Department for Environment and Heritage

Ecological Character Description



Coorong, Lakes Alexandrina and Albert Wetland of International Importance



Ecological character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance



Technical assistance provided by Rhonda Butcher and Jennifer Hale.

Advice also provided by an expert panel, representatives of the Ngarrindjeri community, long-term fishermen and their families plus others with specialist knowledge of the Coorong and Lakes.

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The project team consisted of the following people: Team leaders: Dr Bill Phillips (Mainstream Environmental Consulting Pty Ltd) and Dr Kerri Muller (Kerri Muller NRM). Dr Rhonda Butcher (Water's Edge Consulting) and Jennifer Hale assisted with technical input, especially in the early stages of data gathering and analysis, and the development of the consultation draft of the report. Derek Walker and Richard Young facilitated the consultations with the Ngarrindjeri community which were undertaken by Dr Muller.

Expert Panel and others who have contributed

For this project, an Expert Panel (see below) was established to provide direct inputs and review the draft of the report leading up to when it was circulated for peer review (see Figure 2 for details). Thereafter the project team took responsibility for finalising the report. The development of the report was also assisted by a number of people who kindly offered expert views on certain sections or assisted with accessing data and relevant information. These people are identified in the Acknowledgements (see below).

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■ Executive summary

In 1985, Australia designated the Coorong and Lakes Alexandrina and Albert as a Wetland of International Importance under what is now commonly referred to as the Ramsar Convention on Wetlands. This designation carried with it certain responsibilities; one of these being to manage the site in a way that would maintain its ecological character.

A description of ecological character is the cornerstone of management of a Ramsar site (see Figure 1). It underpins the development of a Ramsar Management Plan by providing information about the site's values and what is needed to maintain or improve those values. It helps the development of a monitoring and reporting framework, necessary to determine the ongoing health of the Ramsar site. Finally, it provides information against which development activities may be assessed under the Commonwealth Environment Protection and Biodiversity Conservation Act, 1999 (EPBC Act) and any relevant South Australian planning or impact assessment legislation or processes.

The Coorong and Lakes site meets eight of Ramsar's nominating criteria (see Section 3.5). It is renowned for providing habitat for many waterbird species, however, it also has many other values that are recognised by the Ramsar Convention. It has a unique mosaic of 23 wetland types, ranging from the freshwater lakes into the estuarine environments of the Coorong. It provides habitat for nationally threatened species such as the Orange Bellied Parrot, the Southern Mount Lofty Ranges Emu Wren, the Murray Hardyhead, the Yarra Pygmy Perch and the Murray Cod. The site also contains (in part) the critically endangered 'Swamps of the Fleurieu Peninsula', as well as the threatened *Gahnia* sedgeland ecosystem and a number of nationally listed plant species. In short, it is biodiversity 'hot spot' in southern Australia.

This report describes in detail the ecological character of the Ramsar site: the species, communities and habitats that are found there and the processes and system drivers, which make this place unique to Australia and the world. The report applies a systematic approach for describing ecological character; logically working through a description of the primary ecosystem drivers, levers, components and processes that work collectively to support the vast array of significant species and wetland types. For each of these, where the data will permit, limits of acceptable change (defined in Section 2.6) are recommended in order to guide future

monitoring and management actions. In addition, so-called 'traffic light' assessments are provided against each system attribute or parameter examined to reflect the overall risk, threat or vulnerability of each.

The Ngarrindjeri Indigenous community and three long-term local fishermen and their families also provided their views on the ecological values and assets of this site, and how these have changed with time. These are presented in Section 7 of the report and also interlaced throughout the document in key places where this more anecdotal (but no less significant) information helps to reinforce or further elaborate the scientific text. As can be seen in the report, these insights provide invaluable information and should be a standard part of future descriptions of ecological character at other sites.

Apart from documenting ecological character through Sections 3-8 of the report, a number of conclusions are drawn that are especially noteworthy, as follows: From a legal perspective, the Commonwealth EPBC Act may have no alternative other than to use the condition of a Ramsar site on the day it was designated (in this case 1 November 1985) as the benchmark condition for the purposes of applying its 'Ramsar trigger'. However, the conclusion drawn in the report (a view strongly supported by stakeholders) is that this site had been in ecological decline for at least 20-30 years prior to the Ramsar listing, and probably longer. By using 1985 as the benchmark condition, the ecological character description, and its associated limits of acceptable change, would be for an already degraded site. The authors were cognisant of these two differing perspectives and have endeavoured to set limits of acceptable change, which, assuming they are acted on, should arrest the incremental decline in the 'health' of this system, see it plateau and slowly turn around. How far along that pathway of recovery back to the condition it once was will be a decision taken by high-level decisions makers, as will be the rate at which that recovery takes place.

It is clear that the ecological character of this site has been altered significantly over the past 20–30 years ...

From the combined scientific assessment, reinforced by the Indigenous and long-term stakeholder oral histories and knowledge of the system (see above), it is clear that the ecological character of this site has been altered significantly especially over the past 20–30 years. This change would appear to have been accelerated and exacerbated by water extractions that are too high for the system to be able to sustain itself through the recent

drought conditions, as it would have under natural conditions. The drought didn't cause the change in ecological character, it simply brought it forward. This view is supported by an examination of the recommended limits of acceptable change and the 'traffic light' assessments provided in the report. The conclusion is that this ecosystem has as its primary determinants of ecological character; salinity, turbidity and sedimentation, water levels, keystone aquatic plants, habitat availability and flows. For these six primary determinants of ecological character, all are presently outside their recommended limits of acceptable change, and in many cases not by a small margin. This is a system that is under significant stress, and has been for some years.

As noted in the report, the 'traffic lights' are in some ways analogous with the dials and gauges in the cockpit of a 767 aircraft; they provide information on how well the vital functions of that highly sophisticated piece of technology are performing. For this complex wetland system they do the same. Red 'traffic lights' are those that would raise alarm for the pilot, as they should for the managers of this site and the State and Federal Governments. Of the 54 'traffic lights' assigned to key functions and attributes of this system by this project (see Table 26), nearly half are 'red' and one-third 'amber', a category where serious concerns are held. This report represents the first attempt to document a comprehensive understanding of ecological character for this site, and its unequivocal conclusion is that urgent management interventions are needed if the former condition is to be reinstated.

For these six primary determinants of ecological character, all are presently outside their recommended limits of acceptable change, and in many cases not by a small margin.

The changes to the ecological character of the site are proceeding faster in some parts of it than others. The Coorong lagoons, once a predominantly estuarine environment with some hyper-saline portions, particularly favoured by wading birds and with great diversity of fish species, are rapidly transforming into more and more turbid and saline systems. This is seeing the rapid loss of the keystone *Ruppia* plant species and with these, declines in much of the biota of the Coorong that justified Ramsar listing.

To summarise the situation, the Coorong ecosystem is becoming increasingly simplified as the loss of *Ruppia* continues; this being a consequence of escalating salinities, increasingly turbid waters and inappropriate water levels. All of these are essentially determined by River Murray flows into and through the system, and historically by flows from the south-east of South Australia. Algae and brine shrimp, more typical of a marine environment, have become dominant biota in the South Lagoon and parts of the North Lagoon since spring 2005. The loss of *Ruppia* and with it the small hardyhead fish, is signalling a significant change in how the Coorong functions and the habitats it has to offer.

It is estimated that the former estuarine Coorong ecosystem is now supported along only a 30 kilometre stretch from the Goolwa barrages to Pelican Point, this representing less than 25% of the original area. All of this indicates that a comprehensive shift in ecological character is underway. Without significant and urgent intervention it may prove irreversible. For this reason the authors are recommending that the Coorong lagoons and Murray Mouth be proposed for listing as a critically endangered ecological community under the EPBC Act.

The changes to the lakes environments are proceeding at a slower pace, but, like the Coorong, they are being negatively impacted upon by sediments and increasing salinity. Again, in simple terms, the lack of flows is seeing the whole system become a sink for salt and silt. This is a direct consequence of the reduced inflows from the River Murray that once provided regular freshening flows that also discharged salt and silt out the Murray Mouth. In terms of the flows needed for restoring the ecological character of the system, there are a number of primary requirements (see Section 6.6.2 especially) including, operating the barrages to ensure low or no flow periods are minimised and preferably that sufficient water is available to keep the Murray Mouth open without dredging, increased frequency of medium-sized or better floods, and the opportunity to have so-named here 'Ramsar site contingency allocation' water available to allow managers scope for strategic on-site water allocations to benefits the Ramsar significant species and ecological communities.

Keeping the Murray Mouth open at all times with barrage releases rather than dredging should be the first target to recovering the ecological character of this site (see Section 6.6.2 and 6.6.4). It is noted that a simplistic cost-benefit analysis, that examines financial considerations only, may indicate that retaining the

dredges is a preferred option over securing the water necessary to keep the mouth open with flows. However, if the value of the full suite of ecosystem and other benefits that would come from the flow option were factored in, then it should be the clearly preferred approach.

Operation of the fishways and reductions in duration and frequency of no-flow periods can be effectively achieved with water that is currently available at the site in most years. This can be done by improving river and barrage operations and utilisation of storages, such as Lake Victoria, to mimic higher flows or extend flow events.

This system formed in response to variability of flows (see several comments from stakeholders in Section 7). That variability has now been lost, in large part, and the once reasonably frequent medium to large floods that flushed and freshened the system are becoming less and less frequent through the combined impacts of upstream water diversions and climate. It will only be with the return of sufficient flows to the river, that medium-sized floods can be 'manufactured' by the river managers through the topping up of the more frequent small-floods.

It is also clear from historical accounts, and indicated by recent core sampling and diatom analysis (Gell and Haynes, 2005), that in the past the South Lagoon of the Coorong received significant natural flows from the South East region. These served to help freshen that end of the system, considering that it is 140 kilometres from the Murray Mouth. Advice from the Ngarrindjeri community is that flows from the south-east used to flow along a clear channel of faster moving water in the centre of the lagoons all the way from Salt Creek to the Murray Mouth and would provide flushing flows for the Coorong Lagoons. These flows are no longer provided. The construction of the Upper South East Drainage Scheme now regulates these flows and discharges only small volumes into the South Lagoon based on a ten year rolling average. Some Coorong stakeholders have expressed concerns about the impact this water may have on the ecology of the southern end of the system given that it is 'drainage' water and comes from an agriculture zone with significant dryland salinity issues. Any attempt to use this water to try to reduce the hypersalinity being experienced in the South Lagoon will need to ensure the water is of a suitable quality. These issues are being investigated by the Department of Water, Land and Biodiversity Conservation at present.

The conclusions are therefore that the Coorong portions of the Ramsar site are critically endangered and that there are strong signals that the Lakes will follow the same pathway without significant management intervention. It is the recommendation of the authors that, in accordance with Article 3.2 of the Ramsar Convention, these findings be communicated to the Secretariat of the Convention, and, that consideration be given to including the site onto Ramsar's Montreux Record of sites where change in ecological character is occurring, or has taken place.

The report makes a number of recommendations, as presented below from Section 8. It is the view of the authors that the findings of this report justify the following operational and administrative actions by the South Australian and Commonwealth governments:

Operationally:

- Pursue, as a matter of high priority, the measures needed to be able to meet the limits of acceptable change recommended by this report, and, in particular, those specified in relation to flows in Section 6.6.2, as summarised below:
 - a) sufficient water to keep the Murray Mouth open without dredging
 - b) increased frequency of medium-sized or better floods to flush and 'freshen' the system
 - c) reduced duration and frequency of no-flow periods which are extremely detrimental to the system
 - d) sufficient water to optimally operate the fishways and provide habitat connectivity between fresh, estuarine and saline units
 - e) the opportunity to have so-named here 'Ramsar site contingency allocation' water available to allow managers scope for strategic on-site water allocations to benefits the Ramsar Significant Biological Components.
- Ensure that barrage operations in the critical period until additional flows can be provided are directed at ensuring no further reduction in the area of the remnant 25% of the former estuarine habitat now found only from the Goolwa Barrage to Pelican Point.
- Accelerate the examination of the feasibility and ecological merits of using water from the Upper South East Drainage Scheme to reduce the very high salinities of the South Lagoon in the short term.

Administratively:

- 4. In accordance with Article 3.2 of the Ramsar Convention, the findings of this study be communicated to the Secretariat of the Convention, and, that consideration be given to including the site on Ramsar's Montreux Record of sites where change in ecological character is occurring, or has taken place.
- The Coorong lagoons and Murray Mouth portion of the site be nominated immediately for listing under the EPBC Act as a critically endangered ecological community.
- 6. The Commonwealth Government allocate significant new resources under its \$36 million National Biodiversity 'hot spots' initiative to see a range of the highest priority remedial actions directed at restoring. ecological character undertaken immediately.
- 7. The South Australian Government, with the Murray-Darling Basin Commission and the Commonwealth Government, undertake a full inventory of relevant data holdings (including those held by researchers), with a view to building an integrated and comprehensive data 'warehouse' for the Coorong and Lakes.
- 8. The South Australian Government, with the Murray-Darling Basin Commission and the Commonwealth Government, agree to merge the planning and implementation processes for the Asset Environmental Plan and the Coorong and Lakes Ramsar Management Plan.
- 9. Publish this report as loose leaf folder, signaling the intent to see it continuously improved as new information comes to light.

Ecological character description: introduction



A sound understanding of ecological character should form the benchmark for management planning and action.

Introduction

The Coorong and Lakes Alexandrina and Albert were designated as a 'Wetland of International Importance' under the Ramsar Convention on Wetlands on 1 November 1985. As a Contracting Party to the Ramsar Convention, Australia has accepted a range of obligations in relation to the management of those sites that it designates as Wetlands of International Importance, or Ramsar sites as they are commonly known. These obligations are set down in Articles 3.1 and 3.2 of the text of the Convention as given below.

Article 3.1

'The Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory.'

Article 3.2

'Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological development, pollution or other human interference. Information on such changes shall be passed without delay to the organization or government responsible for the continuing bureau duties specified in Article 8.'

Since the adoption of the above texts, Conferences of the Contracting Parties to the Ramsar Convention, and most notably the 5th Conference in Kushiro, Japan in 1993, (through Resolutions 5.1 and 5.7) have seen fit to interpret these obligations as being an undertaking on the part of the signatory governments to manage their Ramsar sites so as to retain the 'ecological character'. This management undertaking is considered synonymous with the term to '... promote the conservation of the wetlands included in the List ...'(Article 3.1).

Understanding and describing the ecological character of a Ramsar site is therefore a fundamental management tool for signatory governments and the local site managers. A sound understanding of the ecological character of a site should form the baseline or benchmark for management planning and action; including site monitoring to detect negative impacts (see Figure 1).

For its part, the Ramsar Convention has moved to define 'ecological character' and 'change in ecological character', and to provide frameworks and guidelines for management planning, establishing monitoring programs

and undertaking risk assessments. However, definitive guidance on how to describe ecological character has not been forthcoming from the Convention to date despite recognition that it is needed.

Ramsar's definitions (Ramsar Resolution IX.1, Annex A, November 2005):

'Ecological character is the combination of the ecosystem components, processes and benefits*/services that characterize the wetland at a given point in time.'

And

- '... change in ecological character is the humaninduced adverse alteration of any ecosystem component, process, and/or ecosystem benefit*/service.'
- * Within this context, ecosystem benefits are defined in accordance with the Millennium Ecosystem Assessment's definition of ecosystem services as the benefits that people receive from ecosystems.

Domestically, the Australian Government has introduced legislation, the *Environment Protection and Biodiversity Conservation Act*, 1999 (the EPBC Act) that provides a legal framework for seeing that the ecological character of all Australian Ramsar sites is retained. The EPBC Act establishes a Commonwealth process for the referral, and possible assessment, of proposed actions that may have a significant detrimental impact on 'matters of national environmental significance', which includes Ramsar sites (see Figure 1).

The EPBC Act also requires that the Commonwealth '... use its best endeavours to ensure a plan for managing the wetland in a way that is not inconsistent with Australia's obligations under the Ramsar Convention or the Australian Ramsar Management Principles is prepared and implemented in cooperation with the State and Territory.' (Section 3.3.3, of the Act, as provided in Appendix A).

Taken together, Australia has obligations under the Ramsar Convention with respect to how designated Wetlands of International Importance are managed. In order to meet these obligations the ecological character of each site needs to be carefully described, and then used to guide management action and ongoing monitoring. Such descriptions of ecological character are also fundamental to the effective implementation of the Commonwealth's EPBC Act, which is designed to ensure Australia is not contravening its site management obligations under the Ramsar Convention.

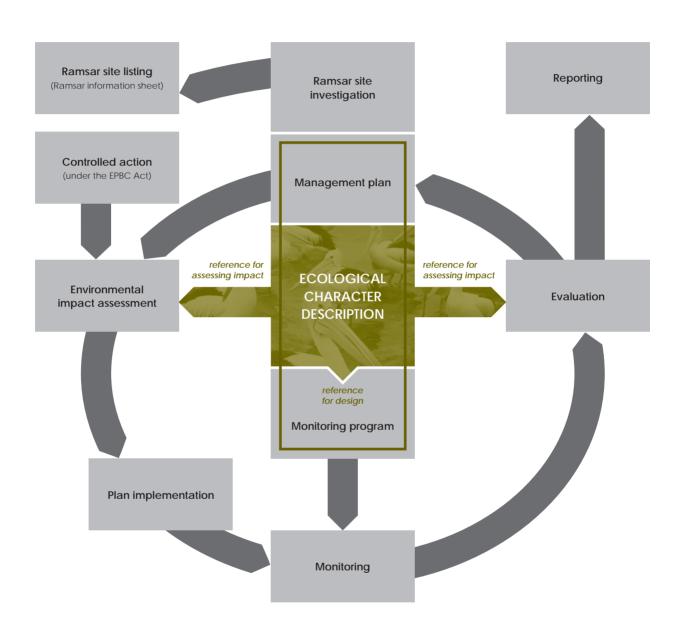


Figure 1 - The ecological character description in the context of other requirements for the management of Ramsar sites (DSE, 2005)

■ 1.1 Where this report fits within planning and management frameworks

As indicated above, the Coorong and Lakes Alexandrina and Albert were designated as a Ramsar site on 1 November 1985 (see Figure 2). A plan of management for the site was prepared and put in place in September 2000. While this plan gave some insights into the ecological assets of the Ramsar area, it did not provide a detailed description of ecological character.

This project, the Coorong and Lakes Alexandrina and Albert Ramsar site ecological character project, is a major component of the Ramsar Plan Review Process which commenced in July 2004. A revised Ramsar Management Plan will be prepared following the preparation of this description of ecological character. The review of the Ramsar plan is timely given the multitude of other programs and initiatives occurring such as the Living Murray Initiative, review of the Coorong National Park Plan, CSIRO's Water for a Healthy Country Initiative, State Natural Resource Management legislation and institutional changes. This description of the ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar site (hereafter abbreviated to the 'Coorong and Lakes') will be invaluable in informing these programs and initiatives.

975 Ramsar Convention on Wetlands enters into force for Australia

Amongst other obligations, Australia agrees to:

- nominate suitable wetlands to the List of Wetlands of International Importance
- to maintain the ecological character of these sites, and monitor their collection

1985 Australia designates the Coorong and Lakes Alexandrina and Albert

Australia designates the Coorong and Lakes Alexandrina and Albert as a Wetland of International Importance under the Ramsar Convention.

Australia's obligation is to maintain the ecological character of the Ramsar site.

Commonwealth Environment Protection and Biodiversity Conservation Act 1999 enacted

This Act enshrines in Commonwealth law the requirements to:

- maintain the ecological character of Ramsar sites endeavour to prepare a management plan for a Ramsar site
- based on the Australian Ramsar Management Principles.

2000 Ramsar Management Plan for the Coorong and Lakes Alexandrina and Albert Ramsar site adopted

2003 South Australia adopted Wetlands Strategy

2004 Ramsar Plan Review Process initiated

Department for Environment and Heritage (DEH) commences review of current plan.

2005 Prepare description of the ecological character of the Coorong and Lakes Alexandrina and Albert site

This is the first step in the review of the Ramsar Management Plan.

Draft Report prepared and released for peer review by more than 100 expert and stakeholder organisations and individuals. Two consultation workshops held in December 2005 (Adelaide and Goolwa), plus a briefing for the Commonwealth Department for the Environment and Heritage in January 2006 (Canberra).

Report finalised in March 2006. The report forms the basis for the review of the current Ramsar Management Plan.

Figure 2 - Where this report fits within planning and management frameworks

Methods and key concepts applied



A robust description of ecological character is made by applying strong science based on sound data and information. Alongside the scientific details, valuable oral histories of the Ngarrindjeri Indigenous community and long-term stakeholders were considered as part of this comprehensive ecological character description.

■ 2.1 Overview

Wetlands are by their very nature both productive and dynamic systems, and these two attributes have implications for describing ecological character. Firstly, because of their productivity and the services they offer, wetlands have become focal points for human activities around the world—the Coorong and Lakes are no exception.

A direct implication of the close human association with this wetland system is a keen interest in the findings of this project within the local community and in South Australia, in particular. For this reason it was possible to gain some insights into the historic condition of the site from those longer-term stakeholders who have lived and worked around this wetland for generations. These insights, based on first-hand observations, can yield invaluable oral histories for the site which scientific data collection may not be able to provide. Section 2.4 details how this information was collected and is used throughout the report.

Secondly, because of their dynamic nature, defining the ecological character of wetland systems requires careful consideration to distinguish natural variability from human-induced impacts. Sometimes human-induced factors may have short-term, immediate impacts as well as longer-term, more subtle changes that incrementally increase over time. One of the aims of describing ecological character is to document the baseline condition '...that establishes the range of natural variation in components, processes and services at each site within a given time frame, against which change can be assessed.' (Ramsar Resolution IX.1, Annex A, paragraph 18). 'Change in ecological character occurs when these parameters fall outside their normal range.' (Res VI.1, Annex). This is considered further in Section 2.6.

Combined with the above two issues is the need to make the description of ecological character robust by applying strong science based on sound data and information. Where this is lacking, then a precautionary approach is required, so that the risk of ecological character changing is minimised.

2.2 Boundaries of the Ramsar-listed area

The area of the Ramsar-listed site is as shown in Figure 3. Summarised, the Coorong and Lakes Wetland of International Importance is approximately 140 500 hectares. Land and water included in the site is as follows:

Lake Alexandrina and Albert and the tributaries of the Finniss River and Currency Creek:

- all unallotted Crown Land and Crown Land occupied under licence that is connected to the lakes
- wetlands on freehold and perpetual lease land, where the wetland is seasonally connected to the lake
- all land and wetland on Hindmarsh, Mundoo, Mud, Reedy, Ewe and Long Islands and the many other small islands in the lakes
- Tolderol Game Reserve, Mud Islands Game Reserve and Currency Creek Game Reserve and Salt Lagoon Islands Conservation Park.

the Coorong:

 all land and water within the Coorong National Park, which includes the Younghusband Peninsula and the Ocean Beach to low water mark, but does not include Sir Richard Peninsula

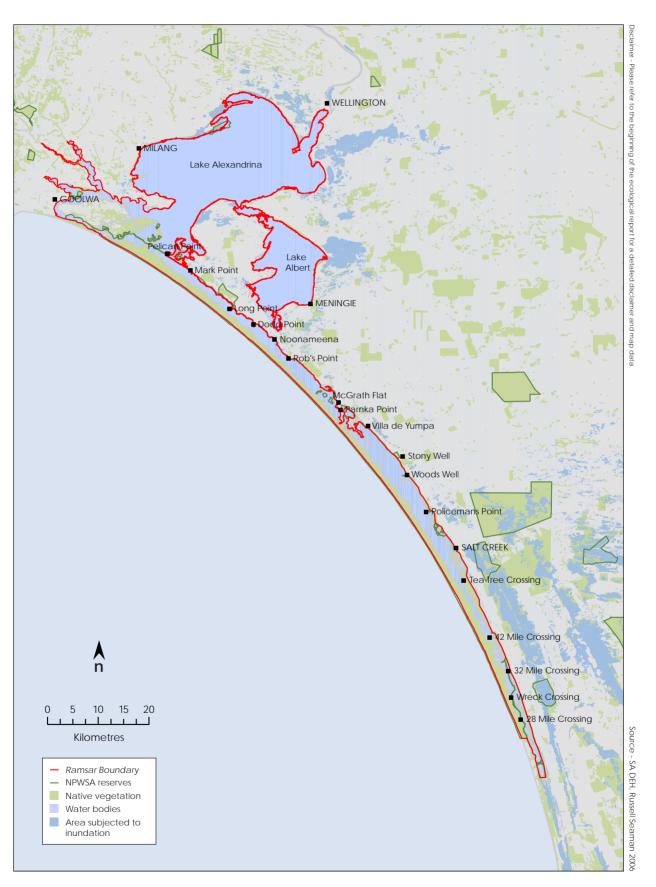


Figure 3 - Map showing the boundaries of the Coorong and Lakes Alexandrina and Albert Ramsar site and other key landmarks

2.3 Defining 'at a given point in time' for this site

The Ramsar Convention's definition of ecological character (see Section 1) was revised only recently on the occasion of the 9th Conference of Contracting Parties (CoP) in Uganda in November 2005. The revised definition states that ecological character is defined for '... a given point in time', or, in other words, is a 'snapshot' of the sites' condition. At Ramsar's 6th CoP in 1996, the Parties adopted Resolution VI.1 which stated that 'It is essential that the ecological character of a site be described by the Contracting Party concerned at the time of designation for the Ramsar List, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).' [added by Ramsar]. This view is echoed in the 2005 publication by the Victorian Department of Sustainability and Environment 'Framework for Describing the Ecological Character of Ramsar Wetlands', when it states that it is '..important to describe the ecological character at the time of listing, as this is the appropriate time for setting the baseline.' (DSE, 2005).

