF	It is often found in muddy areas and seagrass beds in the upper reaches of estuaries. It is also known to penetrate upstream into freshwater and may remain there for extended periods of time.
	Bridled goby	*Arenigobius bifrenatus*	EM	Found in muddy coastal areas to upper estuaries, rocky reefs, in sea grass beds and mangroves.

Family	Common name	Scientific name	Guild/ Functional group	Biology
	Glass goby	*Gobiopterus semivestitus*	EF	Found in quiet coastal estuaries, enters fresh water, usually in small to large schools
		Nesogobius sp	MS	
	Lagoon goby	*Tasmanogobius lasti*	EM	Found in muddy areas of estuaries and bays.
	Largemouth goby	*Redigobius macrostoma*	Am	Found in estuaries, harbors and entering lower reaches of freshwater streams.
	Tamar river goby	*Afurcagobius tamarensis*	EF	Inhabits quiet waters of brackish estuaries and coastal lakes; also in lower reaches of freshwater streams
Hemiramphidae	Southern seas garfish	*Hyporhamphus melanochir*	MO	Found inshore in surface waters of estuaries, bays, inlets and gulfs to a depth of about 20 m
Kyphosidae	Parore	*Girella tricuspidata*	MO	Adults favour estuarine (including mangroves), rocky reef and inshore, coastal water habitats
Monocanthidae	Toothbrush leatherjacket	*Acanthaluteres vittiger*	MS	Named as *Penicipelta vittiger* in Park Victoria (2006). The Toothbrush Leatherjacket lives in a range of habitats from shallow seagrass beds to rocky reefs at depths around 40 m. - See more at: http://australianmuseum.net.au/toothbrush-leatherjacket-acanthaluteres-vittiger#sthash.j6dyTclD.dpuf.
Mordaciidae	Shortheaded lamprey	*Mordacia mordax*	A	Adults inhabit the sea for an undetermined period and are parasitic on fishes; enter freshwater to breed. Majority of adulthood is spent in estuaries or at sea. Upstream spawning migrants occur in fast-flowing sections of rivers with a mud, sand or silt substrate, sometimes seen congregated below barriers to upstream movement such as weirs.
Moridae	Southern rock cod	*Pseudophycis barbata*	MS	Coastal waters of southern Australia from southern New South Wales to Rottnest Island (WA), and New Zealand. Inhabits rocky areas in depths to 275 m (Gomon and Bray 2011)
Mugilidae	Goldspot mullet, Flat-tail mullet	*Liza argentea*	C	Found in fresh to marine waters throughout south east Australia, often co-occurring with *Myxus elongatus*.
	Sea mullet	*Mugil cephalus*	C	