There are two key considerations here.

Firstly, at Ramsar 6th CoP in 1996 the Scientific and Technical Review Panel of the Convention reported that the Information Sheet on Ramsar Wetlands (RIS) was not a sufficiently robust description of ecological character, and, while some modifications were made to the format of the RIS at that time, there is a continuing view that more detailed descriptions are required to set truly robust baselines or benchmarks of ecological character.

The view put was that by using 1985 as the benchmark date this was accepting a condition for the site that was already seriously degraded.

Secondly, the suggestion that the time of Ramsar designation is the 'given point in time' for describing ecological character, while seemingly logical, also needs to be approached cautiously. For sites that are 'healthy' and not requiring or undergoing rehabilitation, the description of ecological character at the time of listing appears appropriate. However, where a site is requiring or undergoing rehabilitation, then some flexibility may be needed. For example, when it was Ramsar-listed in October 2002, the Banrock Station wetland system on the River Murray in South Australia was continuing to undergo rehabilitation commenced several years earlier.

This will see the ecological character of the site improve over the coming years. Likewise, the Kakadu National Park Ramsar site was listed in stages, but throughout that period was addressing issues such as saltwater intrusions onto the freshwater *Melaleuca* floodplains caused by water buffalo and Mimosa weed infestations. For these two sites, a description of ecological character provides a benchmark for that point in time, but one that will need to be updated to 'raise the bar' as rehabilitation works have a positive impact on the wetland.

For the situation where a site warrants rehabilitative actions at the time of listing, but these have not been recognised or activated, the danger is that the description of ecological character may accidentally or inadvertently set the 'bar' too low, and not encourage the managers to seek to make significant positive changes to the ecological character.

For this description of the ecological character of the Coorong and Lakes Ramsar site, the issue of needing to establish a 'given point in time' emerged quite strongly through the consultations with the local stakeholders (see Section 2.3). Their perspective, as expressed in writing and verbally at the consultative workshops, is that it is not appropriate to use November 1985 (the date the Coorong and Lakes were designated as a Ramsar wetland) as the 'given point in time' for this description of ecological character, since the system had been in decline for many years prior to that date. The view put was that by using 1985 as the benchmark date this was accepting a condition for the site that was already seriously degraded.

The Ramsar Convention has given some consideration to this issue, although only in regard to positive not adverse impacts. For example, in the Annex to Resolution VI.1 from the 6th CoP, it states as follows: 'in some instances a Contracting Party may decide to restore a wetland to re-establish the ecological character that existed prior to the date of designation. In the case of such restoration programmes, a new Ramsar Information Sheet should be provided, to establish a new baseline for assessing any future change. Information should also be given concerning the target state that any restoration is aiming at.' (Paragraph 2.8).

Further, Ramsar's 8th CoP, through Resolution VIII.8 indicates the following of note [added by the authors of this report]:

20. Calls upon Contracting Parties to maintain or restore the ecological character of their Ramsar sites, including utilizing all appropriate mechanisms to address and resolve as soon as practicable the matters for which a site may have been the subject of a report pursuant to Article 3.2; and, once those matters have been resolved, to submit a further report, so that both positive influences at sites and changes in ecological character may be fully reflected in reporting under Article 3.2 and in the reporting to all meetings of the COP in order to establish a clear picture of the status and trends of the Ramsar site network at three-year intervals.

It is apparent therefore that in describing ecological character of Ramsar wetlands there is a need for Parties to consider the condition of the site at the time of listing, to assess whether or not that is the desired condition, and, if not, to indicate what that desired condition is by way of target setting. It should not necessarily be assumed that the day of Ramsar designation is the 'given point in time' for such descriptions. This is a point explored later in Section 8.

■ 2.4 Cultural and community knowledge

As part of documenting the ecological character of the Coorong and Lakes Ramsar site, the project team invited, and assisted members of the Ngarrindjeri Indigenous community to provide their views on the ecological and other values of the system, many of which form part of their long-term cultural connection to the land and waters of the region. These views are provided as Section 7.1 of this report, and, where they serve to inform or reinforce elements of the description, extracts have been included in other sections also.

In addition, the views of several long-term fishermen and their families were sought, in order to add further perspectives on the ecological and other assets of the Ramsar site. These views are provided in Section 7.2, and, where appropriate, highlighted throughout this report. While some may view these perspectives as anecdotal and lacking in scientific robustness, the authors believe they are high quality 'data' in trying to document the ecological character of this site as they are based on observations by people working and living in close proximity to the wetland ecosystem over many decades, and for the Ngarrindjeri community, over centuries. Care was taken to record the raw observations of

change in the system where possible, as well as the person's interpretation or perception of the fundamental causes of that change, to allow independent evaluation.

These longer-term views on the condition of the wetland, and how it has changed, are also vital information in trying to describe ecological character, and what the site managers may aspire to through their future actions (see Section 2.3).

■ 2.5 Applying a systematic scientific approach

Allied to the consultations with traditional owners and long-term stakeholders outlined above, the project also adopted a systematic scientific approach to describing ecological character. In early 2005, a trial method for describing ecological character was documented by Victoria's Department of Sustainability and Environment (DSE) and pilot-tested on the Barmah Forest Ramsar site (DSE, 2005). The DSE framework for describing ecological character uses the so-called 'ecosystem services' of the site as the entry point for a structured approach to setting 'condition' benchmarks for a wetland. While the DSE approach was trialled by this project it was found to have limited utility for a site as large and complex as the Coorong and Lakes and an alternative approach, adapted from that used recently by three of the authors of this report (Phillips, Butcher and Hale) for Lake MacLeod in Western Australia, was applied instead.

Table 1 - Step-wise scientific approach
used for this description of ecological character

Step-wise scientific approach used	Where found in this report
Step 1 Provide an overview of the site; its location, climate, hydrology etc. and identify the drivers, levers, components and processes that combine to form ecological character. Include in this a summary of the Ramsar Significant Biological Components of the site; its plant and animal species and the ecological communities and assemblages which provide the biological justification for why the area is considered globally important.	Section 3
Step 2 Document the drivers, levers, components and processes within each of the six system units, noting that because of the size of this wetland system it was necessary to sub-divide it in order to gain sufficient focus on these aftributes within logical management units. Provide, where possible, limits of acceptable change (see Section 2.6) and 'traffic light' assessments (see Section 2.7). Cross-check these conclusions against Ngarrindjeri and long-term stakeholder views (see Sections 2.4 and 7).	Section 4
Step 3 Document the Ramsar Significant Biological Components (RSBC) of the site placing them within the context of drivers, levers, components and processes. Provide, where possible, limits of acceptable change and 'traffic light' assessments (see Sections 2.6 an 2.7). Cross-check these conclusions against long-term stakeholder views (see Sections 2.4).	Section 5
Step 4 Based on the conclusions from Steps 2 and 3 establish those drivers, levers, components or processes that are the primary determinants of ecological character. Document, and where possible quantify these. Set limits of acceptable change and provide 'traffic light' assessments.	Section 6
Step 5 Using the outputs from Steps 2, 3 and 4, produce a whole of system description of ecological character.	Section 8
Step 6 Describe an ideal monitoring framework to give early warning of any potential change in ecological character, prioritising this to assist site managers with directing resource allocations.	Section 9
Step 7 Identify priority knowledge gaps for future attention. These will, in most part, be identified through the preceding steps.	Sections 3-6 and 8

■ 2.6 Limits of acceptable change

In Section 2.1 it was noted that the Ramsar Convention has previously observed that change in ecological character occurs when the key parameters of the wetland ecosystem fall outside their normal range (Ramsar CoP 6, Res VI.1, Annex), Steps 2, 3 and 4 in Table 1, indicate that the approach applied here defines '... baseline conditions and limits of acceptable change ... ' and provides an overview of the system condition in relation to each particular parameter through a 'traffic light' system. Because these terms are used extensively throughout this report, some further consideration here is warranted.

As it is used in this report, limit of acceptable change (LAC) indicates the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of a certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the sites was Ramsar-listed (see Figure 4). In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was Ramsar-listed. For example —if monitoring shows that for a certain species the population within the Ramsar site has fallen to below its lower 'limit of acceptable change' then this would require careful examination to establish the cause, and to respond to it through intensive investigation and possibly adaptive management.

In order to set robust limits of acceptable change (LAC), there should be an understanding of the natural variability of the parameters or populations under consideration and the system drivers, levers, components and processes (see Section 2.6 for definitions of these terms). For parameters such as those relating to water quality it can be helpful to know the ideal range of these, either from research work, or other similar sites; this is especially the case if there is little historical data upon which to base LAC. For example, if a particular submerged aquatic plant species is known to be a vital part of the wetland ecosystem (i.e. a keystone species, see Section 6), then it is possible to set an LAC for water clarity that indicates a range of turbidities that will continue to permit light penetration to the depths normally occupied by that species and considered optimal for sustaining a healthy population.

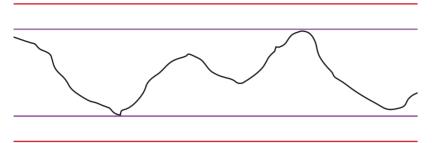


Figure 4 - The limits of acceptable change concept

Limits of acceptable change Limits of natural variability Variations in population, area or some recorded parameter (pH, salinity etc.)

If a recorded parameter moves outside limit, then this should warrant investigation by the site managers, and possible management intervention.

The guidance given regarding limits of acceptable change for the Coorong and Lakes Ramsar site is provided whilst acknowledging that for some measures and parameters the long-term data sets are less than ideal. One of the follow up actions to this report will hopefully be to establish a comprehensive assessment program to avoid this problem in the future (see Section 9). Where the authors believed there was insufficient data to support an LAC, then this is indicated. Where an LAC is based on data collected for this site, the only qualification given is whether they are considered 'interim' or not. Interim LAC are where the authors believe further data is needed and that until that time a more conservative, precautionary LAC should be used.

■ 2.7 'Traffic light' assessments

The 'traffic light' assessments provided in this report are designed to give a quick snapshot of the overall risk, threat or vulnerability profile of the wetland attribute under consideration as part of the ecological character description. Figure 5 provides an overview of how the categories are determined. The system has been introduced here as an aid for high-level decision makers, site managers and other stakeholders so they can, at a glance, gain a clear sense of system health. It is also envisaged that this approach may be useful to adopt as part of regular monitoring of the Ramsar wetland.

The 'traffic light' assessments are used to reflect the overall risk, threat or vulnerability of the various system attributes (drivers, levers, components or processes—see the following section), as determined by the authors based on the collective information gathered together in this report, and particular with the individual sections where 'traffic light' assessments are provided.

- The threatening process or processes have had a significant detrimental impact warranting urgent management intervention.
- There are strong indications that a threatening process or processes are operating. Investigations should be given high priority and management intervention is likely.
- There are some concerns evident that warrant investigation and perhaps management intervention.
- All known risks or threats are being adequately addressed through management actions.

Figure 5 - The 'traffic light' assessment categories

■ 2.8 Defining other terms used

Terms and concepts used throughout this report are defined in Table 2, showing how they are used in the Ramsar definition and also throughout this report.

Table 2 - Defining key terms used in this report		
Term	Ramsar's interpretation	How used in this report
Components	The physical, chemical and biological components of the system, with the latter being defined as habitats, species and genes.	As defined by the Ramsar Convention.
Processes	Interactions between the components that in turn supply the benefits/services.	As used in this report, ecological processes are the dynamic biotic and abiotic interactions within an ecosystem such as primary production, decomposition, carbon and nutrient cycling, sedimentation and provision of habitats for other biota. These may or may not provide direct benefits or services to humans.
Benefits/services	The footnote to the Ramsar definition of ecological character (see Section 1) indicates that: ' ecosystem benefits are defined in accordance with the Millennium Ecosystem Assessment's definition of ecosystem services as 'the benefits that people receive from ecosystems'. Appendix B provides a summary of these for this site.	Where used in this report, the definition of benefits and services aligns with that of the Ramsar Convention.
Drivers and levers	The term drivers is used by the Ramsar Convention to refer to either indirect (economics, science, cultural, religious) or direct (landuses, invasive species, water abstraction) drivers of change within the wetland. This is derived from the Millennium Ecosystem Assessment and focuses on predominantly anthropogenic activities which lead to change in the wetland ecosystem. The Ramsar Convention does not use the term levers.	In this report, the term drivers is used in the way defined by Mitsch and Gooselink (2000), and shown in Figure 7 (Section 3); namely, geomorphology, climate and natural hydrology. The difference being that the focus is on natural, not anthropogenic factors. The term lever is used here to refer to factors that are of anthropogenic origin that alter ecosystem components and/or processes. These may be the result of catchment-based activities (such as discharges to water from land-based activities) or direct manipulation at the site (such as barrage operations).



The Murray Mouth and the estuarine portion of the Coorong

■ 2.9 Consultative approaches used in the development of this report

The development of this report was undertaken by the project team, in consultation with the expert panel (for membership, see inside cover). In addition, as the scope of the Ramsar Significant Biological Components and other factors of note become clearer, other experts in particular fields were invited to review certain parts of the draft or provide data and other inputs. These additional experts are indicated in the acknowledgments. Running in parallel with this process, consultations were underway with the Ngarrindjeri community and other long-term stakeholders (see Section 2.4).

The draft report was finalised in October 2005 and distributed to nearly 120 individuals and organisations which had knowledge or expertise in the ecology and management of the system.

In December 2005, two consultative workshops were held; one in Adelaide and the other in Goolwa. A briefing was provided to representatives of the Commonwealth Department for the Environment and Heritage in January 2006 in Canberra. Verbal comments noted at the workshops and briefing, plus approximately 15 written submissions were then used to help guide the finalisation of the report by the project team authors.

Overview of the Coorong and Lakes ecosystem



The types of wetlands at this Ramsar site have been divided into freshwater and estuarine-saline units. For each of these six units, photographs, maps showing the distribution of wetland types and detailed tabulated information is provided. This assists in the accurate determination of ecological character.



Goolwa Barrage

Overview of the Coorong and Lakes Ecosystem

The Coorong and Lakes Ramsar site is situated at the terminus of the Murray-Darling Basin, Surface water inflows are predominantly from the River Murray into the north of Lake Alexandrina near Wellington, with other inflows from the tributary streams draining the Eastern Mount Lofty Ranges (EMLR) along the south-western edge of Lake Alexandrina (see Figure 6). Rainfall on the lake surfaces and groundwater discharge are also significant inputs.

Lake Albert lies to the south east of Lake Alexandrina connected via a narrow channel (Narrung Narrows) near Point Malcolm. Lake Alexandrina is the primary source of inflows to Lake Albert, with supplementation from local rainfall and groundwater discharge. As Lake Albert has no through-flow connection to the Coorong, it represents a local, inland terminus of the River Murray system.

The fresh waters of the River Murray and Lake Alexandrina are separated by a series of five barrages from the more saline water of the Murray Mouth Estuary and Coorong lagoons. In recent years, inflows from the South East of South Australia into the Coorong's South Lagoon have been re-established, although under regulated conditions. This is via the Upper South East Drainage Scheme.

The Murray Mouth is the only site where silt and salt can exit the Murray-Darling Basin and through-flow is now dependent on co-ordinated barrage releases and dredging to maintain an open Murray Mouth to the Southern Ocean.

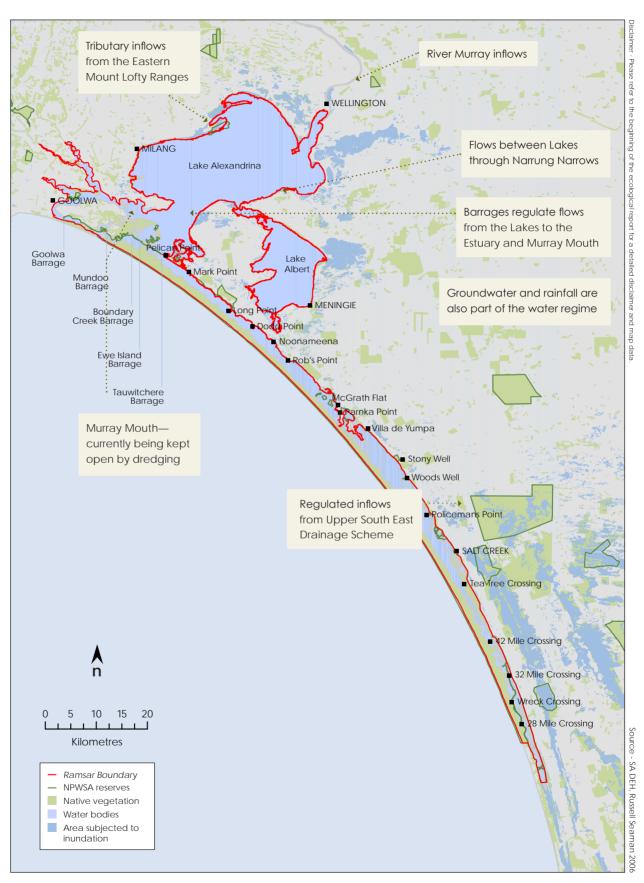


Figure 6 - Overview of primary water sources and flow pathways for the Coorong and Lakes Ramsar site

■ 3.1 Ecosystem drivers, levers, components and processes

Wetland ecosystems are dynamic in space and time, with the given components and processes being primarily determined by the presence or absence of water. There are a number of fundamental or universal drivers that determine how wet or extensive a wetland will be. The naturally-occurring drivers such as climate, geomorphology and hydrology, although they may operate and interact in different ways at different sites, provide a sound basis for beginning to document the foundations of a wetland system.

Drivers that are anthropogenic in nature, such as river regulation, water extraction or barrage operation, are referred to as 'levers' for the purposes of this report (see Table 2). The drivers and levers operate together to determine what types of ecosystem components (e.g. species), processes (e.g. sedimentation) and services (e.g. provision of irrigation water) occur at a given site and therefore determine ecological character.

For the Coorong and Lakes Ramsar site, the fundamental system drivers, levers, components and processes, as shown in Figure 7 are:

Drivers (natural)

- · climate (including rainfall, winds, tides and solar
- · geomorphology (including macro- and microtopography, erosion and depositional patterns)
- hydrology (natural flow patterns, run-off, groundwater flows etc.).

Levers (anthropogenic)

- River Murray flow regulation (via storages, locks and weirs)
- · water extraction (from the River Murray, Eastern Mount Lofty Ranges tributaries and groundwater resources)
- Regulated inflows from the Upper South East Drainage Scheme into the Coorong
- operation of the barrages (to release water from Lake Alexandrina)
- · operation of the dredges (to remove sand and keep the Murray Mouth open)
- discharges to land, water and air, especially from riparian land use (including nutrients, agrochemicals and salt).

Primary ecosystem components and processes:

- physico-chemical environment (including salinity, turbidity and sedimentation)
- biota, particularly keystone aquatic plant species, other plant and animal species and assemblages (taxa and ecological communities)
- habitat availability (including type, accessibility, temporal and spatial connectivity, condition and variety of habitats).

The drivers and levers interact to determine what ecosystem components and processes will occur as described by the colour-coded, directional arrows in Figure 7 on the facing page. The components and processes in turn interact to determine what ecosystem services will be provided by the wetland (also indicated by arrows). It should be noted that:

- a) influence is generally considered hierarchical from left to right in Figure 7
- b) some drivers (such as climate) influence levers such as water extraction while some levers (such as dredging) influence drivers such as geomorphology
- c) that the influence may be positive or negative in terms of maintaining ecological character.

Ecosystem benefits and services are essentially the outputs of the ecological components and processes. These have been documented for this site and can be found at Appendix B. Together, ecosystem components, processes and services are the ecological character of a Ramsar wetland.

It is within this framework that the description of ecological character has been developed. A summary of these drivers, levers and ecological character descriptors follows and leads into more detailed discussion in the following Sections. The ecosystem services of the Coorong and Lakes Ramsar site are given in Appendix B.

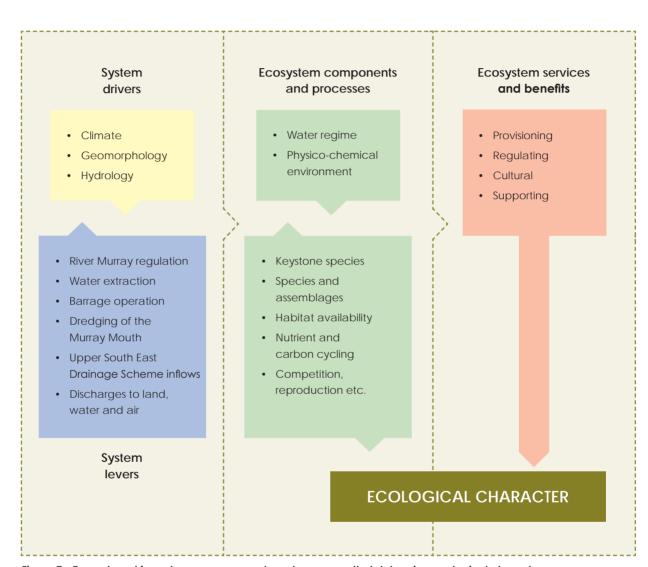


Figure 7 - Ecosystem drivers, levers, components and processes that determine ecological character

■ 3.2 System drivers

3.2.1 Climate—wind, tides, local rainfall, temperature, solar radiation

Climate is universal in its influence acting on the ecological (physical, chemical and biological) components and processes of a wetland. The location of the Coorong and Lakes Ramsar site at the terminus of the Murray-Darling Basin and abutting the Southern Ocean exposes it to the impacts of many climatic perturbations across the catchment as well as extremely strong winds and tidal action at a local scale. Wind impacts on the Coorong and Lakes water regime by causing water to 'slosh' backwards and forwards within the lagoons and lakes and by inducing waves across the long 'fetch' of these waterbodies. Such action causes erosion of the lakeshore, major changes to the water regime experienced at a habitat scale (e.g. daily water level changes of approximately 30 centimetres) and can cause water to overtop structures like the barrages or dry out inland areas such as the mouth of Currency Creek.

Tidal fluxes also impact on ecological components and processes by determining the extent of exposed mudflats and sand flats in the Murray Mouth Estuary and influencing the physico-chemical environment of the North Lagoon. The tidal pulse does not penetrate further south than Pelican Point but the environment of the South Lagoon can be indirectly influenced by tide and windinduced head differences driving flow from the North to the South Lagoons.

3.2.2 Geomorphology—slope, deposition and erosion

Geomorophology is the 'form or shape' that a river, wetland or other topographical feature of a catchment takes on as a combination of gravity, geology and climate. It is also universal in that it provides the physical features of a catchment that allow water to flow downhill along channels or be stored in basins both above and below ground. It also operates at a smaller, habitat scale in terms of micro-topographical changes to water regime, inducing chemical processes and creating erosional and depositional patterns that in turn dictate habitat patterns

3.2.3 Hydrology—natural flow patterns, run-off, groundwater flows etc.

The natural hydrology of a wetland constrains and controls the physico-chemical environment and the biological processes and components that occur in a wetland. To quote Mitsch and Gooselink (2000), 'Climate and geomorphology define the degree to which wetlands can exist, but the starting point is the hydrology, which, in turn affects the physicochemical environment, including the soils, which in turn, determines with the hydrology what and how much biota, including vegetation, is found in the wetland."

■ 3.3 Levers operating in the system

3.3.1 River Murray flow regulation locks and weirs

The flow of the River Murray has been regulated by the construction of locks and weirs from Blanchetown in South Australia to the Hume Dam in NSW. These numerous structures were originally built to provide year-round passage for river traffic but are now operated to maintain water levels in each weir pool for town, domestic and irrigation supplies along the River Murray and to mitigate flood peaks. This regulation means that the water levels in each weir pool are very static and the floods and flows to the downstream sections of river and the floodplain have been mitigated to be less frequent, less extensive, less variable and of altered duration and seasonality. In addition, the static weir pools have reduced flooddependent processes such as fish spawning and altered groundwater processes by creating freshwater lenses near weirs and locks and altering drainage of saline groundwater in other areas.

3.3.2 Water extraction—from the River Murray, EMLR and groundwater resources

The removal of water from surface (via dams, pumps and channels) and under ground (via bores) resources occurs across all parts of the Murray-Darling Basin such that only 27% of the median natural flow still discharges to sea. Water extraction has a direct impact on many aspects of water regime at the point of extraction (e.g. pumping from the EMLR tributaries) and an indirect impact on water regime for ecosystems hydrologically-connected to, but topographically separated from, the resource being utilised (e.g. regional groundwater use impacts on salinas).



Dredge

3.3.3 Barrage operation—flows regulated by 593 gates situated in five barrages

The five barrages, that separate the fresh water of Lake Alexandrina from the more saline waters of the Coorong and Murray Mouth Estuary were built between 1935 and the mid-1940s. The barrages sit at approximately 0.83 m AHD (i.e. 83 cm above sea level) and contain 593 independently operable gates in total. The barrages have been traditionally operated with a 'fill and spill' philosophy resulting in relatively static water levels with target maximum fill of 0.75 m AHD (for managing barrage structural integrity) and a minimum of 0.45 m AHD (for maintaining irrigation supply).

Given the highly managed nature of the River Murray and Lakes system, controlled barrage releases (rather than unmitigated floods) tend to be the major flow events that reset the estuarine salinity gradient and clear the Murray Mouth. Releases of Lake Alexandrina water are also the major source of sediment, nutrients, agrochemicals and organic matter to these receiving environments. Thus barrage operation is the primary lever controlling the physico-chemical environment of the Murray Mouth Estuary and Coorong lagoons.