Family	Common name	Scientific name	Guild/ Functional group	Biology
	Sand mullet	*Myxus elongatus*	C	
	Yellow-eye mullet	*Aldrichetta forsteri*	C	Found over sandy and muddy bottoms of coastal waters, bays, estuaries, and may ascend rivers into freshwaters. Spawn in coastal waters in summer and autumn, probably in estuaries.
Percichthyidae	Estuary perch	*Macquaria colonorum*	EF	Occurs in lentic and lotic freshwater. Most commonly found in tidal waters, but also occurs in rivers and lakes with salinities less than 1-2 ppt. Occurs in estuaries and lower, tidal reaches of rivers. During winter (July and August) they move to the mouth of estuaries to breed.
	Southern pygmy perch	*Nannoperca australis*	FS	Benthopelagic. Occurs in lotic and lentic freshwater bodies, preferring vegetated margins in still or gently flowing water. Forms small groups and is a very common prey item for introduced fishes, such as the Redfin perch and trout. Prefers habitats not affected by stock access. Feeds on small invertebrates. Breeds from September to January, when water temperatures rise above 16°C. Reproductive habits and biology are typical of the family. Maximum life expectancy is about 5 years.
	Yarra pygmy perch	*Nannoperca obscura*	FS	Benthopelagic. Inhabits streams and small lakes; preferring more permanent and flowing water with abundant cover in the form of aquatic vegetation. Occurs in creeks and lakes, usually among aquatic weeds. Feeds on aquatic invertebrates. Breeding season is in spring, slightly earlier than the Southern pygmy perch.
Pleuronectidae	Longsnout flounder	*Ammotretis rostratus*	MS	Occurs in sandy regions of bays and offshore areas.
	Greenback flounder	*Rhombosolea tapirina*	MS	Common on silty sand substrates from estuaries and inshore waters down to 100 m depth. Juveniles occasionally entering rivers.
Pomatomidae	Bluefish	*Pomatomus saltatrix*	MS	Occur in oceanic and coastal waters. They are most common along surf beaches and rock headlands in clean, high energy waters, although adults can also be found in estuaries and into brackish water.
Pseudaphritidae	Tupong (Congolii)	*Pseudaphritis urvillii*	C	Benthopelagic. Found in streams and estuaries. Inhabits slow-flowing water around log snags, under over-hanging banks or among leaf litter. Adult fish migrate downstream to spawn in weedy estuaries from late April to August. Predatory feeding on invertebrates and fishes. Often buries itself in the substrate to ambush passing prey. A highly efficient osmo-regulator, able to withstand direct transfer from salt to fresh water without any indication of stress.

Family	Common name	Scientific name	Guild/ Functional group	Biology
Retropinnidae	Southern smelt	*Retropinna* species	FS	Pelagic in fresh to brackish waters including streams, backwaters, lakes, swamps and estuaries. One of the most widespread species in south-eastern Australia. Most common in slow-flowing streams and still waters, shoaling near the surface or around the cover of aquatic plants and woody debris. Forms large aggregations in open water. Feeds on aquatic insects, microcrustaceans and algae. Spawns throughout the Murray-Darling river system. Breeds between July and March (mostly in spring). Spawning temperature is about 15 °C. Eggs are laid among aquatic vegetation and hatch in about 10 days. Sexual maturity is attained by the end of the first year. There are no major threats to this species.
Sciaenidae	Mulloway	*Argyrosomus japonicus*	MO	Adult fish found mainly near shore beyond the surf zone, occasionally going inshore. Juveniles exclusively found inshore. Juveniles recruit to estuaries at about 30 cm TL.
Sillaginidae	Spotted sillago	*Sillaginodes punctatus*	MS	Inhabit shallow inner continental shelf waters, including bays and inlets. For their first few years, they live mainly where seagrasses occur. Small juveniles like water depths from 2 m to 20 m. Adults inhabit more exposed waters along coastal beaches and reef areas, sometimes to depths as great as 200 m. Spawn in offshore waters from late summer to winter. Juveniles feed on benthic amphipods and other crustaceans.
Sparidae	Black bream	*Acanthopagrus butcheri*	SE	Endemic in coastal areas, rivers and estuaries of Australia. Most abundant in river mouths and estuaries. Inhabit brackish waters of coastal rivers and lakes, occasionally penetrating fresh water. Considered as the only true estuarine sparid in Australia. Larvae and small juveniles are most abundant over seagrass beds in shallow estuarine waters. Spawning period varies considerably between estuaries. Remain upstream in sheltered waters to spawn and is not usually found in purely marine habitats.
	Silver seabream	*Chrysophrys auratus*	MS	Found in rocky reefs and also in estuaries.
Tetraodontidae	Prickly toadfish	*Contusus brevicaudus*	MO	Usually observed in estuaries to about 20 m.
	Smooth toadfish	*Tetractenos glaber*	MO	Found on coastal bays on sandy flats, often in very large schools, entering fresh water in estuaries.

Family	Common name	Scientific name	Guild/ Functional group	Biology
Tetrarogidae	South Australian cobbler	*Gymnapistes marmoratus*	MS	Occur in inshore waters. Most active at night, lying motionless during the day.
Triglidae	Bluefin gunnard	*Chelidonichthys kumu*	MO	Found from estuaries to edge of continental shelves over sand and sandy shell seabed. Reported to be often found in rivers.