3.3.4 Dredging of the Murray Mouth since October 2001

The Murray Mouth is situated along a very energetic coastline. Under natural conditions, River Murray flows kept the Murray Mouth open at all times but river regulation and water extraction have combined to reduce river flows to a point where they can no longer perform this function. The closure of the Murray Mouth in 1981 was the first time the mouth had closed since formation (approximately 7000 years ago). The mouth nearly closed again in 2001 following a period of no barrage releases for more than 630 days. Since October 2001, dredges have been operating in the Murray Mouth to keep it clear of sand deposited from the supersaturated sea water that enters the mouth, maintain tidal signal and hydrological connectivity between the Coorong lagoons and the Southern Ocean.

If the Murray Mouth is blocked or severely restricted, the tidal signal in the Murray Mouth and North Lagoon is depressed, the hydrological connection is reduced or lost and hence the amount of sea water brought into the Coorong is greater than that drained back to sea on any tidal cycle. Therefore, water levels in the Coorong increase which inundates mudflats and leads to physicochemical changes, such as increased salinity (through evaporation), increased water temperature (inducing thermal stratification) and decreased dissolved oxygen to

lethal levels. Changes to the physico-chemical, and thus biological, environment of the magnitude induced by the restricted Murray Mouth directly impacts on all ecosystem components and processes in the Murray Mouth Estuary and Coorong lagoons.

3.3.5 Upper South East Drainage Scheme

Drainage of land and alterations of drainage lines in the South East of South Australia began shortly after European settlement (c.1850s). Since August 2000, drainage water has been released from a regulated storage basin (Morella Basin) into the South Lagoon of the Coorong at Salt Creek (see Figures 5 and 6). Inflows are currently capped by a release limit of 40 GL/y on a ten year rolling average to manage reductions in salinity that may be induced in the South Lagoon. This cap is currently under review by the Commonwealth Government and may soon be varied. To date, flows in the order of 5–15 GL/y have been released, with inflow salinities ranging from 15-20,000 mg/L (= approx 25,000-33,0000 EC), which have only had minor, localised salinity impacts in the southern end of the South Lagoon (DWLBC, 2005).

3.3.6 Discharges to land, water and air primarily lakeshore and riparian activities

The Coorong and Lakes Ramsar site has extensive agricultural activities and some urban development conducted, or proposed, around it. Discharges from human activities to land, water and air can impact directly on ecological components and processes at or near the point of discharge or indirectly via atmospheric and hydro-geological processes. The exact nature of the impacts from these levers will be determined by the nature of the discharge and factors such as the capacity of the wetland to mitigate the impact (e.g. biodegradation of agrochemicals). Fringing vegetation, lakeshore wetlands and riparian areas are particularly at risk.

Together, the drivers (climate, geomorphology and hydrology) and the levers (river regulation, water extraction, USEDS inflows, barrage operation, dredging and discharging) combine to determine what ecological components and processes will occur in a wetland ecosystem over time and space (see Figure 7).

■ 3.4 Ecological components and processes

3.4.1 Water regime—combination of natural hydrology and levers that regulate flows etc.

At a whole-of-site level the water regime of the Coorong and Lakes is dependent on inflows from the River Murray. EMLR tributaries, USEDS, and groundwater and outflows through the barrages, as well as climatic factors such as rainfall on, and evaporation from, the waterbodies themselves (see Figure 6). At a habitat scale, the components of water regime (e.g. duration, timing, frequency etc.) dictate how available a given habitat is and therefore what patterns of plants, animals and processes will occur.

For the highly regulated Coorong and Lakes environment, habitat-scale water regime has been simplified in many areas to be water level dependent. This is because regulated flow translates to water level and physicochemical changes more so than inducing an extensive transition from standing to flowing habitats as natural, dynamic flow regimes would on a seasonal basis.

3.4.2 Physico-chemical environment—physical and chemical components and processes

The physico-chemical environment of any given habitat will be dependent on the interactions between the drivers and levers described above. Physico-chemical components include dissolved salts, suspended sediments, dissolved oxygen, water temperature, and soils. Physico-chemical processes include sedimentation, light penetration, precipitation, nutrient and carbon cycling, and stratification. These components and processes interact with biological processes at such a fundamental level that they can solely dictate patterns of plants and animals. For example, a wetland may have the ideal water regime for a given species but the salinity, turbidity and/or thermal profiles may be beyond the tolerance of that species and thus it won't occur there.

3.4.3 Keystone species—particularly submerged and emergent aquatic plants

Keystone species are those species whose loss from an ecosystem would precipitate many further losses of other species due to their direct or indirect dependence on these keystone species (Mills et al., 1993). Therefore the loss of a keystone species is a fundamental shift in ecological character at a whole site level. In the case of the Coorong and Lakes, the keystone species are the submerged and emergent aquatic plants (both fresh and saline tolerant) that form the 'architecture' of the ecosystem. Plants such as Ruppia spp. give physical



Ribbon weed, Triglochin procerum

structure to habitats, provide a physico-chemical environment conducive to respiration and carbon and nutrient cycling, are a direct and indirect source of food and generate organic matter and oxygen for the system via photosynthesis.

3.4.4 Species and species assemblages —ecological communities and species

The presence and abundance of different plants and animals, and the patterns in which they occur, are determined by the combined forces of the drivers, levers and ecosystem components and processes described above. All species, for example, have requirements for water and a salinity threshold above which they cannot survive which is why water regime and salinity gradients are fundamental parameters for describing ecological character. Similarly, all plants require sunlight to photosynthesise, so turbidity and hence light penetration are fundamental factors affecting aquatic plant distribution. Plants, animals and microbes depend on each other for vital ecological processes such as decomposition, pollination or seed dispersal. Different species are more or less resilient to changes in habitat conditions and thus there will be relatively predictable changes in species and species assemblages as parameters change such as an increase in salinity or turbidity in a given wetland habitat making species and population assessments valuable monitoring tools. Section 3.5 provides an overview of the species and ecological communities that contribute to the Coorong and Lakes qualifying as a Ramsar wetland.

3.4.5 Habitat availability—variety, types, accessibility, competitive extent, condition, connectivity

Habitats are in essence the place(s) where plants, animals and microbes (the biological components of an ecosystem) live, and where physico-chemico-biological processes (the ecological processes) occur and interact. Habitat availability varies over time and space. Measures of habitat availability, and therefore the capacity of a site to support resident and transient species and assemblages, include:

- a) the variety and specific type(s) of habitat(s) (e.g. number of different Ramsar wetland types present)
- b) how accessible they are to the relevant species (i.e. provision of seasonal water level variations required for wader birds to feed on mudflats)
- c) the extent of habitat compared to the competitive pressure for that habitat

- d) the condition of the habitat (e.g. status of keystone species)
- e) and the degree of temporal and spatial connectivity between required habitats (e.g. integrity of habitats connections along migration paths).

The dependent biota need the right habitat type(s) available in the right condition at the right time(s) in their life cycles to have sustainable populations.

3.4.6 Nutrient and carbon cycling —transformation of physico-chemical components

Very little is known about the specifics of carbon and nutrient cycling in the Coorong and Lakes but these cycles are likely to contain key ecological components and processes. A decline in submerged and emergent plant cover may lead to a decrease in detritus (organic matter) and nutrients being transformed within the system and may reduce the capacity of the sediment biota to transform carbon and nutrients by reducing the variability in oxygen supply (and thus redox potential) within the sediments. In addition, the amount and type of carbon and nutrients entering the system from the River Murray during flow events will have changed over time and given that very little water has left the Murray Mouth in the last decade, the system is likely to be acting as a sediment and salt trap for the Murray-Darling Basin.

■ 3.5 Ramsar-significant biological components of the system

At the time a wetland in Australia is Ramsar-listed, the Commonwealth Government is required to submit a formal description of the site using a specified format known as the Ramsar Information Sheet (RIS). In the RIS it is indicated which of the criteria for being declared a Wetland of International Importance the site qualifies against, and a short justification is provided. Ramsar signatories are asked to update the RIS for each site at least every six years, that is, for each second global Ramsar Conference of Parties. The most recent revision of the RIS for the Coorong and Lakes sites was prepared in 2000 and while it showed that the site qualified against Ramsar Criteria 1, 2, 3, 4, 5 and 6 (see Table 3), this revision did not give any consideration to Criteria 7 and 8 relating to fish values. These were adopted by the Convention in 1996 at the Ramsar Conference in Brisbane. Further, during the preparation of this report, Ramsar's 9th Conference was held in Uganda and this adopted a further Criterion 9, which addresses populations of nonavian fauna reliant on a wetland system (see below).

For this project it was assessed that the year 2000 version of the RIS for the Coorong and Lakes site warranted revision and updating, most notably to give consideration to Criteria 7, 8 and 9. The draft revised RIS for the site is provided in Appendix C. It shows that based on the assessments done in this report, the Coorong and Lakes Ramsar sites qualifies against eight of the nine criteria. This revision of the RIS has been able to establish that the site clearly qualifies against both fish-related criteria (7 and 8). However, at this time it is not possible to confirm that the site also qualifies against the very recently added Criterion 9. It may be that it does so for some of the native fish species found within the site, but there is insufficient population data for these species at present to be able to make such a conclusion.

Following is a summary of the Ramsar Significant Biological Components of this site. These are then considered in further detail in Sections 4, 5 and 6.

Significant species and ecological communities from a Ramsar perspective

Reference to Table 3 adjacent indicates that there are eight often-referred to as 'biodiversity criteria' (2-9) that allow Ramsar sites to be recognised for the range of species and ecological communities that occur there. Sections 3.5.1, 3.5.2 and 3.5.3 list the species and ecological communities that contribute to qualifying this site against Ramsar Criteria 2-8. For further details, refer to the new draft RIS for the site at Appendix C. Section 5 of this

report examines these species and communities in greater detail.

Note that the site also qualifies against Ramsar Criterion 1 through being a unique wetland system representative of a range of wetland types found within the bioregion.

	amsar's criteria used to qualify Wetlands of al importance
Criterion 1	Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion.
Criterion 2	Supports vulnerable, endangered or critically endangered species or threatened ecological communities.
Criterion 3	Supports populations of plant and/or animal species important for maintaining the biological diversity of the region.
Criterion 4	Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Regularly supports 20,000 or more waterbirds.
Criterion 6	Regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	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	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	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.

In order to qualify, a site must satisfy one or more of the above.

3.5.1 Ecological communities

There are two ecological communities of note in this context, as follows:

Swamps of the Fleurieu Peninsula

The listing of the swamps of the Fleurieu Peninsula as a critically endangered ecological community under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is notable as this area and the Ramsar site partially overlap. These areas of overlap are also important habitat for the endangered Mount Lofty Ranges Southern Emu-Wren (see Sections 3.5.3 and 5.1.3).

Vegetation association of Gahnia filum

'The Department for Environment and Heritage has compiled a provisional list of threatened ecosystems. The vegetation association of Gahnia filum is identified as a vulnerable ecosystem within the agricultural district of South Australia. This ecosystem is described as a sedgeland located in drainage lines and depressions, the distribution of intact remnants within the agricultural district is largely contained in a number of small areas within NPWSA Reserves. This is an ecosystem that historically has suffered severe degradation from drainage, increased salinity (can only tolerate a certain level) and grazing. There is little regeneration evident

the agricultural districts (DEH 2001).' (Seaman, draft report 2005).

3.5.2 Plant taxa

While relatively few systematic surveys of plant taxa have been undertaken at the site, those that have been done show the presence of the following notable species. Further surveys are expected to find additional plant species of note (see Section 5.1.1 for further consideration of these species).

Table 4 - Plant taxa that contribute to qualifying the site for Ramsar status						
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status	
Family Asteraceae						
Silver Daisy-bush	Olearia pannosa ssp pannosa	2,3	V		V	
George's Groundsel	Senecio georgianus var. georgianus	2,3	V		E	
Family Mimosaceae						
Yellow Swainson-pea	Swainsona pyrophila	2,3	V		R	
Family Orchidaceae						
Sandhill Greenhood	Pterostylis arenicola	2,3	V		V	
Metallic Sun-orchid	Thelymitra epipactoides	2,3	E		E	
Family Proteaceae						
Scarlet Grevillea	Grevillea treueriana	2,3	V		V	
Family Goodeniaceae						
Dune Fanflower	Scaevola calendulacea	3	V			

KEY

Conservation status

National and SA: E - Endangered, V - Vulnerable

IUCN: CE - Critically Endangered, Endangered, V - Vulnerable in the IUCN Red list

3.5.3 Animal taxa

There are a range of animal taxa that contribute to the Ramsar status of the site, among these an amphibian, and many bird and fish species. These are listed below in Tables 5, 6 and 7. For details of the decision rules applied to establish the following lists, refer to Appendix C. Further consideration of these species is given in Section 5.

Amphibians

Table 5 - Amphibian taxa that contribute to qualifying the site for Ramsar status					
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status
Amphibians					
Southern Bell Frog	Litoria raniformis	2,3,4	V	E	V

KEY

Status: E - Endangered, V - Vulnerable

Fish

The native fish community of the Ramsar site includes some 49 species of noted in Table 6. Among these are:

- five species that are listed as vulnerable at either global or national levels
- 20 further species that are classified as protected or have been provisionally listed as of conservation concern within South Australia
- 20 species that utilise the site at critical stages of their life cycle, such as, seven diadromous species, twelve estuarine species that spawn or have large populations and any freshwater species that spawn or recruit within the wetland
- eight so-called 'marine stragglers'; being marine species of fish that randomly enter and leave inlets and estuaries.



River Blackfish

Table 6 - Fish taxa that con	tribute to the Ramsar status o	of the site			
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status
Glassfishes - Family Ambassidae					
Chanda Perch (Agassiz's Glassfish)	Ambassis agassizii	3,4,7,8			P,C
Freshwater eels - Family Anguillid	ae				
Short-finned Eel	Anguilla australis	3,4,7			С
Hardyheads or silversides - Family	y Atherinidae				
Small-mouthed Hardyhead	Atherinosoma microstoma	4,7,8			
Murray Hardyhead	Craterocephalus fluviatilis	2,3,4,7,8	V	E	С
Fly-specked Hardyhead	Craterocephalus stercusmuscarum fulvus	3,4,7,8			С
Herrings - Family Clupeidae					
Sandy Sprat	Hyperlophus vittatus	4,7,8			
Bony Bream	Nematalosa erebi	4,7,8			
Blue Sprat	Spratelloides robustus	4,7,8			
Gudgeons - Family Eleotrididae					
Purple-spotted Gudgeon	Mogurnda adspersa	3,4,7,8			P,C
Flathead Gudgeon	Philypnodon grandiceps	4,7,8			
Dwarf Flathead Gudgeon	Philypnodon sp.	3,4,7,8			С
Western Carp Gudgeon	Hypseleotris klunzingeri	3,4,7,8			С
Midgley's Carp Gudgeon	Hypseleotris sp.	4,7,8			
Murray-Darling Carp Gudgeon	Hypseleotris sp.	3,4,7,8			С
Hybrid Carp Gudgeon (e.g. Lakes Carp Gudgeon)	Hypseleotris spp.	4,7,8			

Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status
Freshwater blackfishes - Family G					
River Blackfish	Gadopsis marmoratus	3,4,7,8			P,C
Galaxids or native minnows - Fan	l				
Climbing Galaxias	Galaxias brevipinnis	3,4,7,8			С
Common Galaxias	Galaxias maculatus	4,7,8			
Mountain Galaxias	Galaxias olidus	3,4,7,8			С
Pouched lampreys - Family Geot	riidae				
Pouched Lamprey	Geotria australis	3,4,7,8			С
Gobies - Family Gobiidae			ı		
Bridled Goby	Acentrogobius bifrenatus	3#4,7,8			
Tamar Goby	Afurcagobius tamarensis	3#,4,7,8			
Western Blue Spot (Swan River) Goby	Pseudogobius olorum	3#,4,7,8			
Lagoon Goby	Tasmanogobius lasti	3#,4,7,8			
Halfbeaks - Family Hemiramhida	9		1		
River Garfish	Hyporhamphus regularis	4,7,8			
Leptoscopids - Family Leptoscop	dae				
Sand Fish	Crapatalus arenarius lasti	7			
Goblin Shark	Mitsukurina owstoni	7			
Shorthead lampreys - Family Mor	daciidae				
Shortheaded Lamprey	Mordacia mordax	3,4,7,8			С
Grey mullets - Family Mugilidae					
Yellow-eye Mullet	Aldrichetta forsteri	4,7,8			
Jumping Mullet	Liza argentea	4,7,8			
Freshwater basses and cods - Fai	mily Percichthyidae				
Southern Pygmy Perch	Nannoperca australis	3,4,7,8			P,C
Yarra Pygmy Perch	Nannoperca obscura	2,3,4,7,8	V	V	P,C
Murray Cod	Maccullochella peelii peelii	2,3,7,8	V		
Golden Perch	Macquaria ambigua ambigua	4,7,8			
Estuary Perch	Macquaria colonorum	3,4,7,8			С
Righteye flounders - Family Rhom	bosoleinae				
Greenback Flounder	Rhombosolea tapirina	4,7,8			
Eel-tailed catfishes - Family Ploto	sidae				
Freshwater Eel-tailed Catfish	Tandanus tandanus	3,4,7,8			Р

Table 6 - Fish taxa that cor	ntribute to the Ramsar status (of the site (contine	ued)		
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status
Congollis - Family Pseudaphritid	ae				
Congolli (Tupong)	Pseudaphritis urvillii	3,4,7,8			С
Smelts - Family Retropinnidae					
Australian Smelt	Retropinna semoni	4,7,8			
Drums - Family Sciaenidae					
Mulloway	Argyrosomus japonicus	4,7,8			
Scorpion fishes - Family Tetrarog	idae				
South Australian Cobbler	Gymnapistes marmoratus	4,7,8			
Breams - Family Sparidae					
Black Bream	Acanthopagrus butcheri	4,7,8			
Pipefishes & seahorses - Family S	yngnathidae				
Big-bellied Seahorse	Hippocampus abdominalis	2,3,7		V	
Grunters - Family Terapontidae					
Silver Perch	Bidyanus bidyanus	2,3,4,7,8		V	P,C
Striped Perch	Helotes sexlineatus	4,7,8			
Pufferfishes - Family Tetraodontidae					
Prickly Toadfish	Contusus brevicaudus	7			
Smooth Toadfish	Tetractenos glaber	4,7,8			
Richardson's Toadfish	Tetractenos hamiltoni	7			

KFY

Conservation status

National: V - Vulnerable under the EPBC Act 1999

IUCN: E - Endangered in the IUCN Red list, V- Vulnerable in the IUCN Red list

State: P – protected under the Fisheries Act 1982, C – provisional State conservation concern under the draft

Threatened Species Schedule NPWSA (refer: http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

Birds

There are 77 bird species listed in Table 7, the majority, but not all, being waterbirds. This includes:

- three species that are listed as endangered or critically endangered at either global or national levels
- five further species that are classified as vulnerable within South Australia
- 49 species that rely on the wetland at critical life stages, such as migration stop-over, for breeding habitat or as refuge during times of drought
- 46 species that are listed under Australia's migratory bird agreements with Japan or China, or the Convention on Migratory Species
- 16 species that occur at the site in numbers 1% of their estimate population or sub-population numbers (Criterion 6 in the table on the following page).



Australian White Ibis

Common name	Scientific name	Ramsar criteria*	National	IUCN	J/CAMBA	SA
Common name	Sciennic name	Kamsai Cittena	Status	Status	or CMS	Status
Pelicans - Family Pelecanidae						
Australian Pelican	Pelecanus conspicillatus	4, 5.1, 5.2, 5.3				
Darters - Family Anhingidae						
Australian Darter	Anhinga melanogaster	4				
Cormorants - Family Phalacroo	coracidae					
Little Pied Cormorant	Phalacrocorax melanoleucos	4				
Pied Cormorant	Phalacrocorax varius	4				
Little Black Cormorant	Phalacrocorax sulcirostris	4, 5.1, 5.2				
Great Black Cormorant	Phalacrocorax carbo	4, 5.1, 5.2				
Grebes - Family Podicipedidae	,	l	'	'		
Great Crested Grebe	Podiceps cristatus	5.3, 6				R
Hoary-headed Grebe	Podiceps poliocephalus	5.1, 5.2, 5.3, 6				1
Geese, swans and ducks - Fan	nily Anatidae			<u></u>		
Cape Barren Goose	Cereopsis novaehollandiae	6			CMS	R
Black Swan	Cygnus atratus	4, 5.1, 5.3			CMS	+
Australasian Shoveler	Anas rhynchotis	4			CMS	R
Musk Duck	Biziura lobata	5.3			CMS	R
Australian Shelduck	Tadorna tadornoides	4, 5.1, 5.2, 5.3			CMS	†
Grey Teal	Anas gracilis	5.1, 5.2, 5.3			CMS	+
Chestnut Teal	Anas castanea	4, 5.1, 5.2, 5.3			CMS	+
Rails, crakes, swamphens, coo	t - Family Rallidae					
Lewin's Rail	Rallus pectoralis	3				V
Spotless Crake	Porzana tabuensis	5.3				+
Dusky Moorhen	Gallinula tenebrosa	4				+
Purple Swamphen	Porphyrio porphyrio	4, 5.3				+
Herons, egrets, bitterns - Family						
Australasian Bittern	Botaurus poiciloptilus	2,3		E		V
Little Egret	Ardea garzetta	4				+
Cattle Egret	Ardea ibis	4				+
Great Egret	Ardea alba	4			J/CAMBA	1
White faced Heron	Ardea navaehollandiae	4, 5.3				†
Rufous NightHeron	Nyctocorax caledonicus	4, 5.3				1
lbises, spoonbills - Family Thres	kiornidae					
Glossy Ibis	Plegadis falcinellus	4			CAMBA	R
Straw-necked Ibis	Threskiornis spincollis	4, 5.1				+
Australian White Ibis	Threskiornis molucca	4, 5.3				+
Royal Spoonbill	Platalea regia	4, 5.3				+
Yellow-billed Spoonbill	Platalea flavipes	4, 5.3				+

Common name	Scientific name	Ramsar criteria*	National Status	IUCN Status	J/CAMBA or CMS	SA Status
Curlews, sandpipers, snipes, g	godwits, phalaropes - Family Scolopa	cidae				
Latham's Snipe	Gallinago hardwickii	3,4			J/CAMBA CMS	V
Sharp-tailed Sandpiper	Calidris acuminata	4, 5.3, 6			J/CAMBA CMS	
Curlew Sandpiper	Calidris ferruginea	4, 5.3, 6			J/CAMBA CMS	
Common Sandpiper	Tringa hypoleucos	4			J/CAMBA CMS	
Marsh Sandpiper	Tringa stagnatilis	4			CAMBA CMS	
Terek Sandpiper	Xenus cinereus (Tringa terek)	4			J/CAMBA CMS	
Pectoral Sandpiper	Calidris melanotos	4			J/CAMBA CMS	
Red-necked Stint	Calidris ruficollis	4,5.3,6			J/CAMBA CMS	
Sanderling	Crocethia alba	4,6			J/CAMBA CMS	
Common Greenshank	Tringa nebularia	4,5.3,6			J/CAMBA CMS	
Red-necked Pharalope	Phalaropus lobatus	4			J/CAMBA CMS	
Eastern Curlew	Numenius madagascariensis	3,4,5.3			J/CAMBA CMS	V
Bar-tailed Godwit	Limosa lapponica	4			J/CAMBA CMS	
Black-tailed Godwit	Limosa limosa	4, 5.3			J/CAMBA CMS	
Great Knot	Calidris tenuirostris	4			J/CAMBA CMS	
Red Knot	Calidris canutus	4			J/CAMBA CMS	
Grey-tailed Tattler	Tringa brevipes	4			J/CAMBA CMS	
Wandering Tattler	Tringa incana	4			J/CAMBA CMS	
Ruddy turnstone	Arenaria interpres	4			J/CAMBA CMS	
Ruff	Philomachus pugnax	4			J/CAMBA CMS	
Oystercatchers - Family Haen	natopodidae					
Pied Oystercatcher	Haematopus longirostris	4,5.3,6				
Sooty Oystercatcher	Haematopus fuliginosa	5.3				
Lapwings, plovers, dotterels -	Family Charadriidae					
Hooded Plover	Charadrius rubricollis	3,4,5.3,6			CMS	V
Red-capped Plover	Charadrius ruficapillus	4, 5.3, 6			CMS	
Pacific Golden Plover	Pluvialis fulva	4, 5.3, 6			CMS	
Grey Plover	Pluvialis squatarola	4			J/CAMBA CMS	
Pacific Golden Plover	Pluvialis fulva	4			J/CAMBA CMS	
Lesser Sand Plover	Charadrius mongolus	4			CMS	
Oriental Plover	Charadrius veredus	4			CMS	
Double-banded Plover	Charadrius bicinctus	4			CMS	
Masked Lapwing	Vanellus miles	4, 5.3			CMS	
Red-kneed Dotterel	Erthrogonys cinctus	5.3			CMS	

Table 7 - Bird taxa that con	tribute to the Ramsar status	of the site (contin	nued)			
Common name	Scientific name	Ramsar criteria*	National Status	IUCN Status	J/CAMBA or CMS	SA Status
Stilts, avocets - Family Recurviros	tridae					
Banded Stilt	Cladorhynchus leucocephalus	5.3,6			CMS	
Black-winged Stilt	Himantopus himantopus	4, 5.3			CMS	
Red-necked Avocet	Recurvirostra novaehollandiae	5.3,6			CMS	
Gulls, terns etc Family Laridae						
Little Tern	Sterna albifrons	3,4			J/CAMBA	
Fairy Tern	Sterna nereis	3,4, 5.1, 5.2, 5.3,6				
Crested Tern	Sterna bergii	4,5.1,5.2			JAMBA	
Caspian Tern	Hydropogne tschegrava (Hydroprogne caspia)	4,5.3,6			CAMBA	
Whiskered Tern	Chlidonias hybridus	5.1,5.2,5.3				
Pacific Gull	Larus pacificus	4				
Silver Gull	Larus navaehollandiae	4, 5.1,5.2,5.3				
Parrots - Family Psittacidae						
Orange-bellied Parrot	Neophema chrysogaster	2,3,4	Е	CE		
Fairy-wrens - Family Maluridae						
Mount Lofty Ranges Southern Emu-wren [®]	Stipiturus malachurus intermedius	2,3,4	Е	Е		
Old world warblers - Family Sylvii	Old world warblers - Family Sylviidae					
Great (Oriental) Reed-Warbler	Acrocephalus arundinaceus	4			САМВА	
Little Grassbird	Megalurus gramineus	4				
Golden-headed Cisticola	Cisticola exilis	4				

The order used follows that of Field Guide to the Birds of Australia, 6th Edition by Simpson and Day, 1999

KEY

Conservation status

E – Endangered, V – Vulnerable, R – Rare

& - This species occupies the critically endangered ecological community, the swamps of the Fleurieu Peninsula. See Section 3.1.1 JAMBA - Japan-Australia Migratory Bird Agreement, CAMBA - China-Australia Migratory Bird Agreement CMS - Convention on Migratory Species

* See draft RIS at Appendix C for explanation of how determinations were made under Criterion 5.

Interplay of drivers, levers, components and processes within the wetland types of the system



The many types of freshwater and saline-estuarine wetlands found at this Ramsar site are described in detail with attention given to the ecological components and processes that underpin ecological character.

Interplay of drivers, levers, components and processes within the wetland types of the system

The Coorong and Lakes Ramsar site lies at the terminus of the Murray-Darling Basin. It incorporates the freshwater bodies of Lakes Alexandrina and Albert and the more saline lagoons of the Coorong (see Figure 6). It is the only estuary within the Murray-Darling Basin and thus the Murray Mouth is the only connection between this one million square kilometre inland basin and the sea.

The Ramsar site covers an area of approximately 140,500 ha which incorporates 23 different wetland types (according to the Ramsar Convention classification system, see Table 8), existing as a mosaic of fresh to hypersaline habitats variously interconnected across time and space. Ramsar Criterion 1 (see Table 3) seeks to recognise sites that contain '... a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion' and the Coorong and Lakes qualify against this criterion in addition to seven of the other eight (see Section 5).

To assist this description of ecological character the Ramsar site has been sub-divided into six units as follows:

Freshwater system units:

- Lake Alexandrina
- Lake Albert
- Tributary wetlands (lower reaches of Finniss River Currency Creek and Tookayerta Creek).

Estuarine-saline system units:

- · Murray Mouth and Estuary
- North Lagoon
- · South Lagoon.

For each of these six units, maps showing the distribution of wetlands types are provided below. These are then followed by detailed consideration of the types, as they occur within the freshwater units and the estuarine-saline units. Sections 4.1.1 to 4.1.3 provide an overview of the three predominantly freshwater units referred to above. This includes a summary qualitative description of each unit plus a more detailed breakdown of the wetland types found there and the key biological components occurring in that habitat. Similarly, Sections 4.2.1 to 4.2.2 document the estuarine-saline units. Section 5 provides more detailed information of the Ramsar Significant Biological Components that contribute to qualifying this site as a Wetland of International Importance—as summarised initially in Section 3.5.



N/	a /Caastal watlands	Ara - (1)
Marin	e/Coastal wetlands	Area (ha)
Α	Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits	50
D	Rocky marine shores; includes rocky offshore islands, sea cliffs	788*
E	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks	1,020#
F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas	2,200
G	Intertidal mud, sand or salt flats	3,142
Н	Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes	536
1	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	4
J	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea	10,128
K	Coastal freshwater lagoons; includes freshwater delta lagoons	41
Inland	d wetlands	
M	Permanent rivers/streams/creeks; includes waterfalls	221
N	Seasonal/intermittent/irregular rivers/streams/creeks	200
0	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes	79,480
Р	Seasonal/intermittent freshwater lakes (over 8ha); includes floodplain lakes	120
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats	1,729
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools	1,289
Тр	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season	4,474
Ts	Seasonal / intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	1,037
W	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	4,875
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	1,470
Υ	Freshwater springs; oases	<10
Huma	n-made wetlands	
4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)	1,235
6	Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha)	1
		

Shaded rows indicate the dominant wetland types within each broad category; marine/coastal, inland, and human-made.

Includes 6 ha from Lake Alexandrina and 1 ha from Lake Albert (freshwater parts of the system)

Ramsar wetland types not found in the Coorong and Lakes system have not been included in the table.

The total area of wetland types is approximately 114,000 hectares. The balance of the land (approx. 26,000 hectares) within the Ramsar site is terrestrial habitat, which is not classified under the Ramsar Convention (see Section 2.2 for a description of the site boundaries).

^{*} Includes 165 ha from Lake Alexandrina (a freshwater part of the system)

4.1 Freshwater system units

4.1.1 Lake Alexandrina

Qualitative description

Area: approximately 76,000 ha.

Lakes Alexandrina and Albert lie at the terminus of the River Murray system receiving freshwater inflows from the River Murray, the Eastern Mount Lofty Ranges tributaries, groundwater discharge, local run-off and rainfall on the lakes surface (see Figure 6). The River Murray confluence with Lake Alexandrina occurs immediately downstream of Wellington and the confluence of Lake Alexandrina and the Coorong is now a highly regulated one, consisting of a series of five barrages connecting the various islands in the southern section of the lake. Constructed in the 1930s, the five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitcherie) in total contain 593 independently-operated gates. Water is discharged from Lake Alexandrina through the gates in the barrages between lake levels of c. 0.75 and 0.85 m AHD (Australian Height Datum) or over wetland areas adjacent to the barrages when lake levels exceed 0.85 m AHD and thus water overtops or runs around the barrage structures.

Hindmarsh, Mundoo, Ewe and Tauwitcherie Islands lie within the transitional zone between Lake Alexandrina and the Coorong. Reserves around Lake Alexandrina include Tolderol, Mud Islands and Currency Creek Game Reserves, otherwise the Lake Alexandrina component of the Ramsar site is mainly open water and Crown Lands (often grazed under licence by adjacent landholders).

Lake levels vary with season, being higher in winter and lower in summer. Actual levels vary considerably due to high variability in River Murray and tributary inflows and climatic factors such as rainfall, wind, tides and evaporation. Historically, the barrages have been operated with a 'fill and spill' philosophy that saw the barrages being opened when lake levels reached 0.85 m AHD (typically in July-August) until the lake level dropped to 0.75 m AHD when the barrages were then closed. In the period between 1981 and 2003, there were seven periods when the barrages were closed continuously for more than 200 days with the longest period being 643 days. A new Barrage Operating Strategy (BOS) is being developed to better utilise water available during low flow conditions and mimic natural water regimes (see Asset Plan, DWLBC, 2005).

Lake Alexandrina and Lake Albert combined hold 2098 GL at 0.85 m AHD, and 2015 GL at 0.75 m AHD (DWLBC, 2005). The low points of Lake Alexandrina (and thus the deepest points) occur at approximately -4.0 m AHD. This means that at 0.75 m AHD the deepest areas in the lake are 4.75 m deep. Whilst the 'average' depth is approximately 2.9 m (Baker, 2000), wind action across the lake surface can vary lake levels considerably (average wind speed 28 km/h¹, Bourman et al., 2000).

The lakes are broad and shallow with complex and extensive fringing vegetation and an array of sand and mud islands (Jensen et al., 2000; Seaman, 2003). Much of the fringing vegetation is dominated by Phragmites australis, the common reed, with the most complex wetland flora found near confluences, channels and drains where the localised water regime is relatively variable.

Freshwater submerged aquatic plant communities were extensive in the lakes system prior to European settlement, spreading for several kilometres out into the lakes (Sim and Muller, 2004). They are now restricted to near-shore, well-illuminated lake habitats, natural confluences such as the River Murray-Lake Alexandrina confluence, tributary or wetland confluences and areas such as irrigation channels and drains that mimic natural confluences and thus may provide 'flow' in terms of irrigation pumping or gravity-fed drainage.

The fringing emergent vegetation has been similarly simplified since installation of the barrages and the creation of static lake levels. Species such as Phragmites australis and Typha domingensis have flourished whilst species dependent on variable water regimes (such as Eleocharis spp. and Baumea spp.) are now restricted to fringing wetlands and tributaries. Many wetlands also support lignum and samphire at the high water mark (behind the reeds) where evaporation provides saline conditions suitable for samphire growth. The hypersaline samphire communities occur at higher elevations, away from the zone inundated by seasonal lake level rise, and contain depressions that often receive run-off from their own mini-catchments and saline groundwater discharge. The freshwater habitats on and immediately surrounding the islands (e.g. Hindmarsh Island) are critical for freshwater fish such as Murray Hardyhead and are unique in that they provide potential and historical through-points for flows between Lake Alexandrina and the Coorong and thus are critical to habitat connectivity at a site scale. The flora of Hindmarsh Island contains many notable species and there is a range of terrestrial and aquatic habitats on and around the island with high to moderate levels of habitat connectivity.

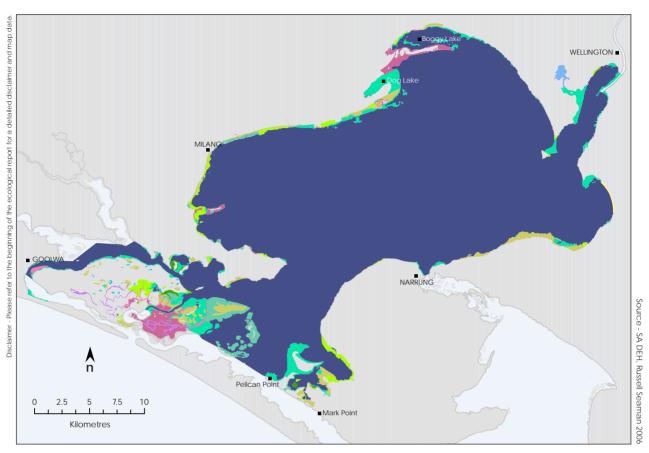


Figure 8 - Map of Lake Alexandrina showing the various wetland types

Key	to wetland types
D	Rocky marine shores; includes rocky offshore islands, sea cliffs
Е	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks
М	Permanent rivers/streams/creeks; includes waterfalls
N	Seasonal/intermittent/irregular rivers/streams/creeks
О	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes
Р	Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools
Тр	Permanent freshwater marshes/pools ; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes
W	Shrub-dominated wetlands ; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils
4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)
9	Canals and drainage channels, ditches

4.1.2 Lake Albert

Qualitative description

Mainly Crown Lands. Area: 16,800 ha approximately.

Lake Albert lies to the south east of Lake Alexandrina Narrung Narrows, a narrow channel between Point Malcolm and Narrung Peninsula, connects the two lakes. The channel is only c. 230 m wide whilst the causeway that meets the ferry at this site is c. 280 m long, suggesting that the original connection between the Lakes was in the order of c. 500 m wide.

Lake Albert does not have a through-flow connection to the Coorong and thus represents a local, inland terminus of the River Murray system. It only receives inflows through the Narrows channel from Lake Alexandrina with its local inputs confined to overland run-off following rain and groundwater discharge during winter when rainfall rapidly converts to run-off and recharge. Lake levels rise in winter and fall in summer in accord with the levels in Lake Alexandrina, although factors such as wind direction and speed, water extraction rates and local rainfall to evaporation rates also affect Lake Albert water levels.

The groundwater table is shallow and saline under much of Lake Albert's floodplain and thus groundwater discharge creates seasonal and permanent salt-water marshes in depressions or swales around the lake edge. In general, it is more saline than Lake Alexandrina and reaches conductivities of 3,000 EC at the end of periods of low river flow. The lakes have a very long fetch (distance of lake surface in-line with prevailing winds) and water can wash backwards and forwards between the two lakes depending on wind direction and speed and resultant wave action. The two lakes combined hold 2098 GL at 0.85 m AHD, and 2015 GL at 0.75 m AHD (DWLBC, 2005). The lowest, and thus the deepest, point in Lake Albert is at -1.7 m AHD.

Lake Albert acts as a sink for salt and sediment from River Murray inflows, overland run-off, groundwater and lakeshore erosion. The slow-moving water allows for deposition of silts and sediments particularly at the southern end of the lake, where extensive siltation is reducing water depth and topographical diversity. This will ultimately promote the growth of reeds and riparian species and decrease the submerged wetland habitat. However, in so doing this sedimentation could result in more high quality island habitat and provide opportunities for *Ruppia* spp. growth, replacing beds from the Coorong and increasing habitat availability for nesting swans and ducks.

Lake Albert is a broad and shallow waterbody which supports remnant patches of *Gahnia filum* and extensive, highly significant *Phragmites australis* and *Typha domingensis* reedbeds. These provide excellent sheltered habitat for a range of fish and other vertebrate species, as well as long-term rookery sites for ibis, spoonbill and cormorants (EconSearch 2004a). Waltowa Swamp is a significant wetland complex connected to Lake Albert at high water levels that supports a range of flora including significant orchids, reeds, lignum, samphire and freshwater marshes.

Prior to European settlement, Lake Albert was significantly fresher than today and supported extensive submerged aquatic plant beds and diverse emergent macrophyte communities that fringed the lakeshore (Sim and Muller, 2004). Submerged aquatic plants are now restricted in range to sheltered, littoral habitats.

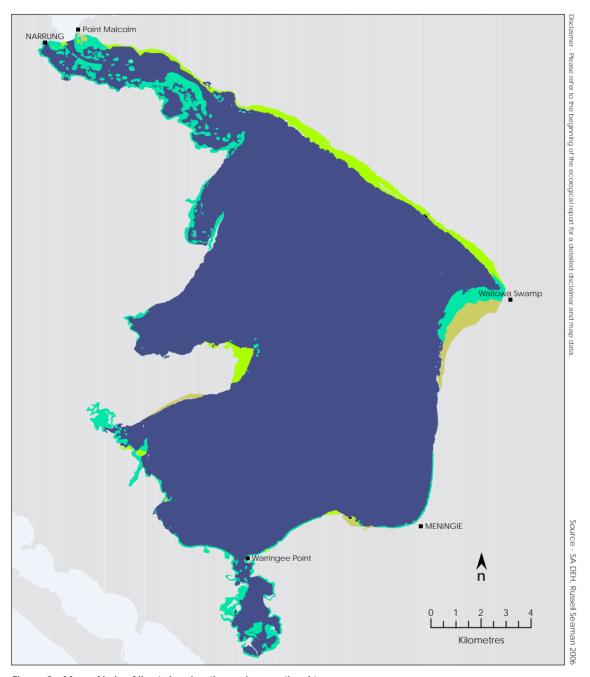


Figure 9 - Map of Lake Albert showing the various wetland types

Key	to wetland types
Ε	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slack
О	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools
Тр	Permanent freshwater marshes/pools; ponds (below 8ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season
W	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils
9	Canals and drainage channels, ditches

4.1.3 Tributary wetlands

Qualitative description

Tributary wetlands associated with three Eastern Mount Lofty Ranges streams: Finniss River, Tookayerta Creek and Currency Creek. Area: 1,488 ha approximately.

The Eastern Mount Lofty Ranges (EMLR) contain 13 streams, five of which discharge into Lake Alexandrina; namely Currency Creek, Tookayerta Creek, Finniss River, Angas River and Bremer River. These streams gain water from catchments that vary in rainfall from 350 mm to 850 mm annually, and from aquifers in the hills and across the plains recharged by stream flow and rain infiltration. The lower reaches of the Finniss River, Tookayerta Creek and Currency Creek lie within the Ramsar site but the Angas and Bremer Rivers are outside the boundary.

Flow was permanent in most of these streams prior to European settlement with summer baseflows being provided by groundwater discharge and wetland drainage (ABWMC, 2004). In modern times, only the Finniss River, Currency Creek and Tookayerta Creek can be considered 'permanent' although flow may stop for several weeks in summer depending on local climatic conditions and extraction rates (RMCWMB, unpub. data). Water resource development was capped at 30% of winter run-off by the River Murray Catchment Water Management Plan in 2003 and Notices of Prohibition and Intent to Prescribe were issued under the Water Resources Act 1997 in October 2003.

Gauging stations on Currency Creek and the Rivers Finniss, Angas and Bremer show that median winter runoff equates to 53 GL (DWLBC, Hydsys data). However, peak inflows are likely to exceed 100 GL if extrapolated to include Tookayerta Creek, the whole annual cycle and parts of the catchments that are ungauged but contribute flow.

The terminal reaches of the Finniss River and Tookayerta Creek, below Tuckers Ford on the Finniss River arm, are structurally diverse, supporting dense and diverse wetland flora, ranging from River Red Gum and reed-lined channels to swamps and peat bog freshwater marsh areas. This wetland system supports significant fauna, such as Mount Lofty Ranges Southern Emu-wren (see Section 5.1.3) and pygmy perches (see Section 5.5.1), and receives generally large but variable discharge from the Finniss River and Tookayerta Creek (via Black Swamp) catchments. The patterns of release are relatively natural in terms of timing, frequency and duration of flows (although flow rates and extent of inundation have been reduced). Capture of flows in the headwaters may delay the onset of flows in dry years when dams take several

weeks or months to fill before upper reaches provide flow. Groundwater inflows across the plains counteract this to a certain extent by sustaining flows over summer or initiating early autumn flows in dry years or more intensely developed sub-catchments. Water quality is generally fresh with a tannic stain and high transparency, particularly in areas directly receiving stream flow.

Currency Creek begins as a narrow, River Red Gum-lined, rocky channel broadening to a wetland habitat, and finally open water as part of Lake Alexandrina. It is characterised by permanently inundated channels and wetlands, although the lower section is known to dry in response to strong winds pushing the creek water into Lake Alexandrina and disconnecting the creek and lake habitats (Wedderburn and Hammer, 2003).

In a recent fish survey of five sites within Currency Creek, submerged vegetation was observed to be generally sparse but notably more abundant in the lower reaches. Water quality only varied slightly, with salinity higher upstream (Wedderburn and Hammer, 2003). Mount Lofty Ranges Southern Emu-wren populations are thought to be locally extinct from Currency Creek wetlands primarily due to habitat fragmentation (reduced connectivity) and/or adverse changes in water regime (see Section 5.1.3).

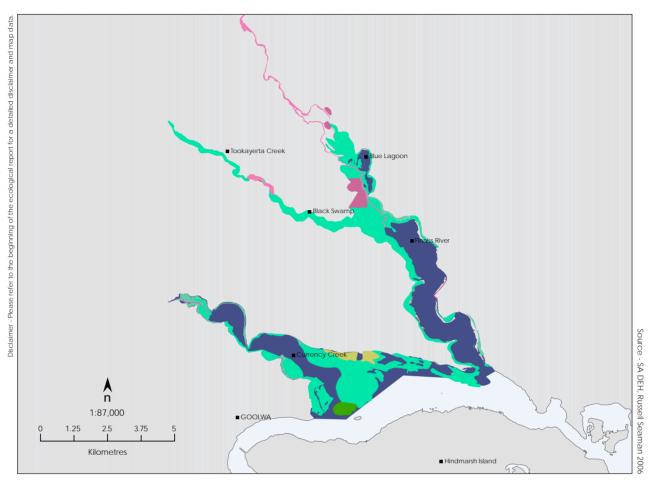


Figure 10 - Map of the tributary wetlands of Lake Alexandrina showing the various wetland types

Key	Key to wetland types			
M	Permanent rivers/streams/creeks; includes waterfalls			
О	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes			
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools			
Тр	Permanent freshwater marshes/pools; ponds (below 8ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season			
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes			
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils			
4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)			
6	Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8ha)			
9	Canals and drainage channels, ditches			

4.1.4 Wetland types and Ramsar Significant Biological Components within the freshwater system units (organised alphabetically by Ramsar type code)





Traffic light assessment

The ecological roles of this wetland type are poorly understood, it has limited areal extent and the rocky shores are threatened by cattle grazing, therefore a precautionary approach of rating this type as under threat has been applied. If it is found that this habitat is critical habitat for Ramsar or other significant biota it should be changed to 'amber' unless habitat condition and threat assessment at the time shows otherwise.

Ramsar wetland types	D	Rocky marine shores; includes rocky offshore islands, sea cliffs	
Units where found	Lake Alexandrina		
Estimated areal extent in 2005 (ha)	171		
than 50% cover of strew (some strew strews). Typically the vegetation is These rocky areas are locus eastern shore of Lake A southern edge of Point street.		narine but inland remnants of ancient shorelines. The rocky shorelines of Lake Alexandrina contain more 50% cover of strew (stones) on the beaches and have cliff areas comprising of exposed calcrete outcrops. ally the vegetation is dominated by exotic grasses that are degraded by cattle grazing and trampling. erocky areas are located along the: tern shore of Lake Alexandrina below Wellington (Poltalloch Plains) thern edge of Point Sturt atches along lakeshore between Clayton and Point Sturt.	
Key biological components supported and how	The relative importance of this habitat type in supporting ecological communities is not known but it is likely to be an important nesting site for some bird species and the complex shorelines are likely to be important for fish and other aquatic biota. Rocky outcrops on Point Sturt contain notable plant species including orchids.		
Limit of acceptable change—rationale 5% (areal extent)—there is relatively little area of this type and while the ful an LAC of 5% is applying the precautionary approach.		real extent)—there is relatively little area of this type and while the full ecological roles are yet to be defined, AC of 5% is applying the precautionary approach.	

pe E: Sand, shingle or pebble shores



Traffic light assessment

Only 1 ha of this wetland type remains and thus this type is extremely vulnerable to loss from the Ramsar site. It is an important part of habitat variability and connectivity. Given its location on the lakeshore near a major township, it is considered to be under immediate and extreme threat from a range of direct and indirect anthropogenic factors.

Ramsar wetland types	E Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks
Units where found Lake Albert	
Estimated areal extent in 2005 (ha)	1
Description(s)	Patches of sandy shoreline occur on the banks of Lake Albert on the western side of Meningie.
Key biological components supported and how	Opportunistic habitat for waders, roosting site for pelicans and other waterbirds.
Limit of acceptable change—rationale	0% (areal extent)—there is little area remaining, and it provides habitat diversity for waterbirds in particular.

Type M: Permanent rivers/streams/creeks

Ramsar wetland types	Ramsar wetland types M Permanent rivers/streams/creeks; includes waterfalls		
Units where found	Lake Alexandrina (islands)	Tributaries	
Estimated areal extent in 2005 (ha)	135	81	
Description(s)	Natural and constructed channels on Hindmarsh Island allow for through-flow of water from Lake Alexandrina to the Coorong thereby connecting fresh and estuarine-saline habitats when lake levels are high. Holmes Creek has two main entrances (one modified natural and one constructed channel) and one main outlet. Water can flow in from Lake Alexandrina into a series of blind channels with very high habitat value. The flow patterns in the channels are complex and highly dependent on wind and head differences between the groundwater, Lake Alexandrina, the channels and the Coorong. Mundoo Barrage fords Holmes Creek, below which the watercourse is known as Mundoo Channel. Seasonal influxes of saline groundwater provide variation in stream salinity and reverse flow of sea water into fresh channels upstream of the barrages can occur during storm surges. 'Wyndgate', now owned by SA Government and managed by SA DEH, is a 1088 ha property (covering approximately 22% of Hindmarsh Island). Hunters Creek flows through the Wyndgate property. Boundary Creek and Fishtrap Creek are permanent channels that transect Mundoo Island.	Three permanent streams enter Lake Alexandrina between Milang and Goolwa. These streams are the Finniss River, Currency Creek and Tookayerta Creek. Inflow estimates vary from 35–100 GL per year (NB: flows may be significantly higher in very wet years). Dam capture rates are approaching 30% of winter run-off and are delivered in a pattern that has not been significantly altered by water resource development (DWLBC, 2004). Currency Creek has the least reliable flows of the three streams and has recently become more ephemeral in nature. Flow quantification in progress by DWLBC and SAMDB NRM Board.	
Key biological components supported and how	The complex nature of the habitat provided by the network of streams, channels and drains on Hindmarsh Island, combined with through-flow and close proximity to the Murray Mouth Estuary provides high habitat value for waterbirds (Jensen et al., 1996) and for most of the sites biota at some stage. 'Wyndgate' includes habitat for Cape Barren Geese (Rare in SA—see Section 5.5.1) and 27 other JAMBA and CAMBA bird species (see Section 5.4). There is limited, but controlled cattle grazing and cropping on 'Wyndgate' to provide food for Cape Barren Geese which utilise the close-cropped or grazed pastures that are browning off (Seaman pers. comm.). Cattle grazing occurs to the water's edge on Mundoo Island. Approximately half the fish species found in the Lower Murray occur in these habitats, including Murray Hardyheads and Yarra pygmy perch. Dunn's Lagoon and the drains on 'Wyndgate' are particularly important low flow refugia for native fish. Core Murray Hardyhead populations are located on and around Hindmarsh Island (Wedderburn and Hammer, 2003). (see Section 5.6.1). Key wetland flora assemblages are Tea-tree woodlands, samphire shrublands, freshwater sedgelands and brackish herb- and sedge-lands (Typha and Phragmites dominated), providing diverse and highly connected habitats.	The termini of these tributaries form extensive freshwater wetlands, including Black Swamp, Blue Lagoon and other EPBC-listed Fleurieu Swamps, (see Section 5.1.2) stretching from approximately 10km south of Milang to 3km north of Goolwa. The relatively natural patterns in flow from the permanent tributaries provides habitat for a range of aquatic plants. The floral assemblages in these wetlands are highly diverse ranging from submerged aquatic plants to silky tea tree, red gums and lignum and as such supports a wide range of significant fauna, including Southern Emu-wren and Southern Pygmy Perch (see Sections 5.1.3 and 5.6.1, respectively). This wetland type is the only one within the Ramsar site to contain River Red Gums growing along the sides of the tributary channels and wetlands.	
Limit of acceptable change—rationale			

» continued »

ermanent rivers/streams/creeks



Traffic light assessment

This wetland type is considered to be under extreme threat and highly vulnerable. This rating is based on the combined factors of the high ecological value of this wetland type and immediate risks of damage from anthropogenic factors such as land and water resource development. The variable water regimes and habitats available in these wetland types support under-represented species assemblages and Ramsar Significant Biological Components. Combined with other island habitats and the Murray Mouth Estuary these wetlands are the 'jewel in the crown' of the modern Ramsar site.