Appendix G: Plant List

This plant list, compiled by Leila Huebner, represents all known wetland species in Sector A of the Discovery Bay Coastal Park section of the proposed Ramsar site. Includes all vouchered plant species lodged in the Melbourne Herbarium (unless stated otherwise).
Key: ^ = name change, * = alien/weed, L.I. = Livingston Island, Leila Huebner and Mary S. collected 2013/14.

Family	Common name	Scientific name
Isoetaceae	Plain quilwort	*Isoetes drummondii* subsp. *drummondii*(?)
Ophioglossaceae	Austral adder's-tongue	*Ophioglossum lusitanicum subsp. coricium?*
Centrolepidaceae	Pointed centrolepis	*Centrolepis aristata*
	Tufted centrolepis	*C. fascicularis*
	Hairy centrolepis	*C. strigosa subsp.strigosa*
Cyperaceae	Pale twig-rush	*Baumea acuta (AP)*
	Jointed twig-rush	*Baumea arthrophylla*
	Bare twig-rush	*Baumea articulata*
	Lax twig-rush	*Baumea juncea*
	Soft twig-rush	*Baumea laxa*
		Baumea rubiginosa
	Sea club-rush	*Bolboschoenus caldwellii (AP)*
	Tall sedge	*Carex appressa*
		Carex breviculmis
	Tassel sedge	*Carex fascicularis*
		Carex gunniana
		Carex inversa
	Strand sedge	*Carex pumila*
	Leafy twig-rush	*Cladium procerum*
	Leafy flat-sedge	*Cyperus lucidus*
	Tiny flat-sedge	*tenellus (*Isolepis levynsiana)* ^
	Common spike-rush	*Eleocharis acuta*
	Knobby club-rush	*Ficinia nodosa*
	Tall aaw-sedge	*Gahnia clarkei*
	Chaffy saw-sedge	*Gahnia filum*
	Red-fruit saw-sedge	*Gahnia sieberiana*
	Coast saw-sedge	*Gahnia trifida*
	Nodding club-rush	*Isolepis cernua var cernua?*
	Floating club-rush	*Isolepis fluitans*
	Swamp club-rush	*Isolepis inundata*
		Isolepis marginata
		Isolepis cernua var.platycarpa

Family	Common name	Scientific name
		Isolepis producta
	Star club-rush	*Isolepis stellata*
	Hoary rapier-sedge	*Lepidosperma canescens*
	Sand-hill sword-sedge	*Lepidosperma concavum*
	Little sword-sedge	*Lepidosperma curtisiae (syn.lineare)*
	Pithy sword-sedge	*Lepidosperma longitudinale*
	Stiff rapier-sedge	*Lepidosperma neesii*
	Club-rush	*Schoenoplectus pungens*
	River club-rush	*Schoenoplectus tabernaemontani* (syn.*validus*)
	Common bog-rush	*Schoenus apogon*
	Zig-zag bog-rush	*Schoenus brevifolius*
		Schoenus carsei
		deformis
	Floating bog-rush	*Schoenus fluitans*
	Leafy bog-rush	*Schoenus maschalinus*
	Shiny bog-rush	*Schoenus nitens*
	Slender bog-rush	*Schoenus lepidosperma (*syn*. tenuissimus*
	Hair-sedge	*Tetraria capillaris*
Hydrocharitaceae	Eel-weed	*Vallisneria americana* var. *americana* (syn. *gigantea*)
Iridaceae	Morning-flag	*Orthrosanthus multiflorus*
	Short purple-flag	*Patersonia fragilis*
	Long purple flag	*Patersonia occidentalis* var. *occidentalis*(?)
Juncaceae	Jointed rush	*Juncus articulatus subsp. articulates(?)
	Austral rush	Juncus australis
	Toad rush	Juncus bufonius
	Bulbous rush	*Juncus bulbosus
	Grassy rush	*Juncus caespiticius*
	Capitate rush	*Juncus *capitatus*
	Thread rush	*Juncus filicaulis*
	Joint-leaf rush	*Juncus holoschoenus*
	Sea rush	*Juncus krausii* subsp*. australiensis*
	Pale rush	*Juncus pallidus*
	Loose-flower rush	*Juncus pauciflorus*
	Broad-leaf rush	*Juncus planifolius*
		Juncus procerus
	Finger rush	*Juncus subsecundus*

Family	Common name	Scientific name
Juncaginaceae	Dwarf arrowgrass	*Triglochin nana (syn.centrocarpa)*
	Water-ribbons	*Triglochin procera*
	Streaked arrowgrass	*Triglochin* striata
Lemnaceae	Common duckweed	*Lemna minor*
	Blue stars	*Chaemiscilla corymbosa var. corymbosa(?)*
	Fringe-lily	*Thysanotus aff. bauera (LWH, Livingston Island)*
	Branching fringe-lily	*Thysanotus juncifolius (syn. dichotomus)*
Orchidaceae	Slender onion-orchid	*Microtis parviflora*
	Sweet onion-orchid	*Microtis rara*
	Common onion-orchid	*Microtis unifolia*
	Tall leek-orchid	*Prasophyllum elatum*
	Maroon leek-orchid	*Prasophyllum hartii (frenchii group)*
	Slender leek-orchid	*Prasophyllum parviflorum*
	Sweet leek-orchid	*^Prasophyllum robustum (syn. patens var. robustum, odoratum)*
	Marsh leek-orchid	*Prasophyllum niphopedium (syn. rogersii)(APNI/CHAH)*
	Swamp greenhood	*Pterostylis tenuissima*
	Austral ladies' tresses	*Spiranthes australis (syn. sinensis)*
Poaceae	Cocksfoot	**Dactylis glomerata*
	Common wallaby-grass	*Danthonia caespitosa (Austrodanthonia caespitosa)*
	Common love-grass	*Eragrostis brownii*
	Tall fescue	**Festuca arundinacea*
	Coast fescue	*Austrofestuca littoralis*
	Australian sweet-grass	*Glyceria australis*
	Mat grass	*Hemarthria uncinata var. uncinata (aquatic plant)*
	Toowoomba canary-grass	**Phalis aquatica*
	Reed canary-grass	** Phalis arundinacea*
	Common reed	*Phragmites australis*
	Coast beard-grass	**Polypogon maritimus*
	Annual beard-grass	**Polypogon monspeliensis*
	Salt couch	*Sporobolus virginicus*
	Hairy rice-grass	*Tetrarrhena distichophylla*
Potamogetonacea	Fennel pondweed	*Potamogeton pectinatus*
Restionaceae	Floating pondweed	*Potamogeton tricarinatus*
	Spreading rope-rush	*Empodisma minus*
	Tassel rope rush	*Hypolaena fastigiata*