Traffic light assessment

Similar to Type M above, Type N wetlands are also considered to be under immediate threat and extremely vulnerable to land and water resource development. These channels are critical connectors of various habitats and vital for maintaining the ecological functionality of the island habitats.

Ramsar wetland types	N Seasonal/intermittent/irregular rivers/streams/creeks	
Units where found	Lake	Alexandrina (islands)
Estimated areal extent in 2005 (ha)	200	
Description(s) Winter rainfall on Hindmarsh Island percolates through the sandhills and consequently drives stream flow discharge of groundwater into depressions on the flats. This creates annual cycles of inundation of, and through, a complex network of intermittent streams, freshwater wetlands, samphire channels and mudt thereby providing habitat connectivity across a wide range of habitat types, time and space.		arge of groundwater into depressions on the flats. This creates annual cycles of inundation of, and flow gh, a complex network of intermittent streams, freshwater wetlands, samphire channels and mudflats,
months through brackish to saline conditions occur across the Hindmarsh Island flats. Melalei trees are sparse and are being planted around some of these samphire areas to increase habitats are considered important to the natural hydrological regime on Hindmarsh Island maconnectivity and diversity on the islands, which in turn supports significant ecological common and intermittent nature of these habitats may mean they play a key role in the delivery and		whire channels, with open areas of mudflat that receive flow during winter and dry off over the summer his through brackish to saline conditions occur across the Hindmarsh Island flats. Melaleuca halmatuorum are sparse and are being planted around some of these samphire areas to increase habitat value. These ats are considered important to the natural hydrological regime on Hindmarsh Island maintaining habitat ectivity and diversity on the islands, which in turn supports significant ecological communities. The seasonal intermittent nature of these habitats may mean they play a key role in the delivery and cycling of sediments nutrients, however this is a knowledge gap.
	Moreover, because the habitats of Hindmarsh Island connect fresh conditions of the lake to estuariness conditions of the estuary and Coorong lagoons, they represent the last remnants of these transitional has were irreversibly damaged by the construction of the barrages. As such, species that depend on varia regimes which are not provided in the greater lake environment can reside and breed on and around Hindmarsh Island.	
Limit of acceptable change—rationale		

Type O: Permanent freshwater lakes

Ramsar wetland types	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes		
Units where found	Lake Alexandrina	Lake Albert	Tributaries
Estimated areal extent in 2005 (ha)	62,040	17,369	71
Description(s)	Lakes Alexandrina and Albert are vast beaches and pockets of reeds. Wetlar the most significant of which occur at a between the two lakes, with the EMLR. The open areas of the lakes once supp which extended for several kilometres settlement). These have since been sim of static water levels in the lakes, lakest availability from increased turbidity. Suithe near-shore, wetland and channel as	The waters of Lake Alexandrina mix with the EMLR tributary flows in this zone. In general, these areas represent the best fresh, submerged vegetation habitat in the Ramsar site in terms of species diversity and abundance, primarily because of the variable water regime and good quality water provided by tributary inflows. These localised variations in water regime are critical for some species assemblages, habitat connectivity and for providing drought refuge. Some of the submerged aquatic plants now considered extinct in the lakes themselves still occur in the tributaries.	
Key biological components supported and how	Fringing lakeshore habitats are important for a range of fauna, but they are believed to be depauperate in species such as Baumea spp., that rely on variable water regimes for growth and reproduction (Ganf, 2002) and thus are mostly confined to the tributary influenced areas. River Murray confluence has several drains, backwaters and freshwater lagoons and includes Pomanda Island, an area of extensive reedbeds that dries when river/lake levels are low (e.g. Wedderburn and Hammer, 2003) which also supports these less common species. Areas containing variable water regime dependent emergent plants from the Eleocharis, Schoenoplectus, Baumea or Cyperus genera and/or submerged plants from the Vallisineria, Chara, Nitella, Ottelia, Villarsia and Potamageton genera are now under-represented in the lake environment. Ottelia ovalifolia appears to be locally extinct (Mallen, van der Wielen, Hammer and Muller, obs.). Submerged aquatic plants are critical habitat for a range of small- and large-bodied native fish. Lake Albert has a more restricted range of freshwater fish (14 species) than Lake Alexandrina (25 species). Table 4.1: Wedderburn and Hammer, 2003) see Section 5.6.1) although the open water areas of the lakes were not adequately sampled for safety reasons. This difference in fish diversity is likely to be indicative of the more restricted submerged vegetation cover, higher salinities and the lack of connectivity to sources of variable inflows (such as the tributaries provide for Lake Alexandrina) in Lake Albert compared to Lake Alexandrina. The relative importance of the open water habitat of the main lake body for sustaining ecological communities has not been well studied, with the majority of surveys having focused on the near shore, more highly productive areas. For example Wedderburn and Hammer (2003) did not sample the open water sections of the lakes, and felt that this may have influenced the data recorded in the 2003 survey for some fish species which		These areas are important as habitat for a wide range of fauna. They are believed to contain species such as Baumea spp., Eleocharis spp., Schoenoplectus pungens and Cyperaceae that are now under-represented in the lakes units. These plants rely on variable water regime for growth and reproduction (Ganf, 2002 cited in DWLBC, 2005) which is provided for by EMLR tributary inflows. The plant species of these wetlands are declining in cover and are threatened by reduced water regime variability and shifts in inflow seasonality by water resource development.
Limit of acceptable change—rationale	5% (areal extent)—these areas play important ecological roles. 0% (Tributaries water regime—see Section 6.6 also)—the patterns and volumes of EMLR tributaries need to be maintained to maintain these habitats.		

Type O: Permanent freshwater lakes



Traffic light assessment

Type O wetlands are abundant in the Ramsar site but those with clear, cool water, as in the Tributaries unit, are rare and under extreme threat from water resource development and increasing lake turbidity levels. Fringing lake habitats support species assemblages that once extended much further into the lake and thus are important and extremely vulnerable remnants. The turbidity of the main lake bodies needs to be below 90 NTU and the abundance and health of variable water regime-dependent biota higher for the rating to be 'green'.

Type P: Seasonal /intermittent freshwater lakes



Traffic light assessment

The wetlands are important remnants of the pre-European lower River Murray system that support RSBC and other species of note. They are considered to be under extreme threat and highly vulnerable because of relatively small area, location near areas of intensive human activities and capacity to support under-represented ecosystem components and processes.

Ramsar wetland types	Р	P Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes	
Units where found	Lake	Alexandrina	
Estimated areal extent in 2005 (ha)	120		
largest and falls into the Type P category. It lies to the southwest of Wellington of With extensive but degraded fringing vegetation (reeds and sedges). The categrazed, cropped and contains a dairy on the eastern edge. Pelican Lagoon its		and complexes that fill at higher lake levels occur near the River Murray confluence. Pelican Lagoon is the stand falls into the Type P category. It lies to the southwest of Wellington and contains extensive mudflats extensive but degraded fringing vegetation (reeds and sedges). The catchment for Pelican Lagoon is d., cropped and contains a dairy on the eastern edge. Pelican Lagoon itself is used as a point for water action. It is connected to the River Murray by a channel that is maintained and is one of a few wetlands in region that could have pool level connection to the River Murray.	
components supported and how for wo that the species Consider		at connectivity between wetland and the River Murray important in supporting ecological communities itated with this habitat type and providing connectivity between a range of diverse habitats important drerbirds. The reliance on topography at the confluence and river flows for water regime variability means this habitat type is not common in the very static environs of Lake Alexandrina and thus it is core habitat for es reliant on variable water regimes. dered critical bird habitat for waterbirds, waders and waterfowl (Paton, 2000) (see Section 5.4) and given meral nature also likely to be important for turtles, frogs and yabbies.	
change_rationale		real extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. abitat connectivity)—important location near confluences and thus connection between ephemeral and anent habitats.	

Type Ss: Seasonal/intermittent saline/brackish

Ramsar wetland types	Seasonal/intermittent saline/brackish/alkaline marshes/pools			
Units where found	Lake Alexandrina	Lake Albert	Tributaries	
Estimated areal extent in 2005 (ha)	15	241	48	
Description(s)	typically supports samphire vegetatio result from the competing processes of hypersaline soils and standing water. 1	similar to Type W below but dominated to n. The key determinants for samphire ver of rainfall, run-off, evaporation and saline of the mosaic of habitats thus created are the habitat connectivity (see Section 6).	getation are salinity levels, which e groundwater inputs creating	
	Polltaloch Plains (near Wellington), Hindmarsh Island and Mundoo Island have the greatest concentration of these salinas in Lake Alexandrina. Groundwater levels vary considerably on Hindmarsh Island, being highest in winter following storm events. Groundwater tends to be saline (35–55 ppt) and fills depressions on the flats forming samphire-fringed salinas and lined channels. Mundoo Island contains patches that are wet all year (due to higher groundwater table and more channel influence than Hindmarsh Island) and support more diverse and abundant reeds and sedges.	Within Lake Albert there are five areas of seasonal saline marshes, the largest and most significant is Waltowa Swamp on the eastern edge of the lake. This represents a series of separate salina basins, interconnected at high lake levels with each other and Lake Albert. Lignum and reeds occur in areas where freshwater inputs support fresher patches of soil and thus a wetter water regime.	Samphire and samphire-lignum communities associated with high elevation basins or depressions occur on the peninsula between Currency Creek and Finniss River, behind extensive reedbeds along the lake margin. These communities typically receive significant freshwater run-off as well as groundwater inputs during winter and spring which accumulates in the depressions. The water evaporates over summer through brackish to saline conditions providing a range of habitats and physicochemical environs over time and space. The salinity regime of individual depressions is affected by water regime and rates of evaporation on a seasonal basis.	
Key biological components supported and how	This habitat is important as feeding habitat for migratory waders, waterfowl, and waterbirds and after flooding, biota that could opportunistically utilise inundated brackish wetlands for breeding and feeding (EarthTech, 2003 and MDBC, 2003). The depressions that seasonally fill and dry form important mudflats in spring and summer.			
	The Poltalloch Plains area is considered critical habitat for waterfowl, waders, waterbirds (Wetland Types W, Ss) by Paton (2000) (see Section 5.4).	The high degree of interconnectedness of this site and the diversity of wetland flora enhance its capacity to support a diverse range of plants and animals. Sand dunes are often intersperse a with the salinas providing protected habitat for significant flora such as Pterostylis arenicola, Sandhill greenhood orchid and Thelymitra epipactoides, Metallic sun-orchid. (see Section 4.4.1). The Goolwa to Wellington Local		
		Action Planning group is currently preparing Discussion Paper on Waltowa Swamp. This wetland is connected to but outside the Ramsar site.		
Limit of acceptable change—rationale	0% (habitat availability)—connections	ttle area, this is a vulnerable type and plass between habitats of varying salinities, ir larly connections with wetland types Tp,	n good condition, across time and	

Type Ss: Seasonal/intermittent saline/brackish.



Traffic light assessment

This is an important wetland type in the freshwater units assemblages that connect various other wetland types. They are under threat from grazing and altered water regime. These habitats are also considered extremely vulnerable because they occur at the top of the seasonal variations in groundwater levels and thus are vulnerable to reduced hydraulic pressure and also because of trampling of brittle vegetation and pugging of anoxic soils by cattle.

easonal freshwater marshes



Traffic light assessment

Once the dominant type, these wetlands are considered to be under extreme threat because they are high-elevation wetlands dependent on variable flows and floods. They are also considered vulnerable because they connect important habitats and support ecological processes and components that are dependent on variable water regime and flooding.

Ramsar wetland types	Ts Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes		
Units where found	Lake Alexandrina	Tributaries	
Estimated areal extent in 2005 (ha)	941	96	
Description(s) Seasonal freshwater marshes occur on the Holmes Creek floodplain, on Long Island and in a strip along the shore of Lake Alexandrina from Milang north to the Mouth of the Bremer River. These wetland areas fill in winter when lake levels rise, then become disconnected from the lake acting as nurseries for frogs and turtles. Vegetation is dominated by emergent reeds and sedges as for wetland Type Tp. Holmes Creek floodplain contains a complex of high elevation wetland areas. Inundation occurs in winter when lake levels approach approximately 0.8 m AHD. Similarly, Long Island contains areas with seasonal freshwater marshes. The area of lakeshore from Milang north past the Mouths of the Angas and Bremer Rivers is described by Thompson (1986 cited in EarthTech, 2003) as an almost continuous series of temporary and permanent wetlands stretching for 5-6 km each side of Milang.		During periods of high flows in the tributaries and/or flooding in the lakes, the areas of wetland inundated around the tributary confluences increases. These higher level wetland communities blend with the wetland assemblages that require more permanent water (and thus occur down-gradient) to complete the gradation from terrestrial plant communities to obligate aquatic communities.	
Key biological components supported and how Seasonal freshwater marshes can support significant ecological communities with many species of invertebrates and plants being adapted to the wetland having a dry period. Seasonal freshwater marshes can be highly productive systems and are often important feeding habitat for waterbirds. Around Lake Alexandrina these areas are filled in winter then become disconnected from the lake and are considered especially important for frogs and turtles that feed on the abundant insects. Habitat connection to permanent inundated wetlands and channels and drains (e.g. Hindmarsh Island and Angas and Bremer irrigation channels) provides a wide range of water regimes to which different species are adapted, and effectively extends the wetland habitats. The area of this habitat type suggests that it provides a significant contribution to the diversity of the ecological communities of Lake Alexandrina.		Species such as Acacia retinodes, Swamp Wattle and Leptospermum lanigerum, Woolly Tea-tree are contained within this wetland type (EarthTech, 2003). Obligate aquatic plants include Triglochin procerum, Water ribbons, Ceratophyllum spp., Hornwort, charaphytes and Myriophyllum spp., Water Milfoil. A range of orchids, daises, ferns and grasses, including Silver Daisy-bush, Olearia pannosa var. pannosa, that are otherwise underrepresented in South Australia also occur here within or adjacent to Tookayerta Creek. The Finniss Estuary is considered critical bird habitat for waterfowl, waterbirds and the Mount Lofty Southern Emu-wren (Paton, 2000) based on the birds dependence on seasonal wetlands. Currency Creek is also considered critical bird habitat for waterfowl and waterbirds (Paton, 2000; Seaman, unpublished data), although Southern Emu-wren has not been sighted in Currency Creek in recent times, suggesting the local population may have died out (see Sections 5.4 and 5.1.3, respectively).	
Limit of acceptable change—rationale			

Type Tp: Permanent freshwater marshes

Ramsar wetland types:	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season		
Units where found	Lake Alexandrina	Lake Albert	Tributaries
Estimated areal extent in 2005 (ha)	2410	958	1106
Description(s)	Extensive reedbeds fringed both lake Muller, 2004). Distribution has change salinities prior to barrage constructior altered lake levels since barrage cor Areas near the River Murray and tribu Lake, Dog Lake and Tolderol point ar have reedbeds which have persisted (EarthTech, 2003). The Mouth of Lake Narrows supports extensive reedbed: Phragmites australis. Static water leve The wetland complexes, such as Wes Belcanoe, contain extensive reeded vegetation.	ed over time with variations in lake in (due to sea water ingression) and instruction. Utary confluences, such as Boggy rea and south towards Milang is since before barrage operations. Albert referred to as the Narrung is of Typha domingensis and els promote growth of these species. It Kilbride, Waltowa Swamp and	The bulk of the Tributary component is made up of wetlands of this type, fringing the tributary wetlands and extending into the water further around confluences. This area has supported freshwater swamp vegetation since before barrage operation. Black Swamp is a freshwater marsh (with areas of peat bog) associated with the Mouth of the Finniss River and Tookayerta Creek, with extensive reedbeds, riparian shrubs and tree species such as Eucalyptus camaldulensis, River Red Gum.
Key biological components supported and how	Emergent macrophyte beds are dominated by <i>Typha domingensis</i> , <i>Phragmites australis</i> and <i>Bolboschoenus medianus</i> . These plants often form dense stands and allow other species to colonise in the sheltered areas of the reedbeds, for example submerged plants like <i>Utricularia</i> , <i>Wolfia</i> , <i>Lemna</i> , <i>Spirodella</i> , <i>Nitella</i> and <i>Chara</i> and herbland species such as <i>Triglochin procerum</i> and <i>T. striatum</i> . Species under-represented in the Type O wetlands such as <i>Baumea</i> spp., <i>Eleocharis</i> spp., <i>Schoenoplectus pungens</i> and <i>Cyperaceae</i> can be found at confluences and tributary influenced areas due to their reliance on natural variation in water regime for growth and reproduction (Ganf, 2002). Whilst the extension of the reedbeds throughout the Lakes post barrage construction is well documented (EarthTech, 2003; DWLBC, 2005) there does not appear to be an associated expansion of rookery sites in reedbeds that have developed since the construction of the barrages (EarthTech, 2003). The reedbeds in the permanent freshwater marshes provide important refugia for biota with regard to feeding sites, areas of protection from predators (e.g. small fish, tadpoles etc.), and as breeding areas. EarthTech (2003) and Pedler and Mallen (2001 cited in EarthTech, 2003) found that the most diverse plant assemblages associated with this habitat type were usually in sites found behind the main lakeshore ranging from shallow depressions to large freshwater swamps, and areas in the Finniss River, Tookayerta Creek and Currency Creek tributaries where wave action was limited.		
	The areas of reedbeds that were recorded as waterbird rookeries pre-barrage construction still exist and support seasonal breeding colonies. Waterbird breeding areas on Lake Alexandrina include: Tolderol Point—Snake Island, Mosquito Point—Boggy Lake area, South of Milang, Kindaruar Corner – Reedy Point, Opposite Clayton – Goat Island, Goose Island, Finniss River Mouth, Currency Creek Mouth, Salt Lagoon islands, Coolindawerh Lagoon, Rat Island and Rushy Island (EarthTech, 2003) (see Section 5.3). Other areas of extensive and dense emergent vegetation include: Loveday Bay, connection between Mud Island and long Island, Pelican Lagoon, River Murray confluence near Wellington and tributary confluences.	The reedbeds in the Narrung Narrows and other areas have become noted as long term rookery sites for several species of lbis, Spoonbill and Cormorants. The protected shallow wetland areas on the inshore areas of the reedbeds are important habitat for small fish species (MDBC, 2003). (see Section 5.3). In Lake Albert, this habitat is identified as critical bird habitat in the following areas (from Paton, 2000): Narrung Narrows—waterbirds and ibis (area incorporates Tp, O, W and Ss habitats) Reedy Point—waterbirds, pelicans (Tp, O) Waltowa Swamp—waterfowl, waterbirds, waders (Tp, O) Waterbirds, waders (Tp, Ss, W) Waringee Point—waterfowl, waders (Tp, O) (see Sections 5.3 and 5.4). Phragmites beds on Lucerne Island and Lake Albert Station also important (MDBC, 2003).	The tributary wetlands provide freshwater habitats that were once more widespread in Lakes Alexandrina and Albert. Mount Lofty Southern Emu-wren (see Section 5.1.3) utilise the wetlands at the termini of Finniss River and Tookayerta Creek for feeding amongst the dense vegetation. Juncus pallidus, in particular, is an important food plant providing the birds with insects (Fletcher, 1915). Since land clearance, they have been forced to also utilise the tributary wetlands as nesting sites (Littley and Cutten, 1994 as cited by Kahrimanis et al., 2001). Submerged macrophytes such as Myriophyllum sp., Water Milfoll and Ceratophyllum demersum, Hornwort occur in dense beds throughout this area. These types of macrophytes are critical for spawning and habitat of a range of obligate freshwater fish which rely on the fresh, cool, clear water (see Section 4.8.1). Emergent and herbland plant species of note include:

Key biological components supported and how (continued)	The entrance to Wallowa Swamp is considered critical abilitat for threatened small native fish species by Wedderburn and Hammer, (2003) (see Section 5.6.1). Notaby Murray Hardyhead was recorded for the first fime in Lote Albert at this wetland entrance. Be wall and the section of the secti
components supported and how	eal extent)—this type plays important ecological roles. bitat availability)—all aspects of habitat availability considered important for maintaining species blages. Maintaining connectivity between Tp, O, W, Xf and Ss types is considered essential.

Type Tp: Permanent freshwater marshes



Traffic light assessment

Urgent need to reverse the simplification of the emergent vegetation communities around the lakeshore that has resulted from static regulated lake levels to ensure on-going provision of habitat for RSBC and other species. Diverse emergent and submerged wetland vegetation are considered keystone assemblages for the freshwater units. Given the above, plus poor current condition and diversity, and high exposure to human activities, these wetland types are considered to be under threat and extremely vulnerable.

Type W: Shrub-dominated wetlands



Traffic light assessment

Samphire communities cover relatively large areas of both the fresh and estuarine-saline units. They are however under threat from activities such as cattle grazing and alterations to groundwater and surface water dynamics. Although abundant, these wetlands are not given a 'green' rating primarily because of threats from land and water resource development to habitat connectivity between wetlands of this type and types Tp, O, Xf and Ss.

Ramsar wetland types	W	W Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils		
Units where found	Lake Alexandrina		Lake Albert	
Estimated areal extent in 2005 (ha)	2190		525	
Description(s) The reedbeds around the lake margins grade into lignum and samphire flats as elevation or from the lake increases. These samphire and lignum flats are relatively flat and receive regul when the lake level exceeds approximately 0.85 m AHD. Evaporation provides the saline soil samphire vegetation with intrusions of freshwater provided via static and raised lake levels at from wind action. Shrub-dominated wetlands in Lake Alexandrina have undergone a number of changes in docondition since European settlement, primarily due to variations in salinity between 1880s and intrusions pre-barrages), the higher and more static lake margin post-barrage construction at clearance and grazing. They now fringe many parts of the lake, although they are subject to most areas. This is also the dominant habitat type along the northern edge of Lake Albert as edges of Type Ss and Tp wetlands.		ts are relatively flat and receive regular fresh flushes D. Evaporation provides the saline soils needed by the ded via static and raised lake levels and wave splash andergone a number of changes in distribution and variations in salinity between 1880s and 1940s (sea water e margin post-barrage construction and agricultural land the lake, although they are subject to cattle grazing in		
Key biological components supported and how	Melaleuca halmatuorum, Swamp Paperbark depending on the water regime. The close association with other plant communities are an important feature of the habitat value of samphire shrublands samphire species include Halosacrcia pergranulata ssp pergranulata, Black Seed Samphire; Sclerca arbuscula, Shrubby Samphire; Suaeda australis, Austral Seablite, and species of Sarcocornia (Earth Refer to Brandle (2002) for listing of additional samphire species. Remnant samphire communities support diverse faunal assemblages. When combined with lignum paperbarks they become important rookery sites, and also offer sheltered feeding grounds in semi lagoons (MDBC, 2003). For example, Coolinderwerh Lagoon is a swamp paperbark fringed samphire.		ng on the water regime. The close associations thus made of the habitat value of samphire shrublands. Dominant opergranulata, Black Seed Samphire; Sclerostegia Seablite, and species of Sarcocornia (EarthTech, 2003). especies. I assemblages. When combined with lignum or also offer sheltered feeding grounds in semi-permanent goon is a swamp paperbark fringed samphire wetland	
	representing habitat that is now considered very rare in the Lakes. Samphire wetlands Type W occur in a number of areas which are considered as critical habitat for waterbir (from Paton, 2000): • Hindmarsh Island and other barrage islands—waterfowl, waders, waterbirds, and Cape Barren Geese (including habitat types W, 4) • Milang shore—waterfowl, waders, waterbirds (W, Ts, 4, Tp) • Milang Town—Latham's Snipe (W) • Wellington Point—Darters, waterbirds (W) • Poltalloch—waterfowl, waders, waterbirds (W, Ss) • Yalkuri and Salt lagoon—waterfowl, waders (Tp, W, Xf). • Cormorant nesting site Salt Lagoon Conservation Park, Lucerne Island (W, Xf) (see Sections 5.3 and 5.4) Other locations supporting W type wetlands include: Holmes Creek, Boggy Creek, Goolwa Channel, Mundo Channel, Murray Mouth Mud Island Game Reserve Island and Clayton—Goat and Goose Islands (MDBC, 20). The samphire flats near the Mouth of the Angas and Bremer Rivers are connected to overland flow, from the Angas River in particular, and lie adjacent to other valuable habitats such as submerged vegetation in irrigative contents.		which are considered as critical habitat for waterbirds owl, waders, waterbirds, and Cape Barren Geese (includes owl, waterbirds, and Cape Barren Geese (includes owl, Tp)). k, Lucerne Island (W, Xf) olmes Creek, Boggy Creek, Goolwa Channel, Mundoo and Clayton—Goat and Goose Islands (MDBC, 2003). emer Rivers are connected to overland flow, from the	
Limit of acceptable change—rationale 5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connections between Tp, O, W, Xf and Ss considered essential.				