Family	Common name	Scientific name
	Course twine-rush	*Leptocarpus brownii*
	Slender twine rush	*Leptocarpus tenax*
Ruppiaceae	Sea tassel (saltwater-tolerant)	*Ruppia maritime*
Typhaceae	Bulrush	*Typha domingensis*
Zannichelliaceae	Long-fruited water-mat	*Lepilaena cylindrocarpa*
Apiaceae	Annual celery	*Apium annuum*
	Sea celery	*Apium prostratum*
	Centella	*Centella cordifolia*
	Thread pennywort	*Hydrocotyle capillaris*
	Hairy pennywort	*Hydrocotyle hirta*
	Stinking pennywort	*Hydrocotyle laxiflora*
	Mossy pennywort	*Hydrocotyle muscosa*
	Shining pennywort	*Hydrocotyle sibthorpioides*
	Australian lilaeopsis	*Lilaeopsis polyantha*
	Cut-leaf xanthosia	*Xanthosia dissecta*
Asteracaea	Salt angianthus	**^Angianthus preissianus*
	Grass daisy	*Brachycome graminea*
	Coast daisy	*Brachycome parvula*
	Common sneezeweed	*Centipeda cunninghamii*
	Common cotula	*Cotula australis*
	Water buttons	*Cotula coronopifolia*
	Creeping cotula	*^ Cotula reptans (Leptinella reptans)*
	Slender cotula	*Cotula vulgaris* var. *australasica*
	Common billy-buttons	*^Craspedia glauca (Craspedia spp undergoing revision)*
	Creeping cudweed	*^Gnaphalium gymnocephalum (Euchiton collinus)*
	Tiny cudweed	*Gnaphalium indutum*
	Common lagenophora	*Lagenophera stipitata*
	Pleated podolepis	*Podolepis rugata* var. *rugata*
	Jersey cudweed	*^Pseudognaphalium luteoalbum (Helichrysum luteoalbum)*
	White cudweed	**Vellereophyton dealbatum*
		**Vellereophyton maritima subsp. maritima*
Brassicaceae	Slender bitter-cress	**Cardamine tenuifolia*
		** Cardamine* sp. *(Rorippa* sp.*?)*
	Whitlow grass	**Erophila verna* subsp. *verna?*
	Oval purse	*Hymenolobus procumbens*

Family	Common name	Scientific name
	Hairy shepherd's purse	*Microlepidium pilosulum (R)*
	One-row water-cress	*^Rorippa microphylla (Nasturtium microphyllum)*
	Two-row water-cress	*^ Rorippa nasturtiumaquatica (Nasturtium officinale)*
Caprifoliaceae	White elderberry	*Sambucus gaudichaudiana*
	Erect chickweed	*Moenchia erecta*
	Spreading chickweed	*Moenchia procumbens*
	Coast sandspurry	*Spergularia media*
	Red sandspurry	*Spergularia rubra*
Chenopodeacea	Hastate orache	*^Atriplex hastata (Atriplex prostrata)*
	Glaucous goosefoot	*Chenopodium glaucum*
	Trailing hemichroa	*Hemichroa pentandra*
	Seaberry saltbush	*Rhagodia candolleana subsp. candolleana*
	Thick-headed glasswort	*Sarcocornia blackiana*
	Beaded glasswort	*Sarcocornia quinqueflora subsp. quinqeflora*
	Austral seablite	*Suada australis*
	Glistening saltbush	*^Theleophyton billardieri (Atriplex billardierei)*
	Coast bonefruit	*Threlkeldia diffusa*
Convulvulaceae	Pink bindweed	*Convolvulus erubescens (amongst Phragmites, Glenelg River)*
	Narrow-leaf wilsonia	*Wilsonia backhousei*
	Silky wilsonia	*Wilsonia humilis*
	Round-leaf wilsonia	*Wilsonia rotundifolia*
Crassulaceae	Swamp crassula	*Crassula helmsii*
Dillenaceae	Scrambling guinea-flower	*Hibbertia Hibbertia empetrifolia subsp. empetrifolia*
Droceraceae	Forked sundew	*Drosera binata (LWH, allot. 4 Sect. A LS)*
	Tiny sundew	*Drosera pygmaea*
	Leafless globe-pea	*Sphaerolobium vimineum*
Gentianacea	White sebaea	*Sebaea albidiflora*
	Yellow sebaea	*Sebaea ovata*
Goodeniaeae	Swamp goodenia	*Goodenia humilis*
	Selliera	*Selliera radicans*
Haloragaceae	Swamp raspwort	*Haloragus brownii*
	Eichler's raspwort	*Haloragus eichleri*
	Prickly raspwort	*Haloragus myriocarpa*
	Broad water-milfoil	*Myriophyllum amphibium*
		Myriophyllum caputmedusae