Type Xf: Freshwater tree-dominated wetlands



Traffic light assessment

These trees are under extreme threat of local extinction due to their poor current condition at most freshwater remnant sites supported by River Murray flows. Once a dominant wetland type, the trees, and the species dependent on them (e.g. birds of prey), are considered extremely vulnerable, based on the lack of regular recruitment and their very small areal coverage. Local replanting efforts require additional resources to be truly effective at arresting the decline.

Ramsar wetland types	Xf Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils					
Units where found	Lake	Alexandrina	Tributaries			
Estimated areal extent in 2005 (ha)	100		10			
Description(s)	Alexa locat Sali Co Dui Hol Bog fring Hur Cui Pape confil (e.g.	leuca halmatuorum, Swamp Paperbark distribution in the Lake andrina component of the Ramsar site is very patchy, with stands ed at: Lagoon linderwerh Lagoon mes Creek floodplain aging salinas (Type Ss) yndgate' freshwater channels neter Creek confluence with Coorong rency Creek confluence with Lake Alexandrina. In-bark primarily occurs in two habitats in Lake Alexandrina: near uences (e.g. Holmes and Hunters Creeks) or fringing saline lagoons Coolinderwerah) in association with samphire, native grasses, dunal is and/or reeds depending on water and salinity regimes.	Melaleuca halmatuorum, Swamp Paperbark forms woodlands at the confluence of Currency Creek and Lake Alexandrina, on the northern banks. Water regime is highly dependent on lake levels, wind direction and speed.			
Key biological components supported and how	Gum fringe sites i asser range (MDE Gree hydro esse het pro bre pro pro gree pro Gree	Melaleuca halmatuorum is the only wetland tree species in the bulk of the Ramsar site given that River Red Gums are restricted to the Tributaries. Coolinderwerh Lagoon and Dunn's Lagoon are swamp Paperbark fringed wetlands representing habitat that is now considered very rare in the lakes. The wetland flora at these sites is complex, driven by variation in soil salinity levels and topography. These habitats support diverse faunal assemblages, with the paperbarks being important rookery sites and nesting and foraging grounds for a wide range of waterbirds (Jensen et al., 2000). They also offer sheltered feeding grounds in semi-permanent lagoons (MDBC, 2003) (see Section 5.4). Greenway (1997) discusses some further direct benefits from Melaleuca halmaturorum. These include hydrological and ecological benefits such as: improved water quality and controlled sedimentation by filtering sediments essential cycling of carbon, nutrients and contaminants between rivers and estuaries (food source for heterotrophic micro-organisms and detritivores) provide long-lived temporary and permanent habitat for a variety of flora and fauna, including roosting and breeding areas for wildlife particularly colonial nesting birds providing a protective physical buffer and flood mitigation between shorelines and water bodies act as long-term biomass sinks and drought refugia provide groundwater recharge areas and thus freshwater source for people and wildlife provide valuable food sources for migratory birds that rely on nectar during autumn and winter months. Greenway, M. (1997) Wetlands in a Dry Land: Understanding for Management, Albury, New South Wales, 29–30. Environment Australia.				
Limit of acceptable change—rationale	ecolo 0% (a	2% (areal extent, whole site)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (areal extent, Hindmarsh Island)—critical location and under-represented type 0% (habitat connectivity)—critical connections to types Tp, O, W, Xf and Ss.				

Type 4: Seasonally flooded agricultural land



Traffic light assessment

A 'green' rating has been given to this wetland type because it is not under threat but rather promoted by human activities, particularly by the active management of 'Wyndgate' to provide wetland habitats of this type for Cape Barren Geese (see Section 5.5.1).

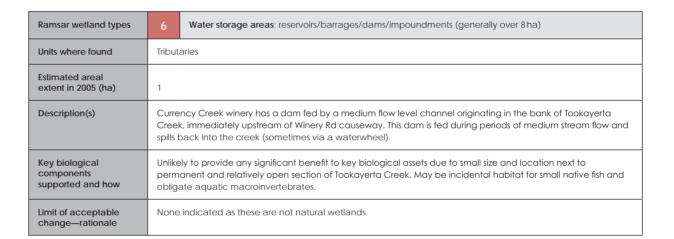
Ramsar wetland types	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)				
Units where found	Lake Alexandrina	Tributaries			
Estimated areal extent in 2005 (ha)	1175	60			
Description(s)	Grazing and cropping land on Hindmarsh and Mundoo Islands and on Mosquito Point between Boggy Lake and Dog Lake.	Low-lying agricultural land within the floodplain of the Finniss River, primarily upstream of its confluence with Tookayerta Creek is subject to seasonal inundation. The majority of this land is or has been used for growing flood or pivot irrigated lucerne crops. Perennial horticulture tends to occur higher on the sandy and limestone rises, out of the wetland area, although vineyards are often planted to break of slope which may be within 100 m of the wetland edge depending on topography.			
Key biological components supported and how	Close-cropped or grazed pastures that are drying off are considered important habitat for Cape Barren Geese on Hindmarsh and Mundoo islands (R. Seaman, pers. comm.), thus the DEH-owned property 'Wyndgate' is in part managed to provide these pastures for Cape Barren Geese (see Section 5.5.1). Swans may also be utilising 'green pick' on grazing lands as a replacement for main native food plants from the Coorong area that are in severe decline (e.g. Ruppia spp.) (see Section 6).	It is assumed that agriculture on these floodplain areas is not intensive or regular. The greatest impact has been land clearance and flow manipulation in the past which has lead to reduced habitat extent and connectivity. It may be that the pasture areas provide 'green-pick' for waterbirds particularly in areas where the aquatic plant distribution and abundance has declined and thus native food sources are limited.			
Limit of acceptable change—rationale	None indicated as these are not natural wetlands. NB: 'Wyndgate' property on Hindmarsh Island contains flooded agricultural land managed for Cape Barren Geese (see Section 5.5.1).				

Type 6: Water storage areas



Traffic light assessment

Dams of this nature are common in the landscape surrounding the Ramsar site, and as are Type 4 wetlands, they are promoted by human activities rather than threatened.



Type 9: Canals and drainage channels, ditches



Traffic light assessment

Although constructed, these channels are valued for providing fresh, flowing, clear, cool habitats that are now under-represented at this Ramsar site. These sites support RSBC, particularly small native fishes (see Section 5.6.1). They are threatened by dredging, infilling and the shutting down of pumps during critical flow periods.

Ramsar wetland types	9 Canals and drainage channels, ditches				
Units where found	Lake Alexandrina		Lake Albert	Tributaries	
Estimated areal extent in 2005 (ha)	28		1	15	
Description(s)	Constructed channels are concentrated at the River Murray confluence, along the shore of Lake Alexandrina from Milang north to the Mouth of the Bremer River and on Hindmarsh Island. Some channels are modified natural channels whilst others have been constructed by evacuating the lake floor and/or floodplain. The main purpose of most of these channels is to feed water to pumps situated at the landward end (50–250 m from lakeshore). Some of the channels on Hindmarsh Island were originally constructed for management of saline groundwater and surface run-off and are generally considered under wetland Type M above. Only a small area of 1 ha of this type of habitat is found within the bounds of Lake Albert. These are located on Lake Albert Station road and on Narrung Peninsula.			Irrigation channels used to deliver Lake Alexandrina or surface tributary water to irrigation pumps occur along the shore near Currency Creek Game Reserve.	
Key biological components supported and how	The key ecological function of irrigation channels in the lakes area is provision of fresh, flowing water habitats, which support extensive edge habitat and a high complexity of habitat types within close proximity. The irrigation channels which line the Lake Alexandrina from the Mouth of the Bremer River to the Mouth of the Angas River provide a simulated freshwater flow (due to pumping up the channel) which in turn provides habitat for submerged aquatic plants and small native fish such as Southern Pygmy Perch. These are considered critical habitats for restoration works by Wedderburn and Hammer, (2003), particularly given that flow rates in both the Angas and Bremer Rivers have declined in recent decades due to water resource development. Irrigation drains near the Murray confluence are also key habitats and add to the complexity of habitats in that area (see Section 5.6.1). The channels on Hindmarsh Island provide unique fish habitat and have the potential to provide through-flow from the lakes to the Coorong. See discussion above under Type M.			These channels tend to support dense stands of submerged aquatic vegetation such as Ceratophyllum spp., Hornwort, charaphytes, Vallisineria sprialis, Water ribbons and Myriophyllum spp., Water Milfoil and are lined with reeds, mostly Phragmites and Typha. Given that this type of submerged vegetation is under-represented these channels are considered critical habitats for small native fish (particularly those that are dependent on natural flow patterns) and are considered targets for restoration works by Wedderburn and Hammer, (2003) (see Section 4.8.1).	
Limit of acceptable change—rationale	10%—these are not natural wetlands but are considered important habitat because type is now rare in freshwater units.				

■ 4.2 Estuarine-saline system units

4.2.1 Murray Mouth and Estuary

Qualitative description

This component of the Ramsar site includes the Murray Mouth from the Goolwa Barrage to Pelican Point, including the Goolwa, Coorong and Mundoo channels (See Figures 6 and 11). Area: approximately 3,400 ha.

Prior to European settlement, flows of River Murray water out of the Mouth exceeded 2,000 ML per day, more than 95% of the time (Sim and Muller, 2004) and were adequate to maintain an open Murray Mouth. Geomorphological studies show that the Murray Mouth has been open for at least 6,000-7,000 years (Barnett, 1991 and Bourman, expert panel). The location of the Murray Mouth has varied over a range of approximately 6 km during the last 3,000 years and over 1.4 km in the last 160 years (Bourman and Murray-Wallace, 1991).

As DJ Walker (2002) writes:

'According to Barnett (1995) the general layout of the River Murray Mouth was finalised around 6,000 years ago when sea level rises and the subsequent formation of sand barriers (Sir Richard and Younghusband Peninsulas) enclosed the Lakes (Alexandrina and Albert) and the Coorong. Based on sediment cores taken in Lake Alexandrina, Barnett was able to provide a description of the lakes over the last 7,000 years ... A key conclusion of the work is that for much of its history the river flows have been sufficient to keep the Lakes fresh, and at a pool level that was similar to that maintained by the barrages (pers. comm. Bourman, 2001).'

The Mouth closed for the first time since formation in 1981. Between 2000 and 2002, the Murray Mouth almost closed again and since 9 October 2002 dredges have been operating to pump sand out of two channels (one leading from the Mouth to the Goolwa channel and the other to the Coorong) and onto the ocean beach. The dredged channels keep the Mouth open and provide 'fresh', oxygenated sea water to the Coorong lagoons, without which oxygen levels would decline and temperatures would rise to beyond threshold levels for most Coorong biota.

The character of the Murray Estuary is now determined largely by seawater inflows and outflows, with periods of freshwater inflows from the River Murray regulated by the barrages (MDBC, 2005). The Murray Mouth is a tidal inlet restricted by the accumulation of dune material on the flanking spits of Sir Richard Peninsula and Younghusband Peninsula (Bourman and Harvey, 1983) cited in MDBC, 2002). It is located in the high-energy

environment of the Southern Ocean, with deposition of sediment (sand) inside the Mouth a function of tidal action counterbalanced by outflows from the Murray over the barrages and water levels in the estuary area. The area is highly dynamic. Single storm events can shift massive amounts of sand (MDBC, 2002). The location, size and shape of the Mouth and the adjacent estuary are variable, dictated by a combination of river flows, tidal flows and ocean and coastal processes (Jensen et al., 2000; MDBC, 2002). River regulation and water resource development of the River Murray catchment, resulting in reduced river flow at the Mouth and the construction of the barrages has lead to a progressive silting of the Murray Mouth. The capacity of tidal flows to transport sand into the Mouth area is a power function of the tidal velocity so even low or small river flows have the potential to reduce the sediment load being carried into the Mouth by the tide (MDBC, 2002). The issue in recent times is the increase in the frequency and duration of periods of zero or very low river flows, which allows a greater amount of sediment to be transported into the Mouth culminating in the closure of the Mouth in 1981 and its severe constriction since 2001. Whilst there have been restrictions in the Mouth in the past, the severity of the sedimentation in recent times is considered much more severe and likely to persist unless there is intervention (MDBC, 2002). Until river flows through the Murray Mouth are increased, the system will be reliant on dredging to keep the Mouth open and maintain exchange between the ocean and the Coorong.

A large variety of habitats are represented in the Murray Mouth and Estuary component ranging from freshwater marshes to intertidal forested wetlands. Recreation in the form of boating, fishing, swimming and camping is concentrated in this component of the Coorong and Lakes because of relatively easy access and close proximity to Adelaide. This is the only estuary in the Murray-Darling Basin and the only natural exit for catchment water and mobilised sediments and salts.

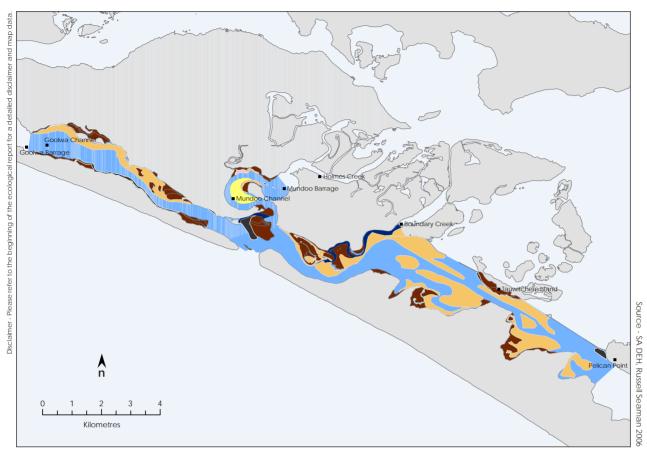


Figure 11 - Map of the Murray Mouth and Estuary showing the various wetland types

Key	Key to wetland types				
Α	Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits				
D	Rocky marine shores; includes rocky offshore islands, sea cliffs				
Ε	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks				
F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas				
G	Intertidal mud, sand or salt flats				
Н	Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes				
-	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests				
J	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea				
К	Coastal freshwater lagoons; includes freshwater delta lagoons				

4.2.2 North Lagoon

Qualitative description

A long coastal lagoon stretching from Pelican Point to Parnka Point. Approximately 50km long with an average width of <3km. Area: approximately 11,069 ha.

The North Lagoon may be classified as estuarine-saline. with salinity controlled by freshwater inflows (primarily from the Tauwitcherie Barrage), tidal exchange through the Murray Mouth, evaporation and inflows of hypersaline water from the South Lagoon (Lamontagne, et al., 2004). Rainfall on the lagoon itself can also be significant. As a consequence of these factors, the North Lagoon has a salinity gradient with lower salinity in the northwest (as low as 5 ppt during times of freshwater inflow) and higher salinity towards the Needles and the connection to the South Lagoon (up to 90 ppt during low flow periods). Horizontal salinity gradients can form in the water column suggesting stratification under certain conditions (Geddes, 2003). The highest readings in the North Lagoon were in March 1982 (up to 65 ppt) and January 2003 (up to 90 ppt), both periods were preceded by Murray Mouth closure (1981) and severe constriction (2001) and long periods of barrage closure (Geddes, 2003), Large volumes of fresh water are required to lower the salinity gradients significantly following long periods of barrage closure because of the large volumes of water held in the Coorong lagoons and the high salinities reached through evaporation in the intervening months/years.

Although the North Lagoon is a permanent waterbody, the area of inundation varies both diurnally and seasonally with the tide and inflows, resulting in the exposure of mudflats and intertidal marshes along the shoreline (Boon, 2000). This area provides important habitat for a large number of waterbirds, including migratory shorebirds, which are recorded in high numbers during spring and summer (Oborne, 2003). The permanent waters of the North Lagoon once contained extensive beds of submerged vegetation, dominated by Ruppia megacarpa. Large numbers of waterfowl consumed the leaves, seeds and turions of the Ruppia, which also provided physical habitat for fish and aquatic invertebrates (Oborne, 2003). In addition, the submerged vegetation provided much of the detritus in the North Lagoon, and as such, this habitat provides the food source for detritivores such as fish and macroinvertebrates. In recent years, these beds of R. megacarpa have been lost and the more salt tolerant R. tuberosa is colonising from the South Lagoon (Nichols, 2005).

Under natural conditions, the North Lagoon was dominated by tidal input of marine water and River Murray inputs at its northern end (Gell and Haynes, 2005). The construction of the barrages in the 1930s-1940s has resulted in a severe reduction in the area of estuarine habitat in the North Lagoon and disrupted the transition between fresh and saltwater conditions (Jensen et al., 2000). This is evidenced by the decline in marine influence since the 1940s and a simultaneous increase in turbidity (Gell and Haynes, 2005). Saline to hypersaline conditions (equal or greater than sea water) now dominate the North Lagoon, and as such much of the estuarine (lower than sea water) adapted flora and fauna is no longer present. Fish populations have declined due to the reduction in estuarine area, as many species are dependant on estuarine salinities to trigger reproduction and recruitment. Only scattered remnants of Melaleuca halmatuorum, Swamp Paperbark, occur in this component (no forest areas) and they are not considered a dominant wetland type. The reduction in reedbed habitat has reduced habitat suited to waders. In addition, constrictions at the Murray Mouth have lead to a decrease in flushing, which has negative impacts on submerged vegetation and promotes conditions more suitable for phytoplankton growth (Jensen et al., 2000). The loss of these keystone submerged plant assemblages will ultimately mean the loss of dependent fauna. Once aquatic plants are lost from a system, an 'alternate steady state' can be reached where algae dominate primary production. If this occurs it is very difficult to move back to a plant-dominated system even if freshwater flows are returned (Scheffer et al., 2001; Davis et al., 2003).

The construction of the barrages in the 1930s-1940s has resulted in a severe reduction in the area of estuarine habitat in the North Lagoon and disrupted the transition between fresh and saltwater conditions.

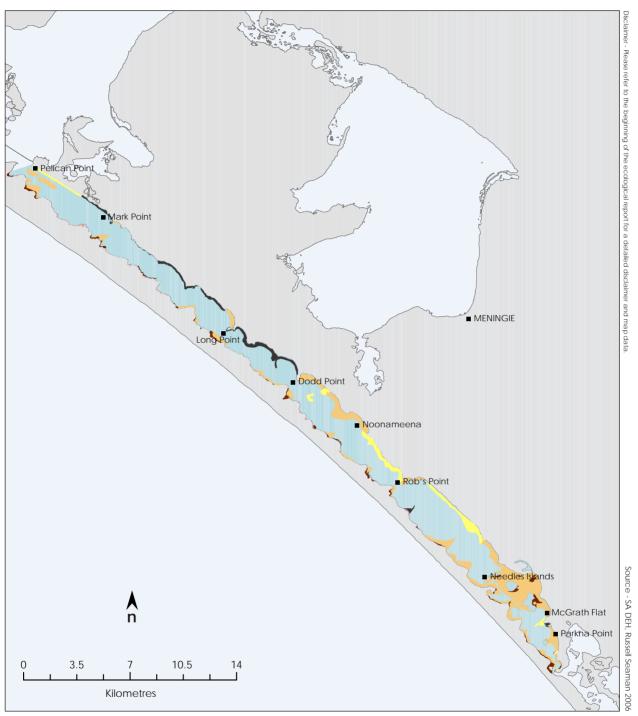


Figure 12 - Map of the North Lagoon showing the various wetland types

Key	Key to wetland types				
D	Rocky marine shores; includes rocky offshore islands, sea cliffs				
Е	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks				
G	Intertidal mud, sand or salt flats				
Н	Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes				
J	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea				
К	Coastal freshwater lagoons; includes freshwater delta lagoons				

4.2.3 South Lagoon

Qualitative description

A long, narrow coastal lagoon extending from Parnka Point to 42 Mile Crossing, comprising the southern most arm of the Coorong. Area: approximately 9,440 ha.

The South Lagoon of the Coorong is a saline-hypersaline permanent waterbody that is connected to North Lagoon by a narrow channel at the northwest end. Water levels vary seasonally by approximately 0.9 m (Lamontagne et al., 2004), being higher in winter and lower in summer, resulting in the seasonal exposure of extensive areas of mudflats which provide foraging and nesting habitat for large numbers of waterbirds. At its southern end, the South Lagoon grades through an annually drying section into a series of shallow and ephemeral salt lakes (Boon, 2000). Salinity in the South Lagoon is controlled by inflows from the North Lagoon, rainfall on the lagoon surface, evaporation, openness of the Murray Mouth and historical inflows of fresh water from groundwater via soaks and the South East of South Australia via Salt Creek. These latter two inputs have been reduced significantly since European settlement due to drainage, land clearance (altering groundwater recharge) and localised water resource development.

Under natural conditions, marine flushing strongly influenced the South Lagoon although less frequently or to a lesser extent than the North Lagoon. Areas at the southern end of South Lagoon may have occasionally become hypersaline prior to European settlement but show biota indicative of regular freshwater inputs presumably from the South East rather than the River Murray. The South Lagoon became more turbid perhaps as early as the beginning of European settlement and more saline after 1940 with further increases in salinity after 1980 (Gell and Haynes, 2005).

River Murray inflows have little direct influence on the water quality of the South Lagoon but indirectly affect it via North Lagoon water quality and inputs such as salt and silt accumulating in the lagoons. River Murray flows also indirectly impact on the South Lagoon by keeping the Murray Mouth open and thus maintaining connectivity between the lagoons and the Southern Ocean. If the connection to the sea is lost or constricted, the volumes of water that enter the Coorong exceed that which leave the Coorong on any given tidal cycle. Therefore water levels in the Coorong lagoons increase, drowning out mudflats and causing major changes to ecological processes such as denying access to mudflats by waders. Water temperatures and salinities also increase with evaporation over summer creating a stratified water column that becomes poor in dissolved

oxygen. Such a scenario is devastating to all biota of the Coorong lagoons and prevention of these physicochemical conditions has been the primary purpose of dredging the Murray Mouth to maintain oceanic exchange since 2001.

As a consequence of the interactions of the above drivers and levers, the South Lagoon has a salinity gradient with lower salinity in the northwest (as low as 20 ppt during times of freshwater inflow) and higher salinity towards the southern end and the boundary of the National Park (up to 140 ppt during low flow periods). The highest readings in the South Lagoon were in recorded in March 1983, 1984 and 1985 (up to 140 ppt) and January 2003 (up to 110 ppt), both periods were preceded by Murray Mouth closure (1981) or severe constriction (2001) and long periods of barrage closure (Geddes, 2003). Once such extremely high salinity levels are reached, large volumes of fresh water are required to lower the salinity gradients significantly and flush out the accumulated silts and salts. Meanwhile, irreversible changes can occur to the ecological character of the salinised wetland because salinity and turbidity levels and sedimentation rates exceed the thresholds for many ecosystem components and processes.

Historically, the submerged annual plant Ruppia tuberosa dominated these areas, and is the primary diet of a number of waterbirds (Oborne, 2003). During spring as water levels recede, Ruppia tuberosa sets seeds and retreats to its underground organs (turions). When water levels rise again in autumn and winter, seeds and turions germinate and sprout (Jensen et al., 2000) and grow to match the rising water levels, forming blankets that float over the water surface and provide cover for fauna when in dense stands. Other submerged aquatic plants such as Lamprothamnion sp. once made up a significant proportion of the submerged biomass in these plant beds but are now considered locally extinct in the Coorong lagoons. Recent surveys, recorded only sparse shoots of Ruppia tuberosa and the biota in general was considered to be extremely depauperate (see Section 5.4). Coupled with the loss of other intertidal habitats, this has impacted on waterbird populations that relied on these habitats and food sources for feeding and/or nesting (see Section 6.3-Keystone species). Redirected groundwater and surplus surface water from the Upper South East Drainage Scheme may be a source of fresh inflows for the South Lagoon. These flows are currently capped at 40,000 ML per annum on a 10 year rolling average. This cap is currently under review by the Commonwealth Government and may soon be varied.

Such freshwater inflows may be of benefit to the declining submerged vegetation of the South Lagoon provided that the water is of good quality. Decreased tidal exchange and flushing has also resulted in an increase in turbidity and nutrients in the South Lagoon, impacting negatively on submerged vegetation and favouring of phytoplankton (Lamontagne et al., 2004).



Murray Mouth closure 1981

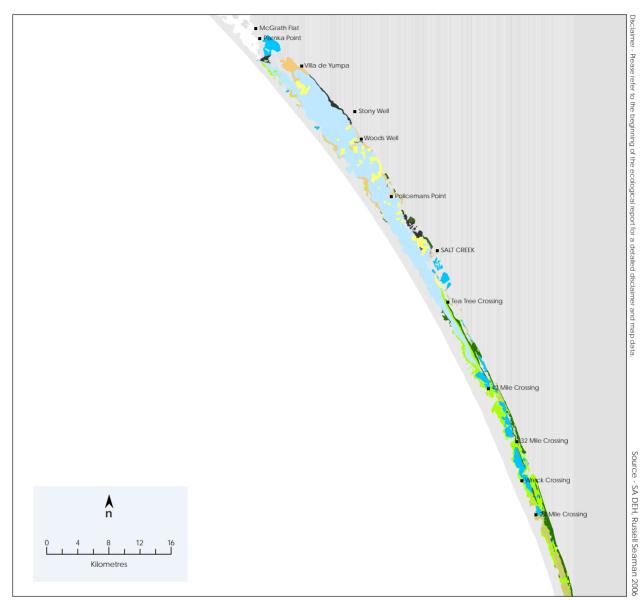


Figure 13 - Map of the South Lagoon showing the various wetland types

Key	Key to wetland types					
D	Rocky marine shores; includes rocky offshore islands, sea cliffs					
Е	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks					
G	Intertidal mud, sand or salt flats					
J	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea					
М	Permanent rivers/streams/creeks; includes waterfalls					
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats					
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools					
W	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils					
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils					
Υ	Freshwater springs; oases					

4.2.4 Wetlands types and Ramsar significant biological components within the estuarine-saline system units (organised alphabetically by Ramsar type code)



Traffic light assessment

Estuarine waters once dominated the whole Coorong, Murray Mouth and Estuary area and are now restricted to just those times and places where freshwater inflows are great enough to reduce salinities to significantly below that of sea water. Consequently, this wetland type now acts as refuge for estuarine species and is considered extremely vulnerable. It is also considered to be under extreme threat from on-going low flows from the River Murray causing increasing salinity and turbidity and effective loss of estuarine conditions.

	,			
Ramsar wetland types	A	Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits		
	F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas		
Units where found	Murra	Murray Mouth and Estuary		
Estimated areal extent in 2005 (ha)	A = 50, F = 2200			
Description(s)	Permanent, shallow waters that once would have alternated between fresh estuarine and saline conditions (MDBC, 2002) but are now dominated by sea water due to low river flows and dredging of channels creating permanent connection to the sea.			
Key biological components supported and how	components For example juvenile stages of Mulloway are reliant on access to protected marine or estuarine waters for			
Limit of acceptable change—rationale	5% (areal extent)—this plays important ecological roles.			





Traffic light assessment

This wetland type is ecologically important. The rocky, intertidal pools and shores are under threat of loss from smothering due to the high rates of sedimentation occurring in the Coorong. Vulnerability is considered high because of the relatively thin tidal band occupied by this type and the relatively low areal extent.

Ramsar wetland types	D Rocky marine shores; includes rocky offshore islands, sea cliffs			
Units where found	Murra	y Mouth and Estuary	North Lagoon	South Lagoon
Estimated areal extent in 2005 (ha)			226	351
Description(s)	shore: the M	ed patch of rocky inland s of approximately 40 ha in undoo Channel comprised posed calcrete outcrops.	A thin band of rocky shoreline occurs along the north western shoreline of North Lagoon.	Isolated patches of inland rocky shorelines occur in the northern part of South Lagoon.
Key biological components supported and how	Rocky marine shores of this nature are important in stimulating which thrive in the warm pools which establish in between tide cycling and for providing macroinvertebrates and algae to see bird foraging especially egrets and larger waterbirds (see Secti areas becomes important nesting sites for waterfowl such as pareas (Oborne, 2003). Cladophora and other macroalgal specinundation and there are abundant 'tube worms' (Ficopomath and North Lagoon. Although there is evidence of abundant 'tu (perhaps 40 years ago) in South Lagoon they are not considered. These rocky shores are at risk from being smothered with sedim odoriferous mud overlain by calcifying algae has formed 5–15c near Wood's Well (see Section 7.2).		establish in between tides. Such system tebrates and algae to seed the main warger waterbirds (see Section 5.4). As was for waterfowl such as pelicans and Cand other macroalgal species can be for tube worms' (Ficopomatus enigmaticus evidence of abundant 'tube worms' (Ficopomatus enigmaticus evidence are not considered to be curred ing smothered with sediments and decains.)	uch systems are important areas for nutrient he main water body. They are important for 5.4). As water recedes in the spring these ans and Caspian tern, particularly in the island can be found in the areas subject to regular nigmaticus) in the Murray Mouth and Estuary worms' (Ficopomatus enigmaticus) in the past o be current residents.
Limit of acceptable change—rationale	2% (areal extent)—there is relatively little area of this type, it is under threat from sedimentation and it plays important ecological roles.			

Type E: Sand shores and dunes



Traffic light assessment

This wetland type is considered to be under threat from wind and water erosion, exotic plant domination and recreation impacts. They are also vulnerable systems because of their dynamic morphology.

Ramsar wetland types	E Sand, shingle or pebble shore humid dune slacks	s; includes sand bars, spits and sandy isl	lets; includes dune systems and
Units where found	Murray Mouth and Estuary	North Lagoon	South Lagoon
Estimated areal extent in 2005 (ha)	56	246	717
Description(s)	The Murray Mouth is the only break in c. 140 km of oceanic sand dunes along the two peninsulas. Sandy shores and bays occur between Goolwa Channel, Sir Richard Peninsula and Bird Island, with spits and sand bars near the Murray Mouth. Bird Island has only formed since the construction of the barrages. Sections of narrow sandy shorelines occur in patches along the Coorong. For example, between the township of Salt Creek and Parnka Point on the landward side of South Lagoon. There are also distinctive bands of sand flats around Type R wetlands, along the coastal dune-wetland interfaces and between the coastal dunes and the lagoons. Sand bars also form between the dunes and the lagoon. Recreation is focussed in the Murray Mouth Estuary and the northern end of North Lagoon around this wetland type.		
Key biological components supported and how	Marsh saltbush and native and exotic grasses are the dominant plant associations within the sand dunes of the Murray Estuary (Brandle, 2002). Significant dunal species include Scaevola calendulacea Dune fanflower (see Section 5.1.1). These areas provide habitat for water rats, and terrestrial mammals such as kangaroos and emus as well as feeding grounds for birds such as parrots (Brandle, 2002). The close proximity of aquatic and terrestrial habitats is considered very important component of ecological character. The spits and sand bars and Bird Island are important waterbird habitats.		
Limit of acceptable change—rationale	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.		

Type G: Intertidal mud, sand or salt flats



Traffic light assessment

This wetland type is vital for waders and is considered to be under extreme threat from increased sedimentation and changes to the organic carbon and sediment profiles. These sites are also extremely vulnerable because of the short life cycles and species-specific salinity tolerances of the decomposers and the macroinvertebrates that utilise these habitats and provide feed to waders (see Sections 5.4 and 6.3).

Ramsar wetland types	G Intertidal mud, sand or salt flats			
Units where found	Murray Mouth and Estuary		North Lagoon	South Lagoon
Estimated areal extent in 2005 (ha)	700		1480	962
Description(s)	Fine to medium sands with a relatively of microbial mats comprised of cyand (Dittman et al., 2005). Inundation is vatide) and seasonally (Diittman et al., 2 water level changes (regime). Groun dune system are driven by 'moon tide Coorong lagoons can rise before surfmay generate head differences. Preliminary information on invertebrate diversity is relatively higher in the Murr to the North Lagoon which is higher the communities are comprised of crusta (Diittman et al., 2005).		ariable both diurnally (with the 2005) and provides the drivers for dwater inflows from the coastal is in autumn thus water levels in the ace water inflows commence which es suggests that abundance and ay Mouth and Estuary compared than the South Lagoon. These	Fine to medium sands occur at either end of the lagoon and coarse sands occur in the middle sections with a very low organic content, and an absence of microbial mats (Diittman et al., 2005). The South Lagoon of the Coorong is not strictly an intertidal lagoon as tidal influence is minimal, but this is the best description of this habitat in terms of wetland types. Water levels vary seasonally, being higher in winter than summer, but diurnal variability due to tidal influence is minimal (Diittman et al., 2005). Groundwater inflows from the coastal dune system are driven by 'moon tides' in autumn thus water levels in the Coorong lagoons can rise before surface water inflows commence. Invertebrate abundance and diversity is very low compared to North Lagoon and Murray Estuary (Geddes, 2003; Diittman et al., 2005) and is comprised of salt-tolerant insects such as the chironomid Tanytarsus barbitarsus (Boon, 2000; Geddes, 2003).
Key biological components supported and how	This wetland type represents an important foraging area for waders given the high concentration and diversity of macroinvertebrates (MDBC, 2002) (see Section 5.4). Also important feeding ground for fish when inundated (Brandle 2002) (see Section 5.6.2). The maximum natural rate of sedimentation rate of the Coorong was <1 mm/yr. This has increased to in excess of 15 mm/yr, representing a more than 70-fold increase in sedimentation rate near Salt Creek since European settlement (Gell and Haynes, 2005). Such an increase in clay-based sediments has major implications for intertidal ecosystem processes and components (see Section 6.2). 2% (areal extent)—while there is significant area, this is vital for wading birds.			9
				near Salt Creek since European
Limit of acceptable change—rationale				

Type H: Intertidal marshes

Traffic light assessment

This wetland type once dominated the tidal influenced units and is now under-represented. As such it represents an extremely threatened and vulnerable refuge area for ecosystem processes and components that will be relied upon to expand into other areas of the Ramsar site once estuarine conditions are restored.

Ramsar wetland types	H Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes		
Units where found	Murray Mouth and Estuary	North Lagoon	
Estimated areal extent in 2005 (ha)	369	167	
Description(s)	These wetlands are areas that are inundated diurnally with tidal flow along the Goolwa channel and into the North Lagoon. They also receive some freshwater inputs from local catchments and groundwater.		
Key biological components supported and how	The saline waters samphire (e.g. Salicornia blackiana) and saltmarsh species with macroalgal mats of cyanobacteria underneath occur in these wetlands (Boon, 2000). Some areas (e.g. Tauwitchere Point) contain areas of lignum and Typha (Brandle, 2002) and other salt-tolerant sedges (Juncus kraussii and Bolboschoenus caldwellii) (Brandle, 2002).		
	These areas are considered important foraging areas for rails, crakes and waterhens, nesting habitats for a range of waterbirds as well as refuge areas for small native fish (Brandle, 2002). Cape Barren Geese have also been recorded utilising this wetland type in the Murray Mouth and Estuary unit (Brandle, 2002) (see Sections 5.3, 5.4 and 5.5).		
Limit of acceptable change—rationale	2% (areal extent)—there is relatively little area and it plays important ecological roles.		

Type I: Intertidal forested wetlands



Traffic light assessment

Critical remnants considered threatened by altered water regime and increased salinities and vulnerable due to low rates of recruitment and relatively old age and poor condition of many trees. There is an urgent need to rehabilitate this wetland type and provide missing habitats for colonial birds and birds of prey.

Ramsar wetland types	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests		
Units where found	Murray Mouth and Estuary		
Estimated areal extent in 2005 (ha)	4		
Description(s)	Small area (approximately 4ha) in the Mundoo Channel near the confluence of Hunter's Creek and Murray Mouth Estuary.		
Key biological components supported and how	Swamp Paperbark (Melaleuca halmaturorum) forms the overstorey with low sedge and shrubs beneath (Brandle, 2002). M. halmatuorum has been planted along the Goolwa channel but there are no intact forest remnants. The trees represent an important nesting site for a range of waterbirds (Jensen et al., 2000). In addition, the reedbeds provide nesting and foraging habitat for some waterbird species and, when inundated, habitat for aquatic invertebrates (see Xf following and Section 5.3).		
	When inundated, this would become habitat for small fish as well as foraging habitat for piscivorus waterbirds (see Section 5.4).		
Limit of acceptable change—rationale	0% (areal extent)—there is little area, this is a vulnerable type and it plays important ecological roles.		

Type J: Coastal saline lagoons



Traffic light assessment

The miniature 'coves' described in the Murray Mouth and Estuary unit are unique, poorly described and considered highly important habitats that are vulnerable because of their morphology and dependence on localised recharge-discharge rates. The coastal saline waters that form the North and South Lagoons may cover a vast area but they are in such poor condition as to be likely to undergo an irreversible shift in ecological character within the next few years unless there is significant management intervention in the near future. Immediate reductions in salinity and turbidity levels and re-establishment of Ruppia spp. beds are required to prevent this occurring (see Sections 6 and 8).

Ramsar wetland types	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea			
Units where found	Murra	ay Mouth and Estuary	North Lagoon	South Lagoon
Estimated areal extent in 2005 (ha)	2		8910	1218
Description(s)	Tidal lagoons and creeks occur on the coastal dune system between Younghusband Peninsula and North Lagoon. Miniature coves have formed within the sand dunes and samphire lagoons with vegetation similar to wetland Type H occur on the fringes of these coves. Freshwater soaks, driven by recharge through the encircling sand dunes, provide sufficient freshwater to support Phragmites (and in some cases Typha) at the break of slope and drain into the 'cove' features.		Permanent, shallow estuarine-saline water body that ranges from 5 ppt salinity at the northern end in periods of high freshwater inflows to 90 ppt near the connection to South Lagoon during periods of no or low flow.	Permanent, shallow saline-hypersaline water body that ranges from 20 ppt salinity at the northern end in periods of high freshwater inflows to 140 ppt at the southern end during periods of no or low flow.

» continued »

Key biological components supported and how

These are unique features that represent a more natural Coorong environment on a micro-scale and thus provide habitats for a range of remnant and threatened species and an opportunity to fill knowledge gaps on ecosystem components and processes.

Little is known about these miniature 'coves' but it is likely from the habitat types, condition, high levels of connectivity and location near the Murray Mouth that they would be important fish nursery and spawning sites. These sites do not represent a significant percentage area cover of this component but they are unique and are likely to be of disproportionally high value ecologically.

The waters of North Lagoon once supported extensive beds of Ruppia megacarpa, locally known as 'blanket weed'. In recent years these beds have been lost (Nicol, 2005). Ruppia tuberosa, the dominant species in the South Lagoon, has started to colonise the North Lagoon, presumably because of increasing salinities (due to decreased freshwater inputs) and lack of competition with Ruppia megacarpa (Nicol, 2005). Seagrasses (Zostera and Heterozostera) have been recorded (Boon, 2000) but are considered locally extinct.

Submerged aquatic plant beds such as Ruppia are the keystone to the Coorong ecosystem and provide foraging for waterfowl such as swans and ducks as well as habitat for estuarine and marine fish (Oborne, 2003) (see Section 6)

The invertebrate fauna in the North Lagoon was considered to be a restricted euryhaline estuarine-lagoon assemblage composed of polychaete worms, crustaceans and molluscs (bivalves and gastropods) that tolerate salinities from near freshwater to approximately 55ppt (Geddes, 1987 cited in Geddes, 2003). However, these species are now missing from most of the North Lagoon sampling locations (Geddes, 2005 and see Section 5.4). A reduction in abundance of species and restriction of distribution patterns. most likely related to high summer salinities, has been recorded since 1980s (Geddes, 2003).

The waters of South Lagoon once supported vast beds of submerged aquatic plant species dominated by Ruppia tuberosa (Nichols, 2005). These beds have effectively been lost from the South Lagoon due to increased salinity and turbidity (Paton (2005) and see Section 5.4)

Other submerged species previously recorded in South Lagoon included Lamprothamnium and Lepilaena (Boon, 2000) but these species were not found in recent surveys (Geddes, 2003) and are presumed locally extinct.

The water column provides habitat for phytoplankton and salinity tolerant macroinvertebrates such as shrimps and copepods (Boon. 2000). In 2005, for the first time the macroinvertebrate community was dominated by brine shrimp (indicating a fundamental shift in ecological character see Section 5.4)

Fish such as Southern Bream and Yellow-eye Mullet were recorded in the South Lagoon in 1985 (Boon, 2000), Small-Mouthed Hardyheads were the only species able to tolerate hypersaline conditions in 2000 (Boon, 2000), However, it appears that even the Hardyheads are no longer thriving in the hypersaline conditions of the South Lagoon as Geddes (2003) found the numbers of Hardvhead in South Lagoon were very low compared to abundances recorded in the 1980s, Paton (2005) concludes.

The water column provides habitat for phytoplankton and macroinvertebrates such as amphipods and copepods (Brandle, 2002). Sampling in June-July 2003 recorded no seagrasses or estuarine macrophytes in the Murray Mouth and North Lagoon (Geddes, 2003). Brown algae Gracilaria and filamentous algae (Enteromorpha and Rhizoconium) were recorded in North Lagoon and the Murray Mouth.

Limit of acceptable change-rationale

2% (areal extent)—while there is significant area, it plays important ecological roles. 0% (Murray Mouth and Estuary)—the unique 'cove' features are considered critical remnant habitats.

Type K: Coastal freshwater lagoons



Traffic light assessment

These wetlands are the only source of fresh water for many terrestrial species as well as being important habitats, per se. The remaining springs are considered extremely vulnerable because of their dependence on undisturbed rechargedischarge processes and their declining quantity and water quality. They are also considered under extreme threat from land and water resource development and altered surface-groundwater interactions.

Ramsar wetland types	K Coastal freshwater lagoons; includes freshwater delta lagoons		
Units where found	Murra	ay Mouth and Estuary	North Lagoon
Estimated areal extent in 2005 (ha)	1		40
Description(s)	Isolated patches of discharging fresh groundwater appear along the dunes, particularly the southern shore of North Lagoon. Freshwater soaks are formed when fresh water that is recharged through the dunes collects as a lens-shaped freshwater aquifer above the saline water that lies around it (Mooney, 1982 as cited in Winter and Squire, 2003). In some areas, water collects in depressions or swales and forms soaks. Standing water may be present in winter drying to damp conditions in summer (Winter and Squire, 2003). There is a strong association with un-vegetated dune systems due to increased rates and volumes of recharge, and thus discharge, from unvegetated areas. Bands of <i>Phragmites</i> reeds hug the dunes in areas where recharge provides their freshwater needs.		
Key biological components supported and how	Dense stands of freshwater reeds form around freshwater soaks, at the base of un-vegetated dunes and at the Mouths of the miniature coves described in Type J above. Often associated with samphire communities, these patches of reeds provide a range of birds with nesting and foraging habitat. These soaks also support a range of other shrubland and emergent wetland flora including Juncus spp. Rushes, Schoenoplectus pungens Spiky Club-rush, Samolus repens Creeping Brookweed, Apium prostratum ssp prostratum Native Celery, Triglochin striatium Streaked Arrow-grass and Sporobolus virginicus Salt Couch (Winter and Squire, 2003). Freshwater soaks along the Younghusband Peninsula may provide the only freshwater source and wetland habitat for many flora and fauna, including kangaroos and emus throughout much of the year (Winter and Squire, 2003). Anecdotal evidence suggests that the pressure, quality and number of soaks has decreased steadily since the 1940s to the point that terrestrial fauna, such as emus, are required to dig for water (see Section 7). See Type Y following also.		
Limit of acceptable change—rationale	0% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.		

Type I: Permanent rivers/streams



Traffic light assessment

Salt Creek is undergoing another period of change in water regime due to regulation of flows from Morella Basin and it contains significant stands of Gahnia sp. (see Section 5.2.1). Based on this it is considered extremely vulnerable and under extreme threat.

Ramsar wetland types	М	Permanent rivers/streams/creeks; includes waterfalls		
Units where found	South Lagoon			
Estimated areal extent in 2005 (ha)	5			
Description(s)	Austro consi to this as to a seri for co	Creek is a natural discharge point for the extensive wetlands and watercourses of the South East of South alia and parts of western Victoria to drain into the South Lagoon. These freshwater inflows would have been derable and regular prior to European settlement. Modifications to these flows began in 1865 and continue stay (England, 1993). Long-term residents report that the flow through Salt Creek was so great in some years be heard approaching like a roaring train (see long-term stakeholder comments below). In recent years, es of deep drains have been constructed that redirect groundwater into Morella Basin which holds water ontrolled releases into the South Lagoon via Salt Creek (capped at 40,000ML per annum on a 10 year graverage).		
components supported and how		nia sedgelands (see Section 5.2.1) and extensive mudflats support a wide range of biota.		
		real extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.		

Comments on Salt Creek from one of the long-term stakeholders—as recorded fully in Section 7:

Frank Gibbs - Coorong fisher and hunter from the 1930s to the present

Water would rush in down at Salt Creek from the South East. We once had to move a Model T-Ford out of a swamp at Martins Washpool because we heard the water coming and we had to get to high ground. It came like a torrent. It sounded like a train, roaring down.

There were masses of birds, thousands of them, ducks and swans mostly all the way to Salt Creek, a place that also used to be the best place to catch Mulloway and bream—they would teem around Salt Creek Island.

Type R: Seasonal/intermittent saline lakes



Traffic light assessment

Although covering a large area, this wetland type is still considered vulnerable because of dependence on close connections with other habitats, and the need for high lagoon levels and/or winter rainfalls for inundation.

Ramsar wetland types	R Seasonal/intermittent saline/brackish/alkaline lakes and flats				
Units where found	South Lagoon				
Estimated areal extent in 2005 (ha)	1689				
Description(s)	Intermittent lakes fill at high elevations around the South Lagoon when lagoon water levels rise and catchment water inflows occur in winter. Extensive salt flats and salinas occur across this area that connect and disconnect over time and space. Supporting samphire shrublands (Ss, W), interspersed with Melaleuca halmaturorum Swamp paperbark				
	woodlands (Xf) and mudflats (G).				
Key biological components supported and how	These wetlands have extensive samphire coverage and are interspersed with other samphire shrublands (Ss, W) interspersed with <i>Melaleuca halmaturorum</i> Swamp paperbark woodlands (Xf) and mudflats (G). This habitat is considered to be very important for Black-winged and Banded Stilts and smaller waders such as Red-capped Plovers (see Section 5.4) as well as a range of other terrestrial and aquatic biota.				
	Whilst not well understood, nutrient and carbon cycling between the lagoon and adjacent fresh, saline and hypersaline samphire and <i>Melaleuca</i> mudflats is believed to be an important feature of the ecology of the lagoon.				
Limit of acceptable change—rationale	5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connects to types G, W, Ss and Xf at high elevations around the lagoon.				

Type Ss: Seasonal/intermittent saline marshes



Traffic light assessment

This type of wetland is well represented in area but is still considered to be vulnerable. This is based primarily on threats to the maintenance of habitat connectivity between these wetlands and Types G, W, R and Xf at high elevations around the South Lagoon. This rating takes into account that this type is partly found within Coorong National Park, and these areas receive management attention.

Ramsar wetland types	Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools				
Units where found	South	South Lagoon				
Estimated areal extent in 2005 (ha)	985	985				
Description(s)	ı	A chain of intermittent saline marshes (salinas), that interconnect with larger salt lakes (Type R) and wetland types G, W and Xf, occur between 42 Mile Crossing and the southern edge of the Coorong National Park.				
Key biological components supported and how	mosc All as	These small saline marshes support complex samphire communities (e.g. Salicornia blackiana) and exist in a mosaic of habitats with wetlands of Types R, Xf and W to form a complex blending of wetland floral assemblages. All aspects of habitat availability are important across this mosaic. Very important habitat for Black-winged and Banded Stills and smaller waders such as Red-capped Plovers (see Section 5.4).				
	l	ent and carbon cycling between these interconnected habitats is considered important for ecosystem ponents and processes, but is poorly understood.				
Limit of acceptable change—rationale		real extent)—this type plays important ecological roles. abitat connectivity)—connects to ypes G, W, R and Xf at high elevations around the lagoon.				

Type W: Shrub dominated wetland



Traffic light assessment

The mosaic of Gahnia sp. (see Section 5.2.1) and M. halmaturorum represents vital habitat that is considered to be under threat due to this wetland type's reliance on freshwater inflows and the likely conversion from W to Ss if inflows reduce. These wetlands are also considered vulnerable because the species assemblages are under-represented at a State level, have very fine tolerances for water regime and are difficult to re-establish if lost.

Ramsar wetland types	W Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils		
Units where found	South Lagoon		
Estimated areal extent in 2005 (ha)	2160		
Description(s)	The Type W samphire communities are supported by a fresher water regime than the Ss communities and are not dominated by evaporating salinas. They are however connected to Type Ss, Xf and R wetlands and form part of a mosaic from fresh to hypersaline wetland habitats.		
	Approximately 90% of this habitat occurs as extensive bands of interconnected wetland assemblages between the Princes Highway and South Lagoon south of Salt Creek and extends as patches north of Salt Creek. The main stands occur in the area between the Loop Road and the highway.		
Key biological components supported and how	Gahnia filum Saw rush (see Section 5.2.1) occurs in dense stands across the lagoon flats and grades into samphire flats/depressions, Melaleuca halmaturorum Swamp paperbark and/or coastal dune vegetation depending on water regime, soil types and elevation. Gahnia sedgelands occur on both the coastal and landward side of South Lagoon and are considered vulnerable in the SA agricultural district (see Section 5.2.1).		
Limit of acceptable change—rationale	5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connects to types G, R, Ss and Xf at high elevations around the lagoon.		

Type Xf: freshwater, tree-dominated wetlands



Traffic light assessment

Large areas of this wetland type remain around South Lagoon but they are considered to be under threat from land and water resource development and vulnerable because they represent the only wetland tree in the bulk of the Ramsar site and as such perform myriad ecosystem processes.

Ramsar wetland types	Xf Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils			
Units where found	South Lagoon			
Estimated areal extent in 2005 (ha)	1345			
Description(s)	These wetlands are dominated by Melaleuca halmaturorum Swamp paperbark woodlands. They occur at a similar elevation to Type W wetlands (Gahnia sedgelands) but tend to occur on calcrete outcrops rather than in swales as Type W do.			
Key biological components supported and how	Bands of <i>Melaleuca</i> occur in close association with coastal dune vegetation and Type W, R and Ss wetlands. They are concentrated between the edge of the South Lagoon seasonal lakes and the highway and are not common on the coastal side of the lagoon. Approximately 90% of this wetland type occurs in an assemblage of G, R, Ss, W and Xf wetlands that extends south of Salt Creek to the Coorong National Park boundary. North of Salt Creek, dense woodlands surround Type R seasonal salt lakes with large forests occurring opposite Gemini Downs.			
	Swamp Paperbark woodland (Melaleuca halmaturorum) provides important nesting and foraging grounds for a wide range of waterbirds (Jensen et al., 2000) and have been directly and indirectly linked with a range of ecological and hydrological functions by Greenway (1997) such as: • improved water quality and controlled sedimentation by filtering sediments • essential cycling of carbon, nutrients and contaminants (food source for heterotrophic micro-organisms and detritivores) • provide long-lived temporary and permanent habitat for a variety of flora and fauna, including roosting and breeding areas for wildlife particularly colonial nesting birds • providing a protective physical buffer and flood mitigation between shorelines and water bodies • acting as long-term biomass sinks and drought refugia • provide groundwater recharge areas and thus freshwater source for people and wildlife • provide valuable food sources for migratory birds that rely on nectar during autumn and winter months.			
Limit of acceptable change—rationale	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat connectivity)—connects to Types G, R, Ss and W at high elevations around the lagoon.			