Family	Common name	Scientific name
		Myriophyllum crispatum
	Hooded milfoil	*Myriophyllum muelleri*
	Red milfoil	*Myriophyllum verrucosum*
Lamiaceae	Slender mint	*Mentha diamenica*
	Self-heal	**Prunella vulgaris*
Lauraeae	Slender dodder-laurel	*Cassytha glabella:* forma dispar *orglabella?*
	Downy dodder-laurel	*Cassytha pubesens*
Lentibulariaceae	Yellow bladderwort	*Urtricularia australis*
	Fairies aprons	*Urtricularia uniflora*
Lobeliaceae	Angled lobelia	*^Lobelia alata (Lobelia anceps)*
	Tall lobelia	*^Lobelia gibbosa*
	Matted pratia	*^Pratia pedunculata (Lobelia pedunculata)*
	Tiny mitrewort	*^Mitrosacme distylis (Phyllangium distylis)*
Lythracaea	Mediterranean loosestrife	**^Lythrum flexuosum (Lythrum junceum)*
	Small loosestrife	*Lythrum hyssopifolia*
Malvaceae	Salt lawrencia	*Lawrencia spicata (Livingston Island)*
Menyanthaceae	Running marsh-flower	*Villarsia reniformis*
	Lax marsh flower	*Villarsia umbricola* var. *umbricola*
Myrtaceae	Swamp eucalyptus	*Eucalyptus ovata* var. *ovata*?
	Woolly tea tree	*Leptospermum lanigerum*
	Swamp paper-bark	*Melaleuca ericifolia (sterile, Nelson caldera, Portland west)*
	Slender honey-myrtle	*Melaleuca gibbosa*
	Scented paper-bark	*Melaleuca squarrosa*
Onagraceae	Robust willow-herb	*Epilobium billardierianum* subsp. *billardierianum*?
	Variable willow-herb	*^Epilobium cinereum* (*Epilobium billardierianum* subsp. *cinereum*)
	Showy willow-herb	*Epilobium pallidiflorum*
	Variable willow-herb	*Epilobium varia*
Polygalaceae	Creeping willow-herb	*^Polygonum prostratum (Persicaria prostrata)*
Portulacaceae	White purslane	*Neopaxia australasica*
Primulaceae	Creeping brookweed	*Samolus repens* var. *repens*
Ranunculaceae	Australian buttercup	*Ranunculus lappaceus*
	Annual buttercup	*Ranunculus sessiliflorus* var. *sessiliflorus*(?)
Rosaceae	Hairy sheep's burr	*Acaena agnipila*
	Sheep's burr	*Acaena echinata*
	Bidgee-widgee	*Acaena novaezelandiae*

Family	Common name	Scientific name
	Silverweed	**Potentilla anserina*
Rubiaceae	Elongate woodruff	** Asperula charophyton*
	Small woodruff	**Galium murale*
Rutaceaea	Swamp boronia	*Boromia parviflora*
Scrophulariaceae	Purple eyebright	*Euphrasia collina*
	Austral brooklime	*^Gratiola latifolia (Gratiola peruviana)*
	-	*Gratiola pubescens*
	Austral mudwort	*Limosella australis*
	Swamp mazus	*Mazus pumilio*
	Slender monkey-flower	*Mimulus gracilis*
	Derwent speedwell	*^Parahebe derwentiana (Derwentia derwentiana)*
	Common parentucellia	**Parentucellia latifolia*
		**Parentucellia viscosa*
		**Veronica catenata*
Stackhousiaceae	Stackhousia	*Stackhousia aspericocca* (subsp.?)
	Creamy stackhousia	*Stackhousia monogyna*
Stylidiaceae	Beauglehole's trigger-plant	*Stylidium beaugleholei*
	Grass trigger plant	*Stylidium graminifolium*
	Hundreds and thousands	*Stylidium inundatum*
Urticaceae	Shade pellitory	*Paratieria debilis*
	Scrub nettle	*Urtica incisa*
Violaceae	Blue violet	*^Viola* sp. aff. *hederaceae (Viola eminens)*

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