Type Y: Freshwater springs



Traffic light assessment

There has been a marked decline in the number of active soaks—see comments from Ngarrindjeri and long-term stakeholders below—and the quality and quantity of water in those that remain. These soaks are considered to be under immediate and extreme threat of loss as a habitat type and vulnerable to changes in groundwater dynamics, reduced recharge in recent years and surface disconnection by animals digging for water. Their loss would be catastrophic to the terrestrial and aquatic fauna biota of the Younghusband Peninsula in particular.

Ramsar wetland types	Υ	Freshwater springs; oases				
Units where found	South	Lagoon				
Estimated areal extent in 2005 (ha)	<10	<10				
Description(s)	epher than 3 Section shape 2003).	In 2001, eight freshwater soaks were located along the margins of South Lagoon and an additional four in the ephemeral lagoon section south of South Lagoon (Winter and Squire, 2003). Prior to 1970s there were more than 30 active soaks along the banks of the South Lagoon and on the Coorong islands (see Section below and Section 7). Freshwater soaks are formed when fresh water that is recharged through the dunes collects as a lens-shaped freshwater aquifer above the saline water that lies around it (Mooney, 1982 as cited in Winter and Squire, 2003). In some areas, water collects in depressions or swales and forms soaks. Standing water may be present in winter, drying to damp conditions in summer (Winter and Squire, 2003).				
Key biological components supported and how	Freshwater soaks along the Younghusband Peninsula may provide the only freshwater source and wetland habitat for many flora and fauna throughout much of the year (Winter and Squire, 2003). These soaks support a range of shrubland and emergent wetland flora including samphires, Juncus spp. Rushes, Schoenoplectus pungens Spiky Club-rush, Samolus repens Creeping Brookweed, Apium prostratum ss prostratum Native Celery, Triglochin striatium Streaked Arrow-grass and Sporobolus virginicus Salt Couch (Winter and Squire, 2003).					
Limit of acceptable change—rationale		areal extent—there is little area remaining, these are a vulnerable type and play and important gical role.				

Comments on the freshwater soaks from members of the Ngarrindjeri Indigenous community and long-term stakeholders—as recorded fully in Section 7:

Ngarrindjeri community

Freshwater soaks and fresh groundwater upwellings are important sources of fresh water to the Coorong lagoons. They are the only source of fresh water for fauna on the Coorong peninsula and an important source on the mainland side of the lagoons.

The soaks on the mainland side have become too salty to drink and many have dried up. On the peninsula, the soaks are still drinkable but the salinity is rising and they are not as plentiful as they were.

Wildlife on the peninsula are now struggling to get water. Emus and kangaroos on the peninsula now need to dig down 20 cm or more into the soaks for water. This suggests a major decline in the pressures of the soaks as they used to bubble up in summer as the water levels in the lagoons dropped. When the freshwater soaks and upwellings were more active, the water would look like it was 'full of diamonds' as the fresh, cool water would rise in 'bubbles' from the sandy floor. The soaks used to support all the water needs of both the aquatic and terrestrial animals of the Coorong as well as providing the Ngarrindjeri people themselves with drinking water.

A small, orange-coloured fish would lie dormant (as eggs) in the mud of the freshwater soak areas for years at a time waiting for good conditions when they would hatch in great numbers. It is unknown which fish species this was, but it is believed that it is now extinct as they were last seen in the late 1970s. The soaks were also full of long, pink worms and were a good place to find red-bellied snakes which are now all but gone due to lack of nursery habitat.

Bob Hera-Singh—Coorong fisher and hunter from the 1940s to the present

Freshwater soaks would teem with ducks and swans. It was clean clear water in the Coorong. Kurrawong, a property south of Salt Creek, had 10-foot deep holes with water flowing in from the South East, underground. It's now dry and grazed.

Frank Gibbs—Coorong fisher and hunter from the 1930s to the present

The freshwater springs would run a lot of water in, easily as much as Salt Creek. It was really fresh.

Ramsar significant ecological communities and species



The Ramsar site is a complex mosaic of wetlands supporting many ecosystems and flora and fauna species of significance locally, regionally, nationally and, in some instances, globally.

Ramsar significant ecological communities and species

As indicated in Section 3.5, the Coorong and Lakes Ramsar site aualifies against 8 of the 9 criteria for determining Wetlands of International Importance (see Appendix C). One of these (Criterion 1) relates to the unique wetland system and in this case its mosaic of 23 different wetland types that provide a diverse array of habitats supporting a range of ecological communities and species. Section 4 considered these different wetland types from the perspective of the interplay between the drivers, levers, components and processes.

Section 3.5 provided a summary of the ecological communities and species that contribute to qualifying this site against Ramsar's 'biodiversity' criteria, in this case Criteria 2–8. In the following Sections, these communities and species are examined in more detail, and where possible, limits of acceptable change have been recommended. Traffic light assessments (see Section 2.6) have also been provided.

The organisation of this Section is as follows:

- 5.1 The site supports globally and nationally threatened species and communities (Ramsar Criterion 2)
- 5.1.1 Endangered and vulnerable plant species
- 5.1.2 Swamps of the Fleurieu Peninsula
- 5.1.3 Mount Lofty Ranges Southern Emu-wren
- 5.1.4 Orange-bellied Parrot
- 5.1.5 Southern Bell Frog
- 5.2 The site supports a high diversity of species and assemblages important for conserving biodiversity at the bioregional scale (Ramsar Criterion 3)
- 5.2.1 Gahnia vegetation association
- 5.3 The site supports animal taxa at critical stages of their life cycle and during drought (Ramsar Criterion 4) -breeding wetland-dependent birds
- 5.4 The site supports significant numbers and diversity of wading birds, including migratory species listed under the JAMBA and CAMBA agreements (Ramsar Criteria 3, 4, 5 and 6)
- 5.5 The site supports a diverse community of wetlanddependent bird species (Ramsar Criteria 3 and 5) 5.5.1 Cape Barren Goose

- 5.6 The site supports significant numbers and diversity of native fish, including migratory species (Ramsar Criteria 3, 7 and 8)
- 5.6.1 Obligate freshwater species
- 5.6.2 Diadromous species
- 5.6.3 Euryhaline or estuarine species
- 5.6.4 Marine 'straggler' species

■ 5.1 The site supports globally and nationally threatened species and communities (Ramsar Criterion 2)

As indicated in the draft revised Ramsar Information Sheet (RIS) for this site (see Appendix C), the Coorong and Lakes Ramsar site provides habitat for a number of globally or nationally threatened taxa as well as one critically endangered ecological community (as listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999). This includes the following, for which detailed information is provided in the sub-sections indicated.

- 5.1.1 Endangered and vulnerable plant species
- 5.1.2 Swamps of the Fleurieu Peninsula
- 5.1.3 Mount Lofty Ranges Southern Emu-wren
- 5.1.4 Orange-bellied Parrot
- 5.1.5 Southern Bell Frog

In addition to these species, there are a further five fish and one bird species that help qualify the site under this criterion (see Tables 6 and 7, respectively). These have been considered as part of appropriate species groupings in Sections 5.3-5.5.

5.1.1 Endangered and vulnerable plant species

Qualitative description

The (draft revised) Ramsar Information Sheet for the Coorong and Lakes Ramsar site (Appendix C) includes reference to the seven species that are listed as either endangered or vulnerable under the EPBC Act. The details are provided in Table 9.

While these species are notable, relatively little is known of their habitat needs and full distribution across the Ramsar site. The South Australian Bio-survey database was the source for the locality information for these seven species, but it is not based on a comprehensive survey covering the whole Ramsar-listed area. It seems likely that such a comprehensive survey would yield more site and habitat data for these significant plants and make it possible to provide details of the ecological drivers and processes associated with those parts of the system they occupy. As can be seen from the tabled information, this



Sun Orchid, Thelymitra species

preliminary data suggests that these species occupy a range of niches, from riparian heath to coastal dunes and the islands within the South Lagoon. These clearly warrant further field investigation so that ecological character benchmarking can be developed for them also.

Of note here is that two (and possibly more) of these species have been, or are at present being considered within recovery plans, the details of which are given below:

- the Eyre Peninsula Regional Recovery Plan includes Olearia pannosa ssp pannosa and Thelymitra epipactoides. This will no doubt help clarify some issues with respect to the distribution and abundance of these two species on the Eyre Peninsula at least
- Thelymitra epipactoides was previously considered in the Recovery Plan for 25 Threatened Orchid Taxa of Victoria, South Australia and NSW 2003–2007 (Coates et al., 2003). This reveals that the wild population of the species is thought to be between 500-3000, although the plan acknowledges that surveys in South Australia are incomplete. The species is usually found in coastal heathlands, open forests and woodlands on moist or dry sandy loam soils. It is reported that species may require environmental disturbance to promote seedling recruitment or flowering (Calder et al., 1989; Coates and Lunt, 2001).

The Regional Recovery Plan for the Mount Lofty and Greater Adelaide Region of South Australia is also in preparation at present; apparently considering 10 nationally listed fauna species, 27 nationally listed flora species, one nationally listed ecological community and numerous State listed threatened species.

Another important point to note here is that during the preparation of the above list, a provisional list of approximately 140 plant species of potential interest was prepared based on a more regional perspective for the Southern Lofty and Murray botanical regions of South Australia. It would seem likely that a comprehensive plant survey within the Ramsar-listed area would show that many of these are also found there, and are contributing to the Ramsar worthiness of the site in relation to Criterion 4. It is also notable that these nearly 140 species did not include truly aquatic species; another plant group warranting priority survey attention.

Table 9 - Significant plant taxa (extract from revised Ramsar Information Sheet, Appendix C)						
Common name	Scientific name	Ramsar criteria	National Status	SA Status	System units where found (see below)	Habitat details
Family Asteraceae						
Silver Daisy-bush	Olearia pannosa ssp pannosa	2, 3	V	V	6	Riparian, dry heath
George's Groundsel	Senecio georgianus var. georgianus	2, 3	V	E	3	South Lagoon islands in association with Gahnia filum
Family Goodeniaceae						
Dune Fanflower (see Section 7.2 also)	Scaevola calendulacea	3		V	2	Coastal dune
Family Fabaceae (Legumir	nosae)	1	'		'	
Yellow Swainson-pea	Swainsona pyrophila	2, 3	V	R	3	South Lagoon islands
Family Orchidaceae						
Sandhill Greenhood	Pterostylis arenicola	2, 3	V	V	4	Shoreline
Metallic Sun-orchid	Thelymitra epipactoides	2, 3	Е	E	4	Shoreline in association with Melaleuca woodlands
Family Proteaceae						
Scarlet Grevillea	Grevillea treueriana	2, 3	V	V	3	South Lagoon islands

KEY

E – Endangered, V – Vulnerable

System units where found:

1 - Murray Mouth and Estuary, 2 - North Lagoon, 3 - South Lagoon, 4 - Lake Albert, 5 - Lake Alexandrina, 6 - Tributary wetlands

Limits of acceptable change and traffic light assessment

While there is an acknowledged gap of comprehensive survey data at present, these species are listed as endangered and vulnerable species either nationally or within South Australia. Therefore, applying a precautionary approach, the limit of acceptable change is recommended as 0%, meaning that any losses beyond natural population fluctuations should considered unacceptable until such time as further surveys provide indications of a contrary view.

Traffic light assessment







the precautionary approach. Surveys are recommended as a high priority to clarify the situation and, if indicated, to introduce specific management interventions.

Despite the lack of comprehensive data,



5.1.2 Swamps of the Fleurieu Peninsula

The swamps of the Fleurieu Peninsula (FP) are listed as a critically endangered ecological community under the Commonwealth EPBC Act. See also Section 5.1.3 following in relation to the Mount Lofty Ranges Southern Emu-wren, a nationally endangered species that relies in part on these swamps.

Qualitative description

Extracts from the 'Nomination for listing an ecological community as a threatened ecological community under section 181 of the Environment Protection and Biodiversity Conservation Act 1999.' Jointly nominated by the Conservation Council of South Australia Inc and the Nature Conservation Society of South Australia Inc 2000.

A. Summary life history details

The Fleurieu Peninsula swamps are characterised by their reedy or heathy vegetation constituents growing on peat, silt, peat silt or black clay soils.

Intact or semi-intact Fleurieu Peninsula swamp habitats typically have three distinguishable layers (which may also contain an additional emergent layer). The highest stratum is a medium to tall shrub layer, the medium stratum is a tall sedge and/or fern layer and the ground layer stratum can be a variety of herbaceous, grass or low-lying sedges.

The community is structurally diverse with 11 formations identified by Duffield, R (based on Biological Survey of South Australian Vegetation Structural Formations 1997) of varied dominant and co-dominant species, these are:

- Leptospermum lanigerum shrubland with sedge understorey
- · Leptospermum lanigerum shrubland with sedge and fern understorey
- · Leptospermum continentale shrubland with sedge understorey
- Leptospermum continentale shrubland with sedge and fern understorev
- Leptospermum continentale/Sprengelia incarnata shrubland with sedge understorey
- · Mixed Leptospermum shrubland with emergent Viminaria juncea or Acacia retinodes and sedge understorey
- · Melaleuca decussata shrubland with sedge understorev
- Leptospermum continentale/Viminaria juncea shrubland with sedge understorey
- Leptospermum continentale/Melaleuca squamea shrubland with sedge understorey

- · Mixed sedgeland (e.g. Lignum—Muehlenbeckia florulenta)
- Phragmites and/or Typha grassland with emergent Viminaria juncea, Acacia retinodes and sedge understorey.

Intact Fleurieu Peninsula swamps are characteristically a mosaic of varied structural formations which merge into one another, depending on soil, hydrology and terrain.

Scattered gums such as Eucalyptus ovata, Swamp Gum and Eucalytpus cosmophylla, Cup Gum are sometimes found around the drier edges of the swamp.

The three major types of FP swamps have been identified (largely based on geomorphology) as spring-fed, floodplains and reedlands (Littlely, 1998).

The Fleurieu Peninsula swamps occur on four main soil types (Adamson and Osborn, 1924) namely:

- · peat
- silt
- peat-silt
- · black clay soils.

B. Importance of the Coorong and Lakes Ramsar site

Apart from their conservation significance as an ecological community, according to the EPBC nominating document 'fifty percent of the native plant species recorded in FP swamps (84 species) are of conservation significance (5 of which are endangered) at the state level and 57% (96 species) have a regional conservation status (Lang, PJ & Kraehenbuehl, DN 1997).' In addition, it is stated in the nomination document that there are five plant species of national conservation significance found within the swamps of the Fleurieu Peninsula. Of these, two are now listed as endangered under the Commonwealth's EPBC Act; namely, Osborns Eyebright (Euphrasia collina ssp osbornii) and the Maroon Leek-orchid (Prasopyllum frenchii). It is not known at this time if these particular species occur within the Ramsar-listed portion of the EPBC-nominated ecological community.

As noted above, the swamps of the Fleurieu Peninsula also support, in part, the nationally endangered Mount Lofty Ranges Southern Emu-wren (see Section 5.1.3).



Part of the critically endangered Swamps of the Fleurieu Peninsula that overlap with the Ramsar-listed area

B - Importance of the Coorong and Lakes Ramsar site				
Ecologically	'The FP swamps once covered 1.8% of the Fleurieu Peninsula's 106,000 hectares but now only cover less than 0.5% (0.47%) of the Fleurieu Peninsula.			
	In 1993 only 25% of the Fleurieu Peninsula swamps' former distribution remained, the current distribution is most likely significantly less than this figure as the last seven years have seen substantial vegetation clearance, water extraction and changed land use.' (EPBC nominating document—see above).			
Areal extent within the Ramsar site in 1985	Not known.			
Areal extent within the Ramsar site in 2005	262.5 hectares approximately (see explanatory comments below).			

C. Distribution within the Ramsar area

See Figure 14 and the explanatory comments.

Explanatory comments:

This estimate of areal extent and provisional map are based on the most recent Fleurieu Wetland Inventory data plus a portion of that done by Littlely and Cutten in 1993 in relation to Mount Lofty Ranges Southern Emu-wren. It should be considered as an estimate only at this time until further surveys and spatial data analysis is done. (Advice from Tim Vale, Works/Extension Officer, Mt Lofty Southern Emu-wren and Fleurieu Peninsula Swamps Recovery Program, December 2005).



Melaleuca swamp

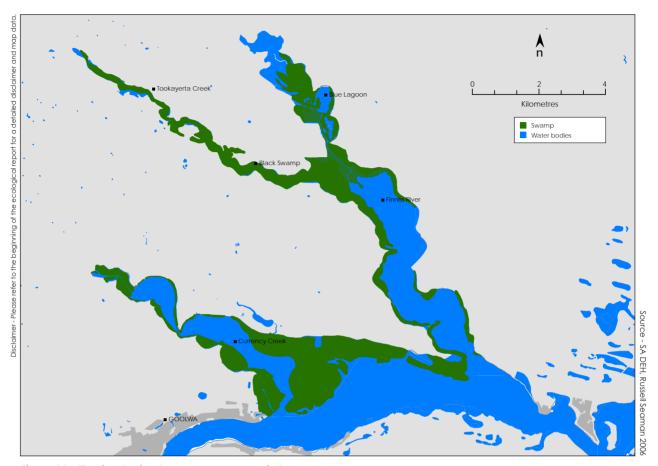


Figure 14 - Fleurieu Peninsula swamp coverage in Ramsar area

D - Key ecological and threatening processes				
Ecosystem components and processes	Description			
Water regime	High dependence on variable water regime provided by EMLR Tributary flows. 'The Fleurieu Peninsula swamps are topogenous, dependent on surface run-off and groundwater for their development (Bickford, 2000). The continued and gradual flow of springs, sedimentary aquifers and catchment processes (also deteriorating in the Fleurieu Peninsula) supports this ecosystem.' (EPBC nominating document—see above).			
Habitat connectivity	Remaining habitats are poorly connected, threatened by on-going disconnection.			
	'Fleurieu Peninsula swamps are highly fragmented, resulting in isolated parcels that are unable to support current native flora and fauna populations. Fragmentation of the FP swamps is resulting in loss of habitat for fauna and threatening the genetic diversity of the local biota.' (EPBC nominating document—see above).			
Competitive extent	Competition for available habitat is high and increasing with decreasing condition and connectivity.			
	'Continued invasion of exotic species is altering the structural composition of the understorey. Common and abundant weed species include 2 potential environmental weeds of Australia and 5 proclaimed plants in South Australia (Animal and Plant Control Act (SA) 1986). The native herbaceous ground layer of FP swamps is absent in swamps that are heavily infested with weeds.' (EPBC nominating document—see above).			
Threatening processes	Threatening processes as documented in EPBC nominating document (see above) are: • altered hydrology and catchment processes • nutrient imbalance—from pesticides, herbicides, weedicides and fertilisers • altered peat accumulation • soil disturbance • excessive (frequency and extent) and inappropriate slashing, burning and grazing • illegal vegetation clearance.			

Limits of acceptable change and traffic light assessment

It is not possible to establish the areal extent of this wetland type at or around the time the site was Ramsarlisted, and even today there are strong caveats placed on the estimated areal extent currently (see above). Further work is urged to confirm the extent of this critically endangered ecological community within the Ramsar site so that appropriate planning and management can be provided. From the perspective of setting limits of acceptable change there are three primary considerations as follows:

- 1. Areal extent—as a critically endangered ecological community this is recommended as 0%.
- 2. Condition of the wetland type—no suitable limit of change can be recommended at present.
- 3. Connectivity between wetland remnants or pockets no further loss of dryland habitats connecting these should be allowed.

Traffic light assessment



While there remain caveats on the estimated areal extent of this ecological community within the Ramsar site, this rating is given taking into consideration that the community is listed as critically endangered and that recovery actions are underway. Without the latter, the rating would be 'red'.



5.1.3 Mount Lofty Ranges Southern Emu-wren

See also Section 5.1.2 Swamps of the Fleurieu Peninsula that are listed as a critically endangered ecological community under the EPBC Act. These swamps provide some of the habitat required by the Mount Lofty Ranges (MLR) Southern Emu-wren.

Mount Lofty Ranges Southern Emu-wren							
Common name Scientific name Ramsar criteria National Status IUCN Status SA Status							
Fairy-wrens - Family Maluridae							
Mount Lofty Ranges Southern Emu-wren	Stipiturus malachurus intermedius	2, 3, 4	Е	E	E		

Qualitative description

A. Summary life history details Extracts from the Mount Lofty Ranges Southern Emu-wren Recovery Plan 1999-2003

The MLR Southern Emu-wren occurs in two broad habitat types: swamp and dry-heath. Most sub-populations occur in dense swamp (which includes wet-heath, sedgeland, reedland, and occasionally Lignum), although one of the two largest sub-populations inhabits dry-heath. These habitats are dense at the 0–1 m level. Sub-populations are apparently isolated due to the bird's poor ability to fly across open spaces, and thus may suffer local extinction due to habitat degradation, fire, flooding, predation, inbreeding depression and other factors.

The 1993 MLR Southern Emu-wren survey found 18 subpopulations (26 sites), 17 in swamps and one in dry-heath (Littlely and Cutten, 1994). Note: as indicated below the 2004 population estimate is 400-800 individuals.

Swamp habitat for the MLR Southern Emu-wren comprises peat-bog vegetation or 'open forest-wet-heath' (sensu Williams and Goodwins, 1987) dominated by Prickly Tea-tree Leptospermum continentale, Silky Tea-tree L. lanigerum, Empodisma minus, Red-fruit Cuttinggrass Gahnia sieberiana, sedges (e.g. Baumea spp., Lepidosperma spp.) and ferns (e.g. Blechnum minus, Gleichenia microphylla) ... They occasionally occur in open samphire/lignum Muehlenbeckia florulenta floodplains with cutting grass Gahnia trifida (e.g. Finniss), and reedland (primarily common reed Phragmites australis, with scattered Leptospermum lanigerum, e.g. Black Swamp).

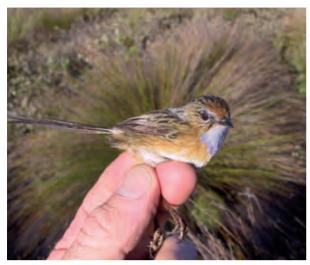
The MLR Southern Emu-wren breeds in the spring-summer months ... territories may be abandoned outside the breeding period, when Emu-wrens seem to move more widely about their habitat. In general, two broods are

raised during the spring-summer breeding season; the first during September–November, and a second during December-February.' (Pickett, in prep.).

Nests are usually situated 0–1m from the ground in dense vegetation, e.g. rush Juncus spp., Leptospermum spp. and Empodisma minus in Fleurieu Peninsula swamps.

Published information on the diet of Southern Emu-wrens is limited. Barker and Vestjens (1984) list a large variety of arthropods, chiefly insects. Common food items, recorded from stomach contents and observations of feeding are spiders, moths, butterflies, caterpillars, leaf-eating beetles, weevils, wasps, ants, bees, and water-beetles. Insect and spider eggs, seeds and pieces of vegetable matter have also been mentioned as food items (Fletcher, 1915; Morgan, 1919; Schodde, 1982).

Emu-wrens use their curved beak, flanked with stout rictal bristles to protect the eyes, to glean along the shrubbery, and occasionally hawk for prey. Fletcher (1915) reported the stems of pale rush Juncus pallidus as an important food supply, the Emu-wrens splitting open stems of reeds and rushes to obtain insects. In a common feeding method in shrubby habitat, Emu-wrens work around and up through a shrub and then flit from there down to the base of the next shrub to start again.' (Recovery plan for the Mt Lofty Ranges Southern Emu-wren Stipiturus malachurus intermedius: 1999-2003).





Mount Lofty Ranges Southern Emu-wren

B - Importance of the Co	orong and Lakes Ramsar site
Ecologically	Of the area of known habitat used by the Mount Lofty Ranges Southern Emu-wren, approximately 250 hectares (T.Vale, pers. comm, 2005) lies within the Ramsar area (see map and preceding section describing the Swamps of the Fleurieu Peninsula).
Habitat requirements	Based on the above information from the Recovery plan:
	General: swamp and dry-heath (Littlely and Cutten, 1994). Swamp habitat for the MLR Southern Emu-wren comprises peat-bog vegetation or 'open forest-wet-heath' (sensu Williams and Goodwins, 1987) dominated by prickly tea-tree Leptospermum confinentale, silky tea-tree L. lanigerum, Empodisma minus, real-fruit cutting-grass Gahnia sieberiana, sedges (e.g. Baumea spp., Lepidosperma spp.) and ferns (e.g. Blechnum minus, Gleichenia microphylla). Littlely and Cutten (1994) found that a common structural characteristic of swamps in which MLR Southern Emu-wrens occurred was that they were dense from 0–1 m above ground level. They occasionally occur in open samphire/lignum Muehlenbeckia florulenta floodplains with cutting grass Gahnia trifida (e.g. Finniss), and reedland (primarily common reed Phragmites australis, with scattered Leptospermum lanigerum, e.g. Black Swamp).
	Food: Predominantly insectivorous but known to taken vegetable matter. Pale rush Juncus pallidus as an important food plant as the wrens have been observed to break open the stems in search of insects.
	Nests: Usually situated 0–1m from the ground in dense vegetation, e.g. rush Juncus spp., Leptospermum spp. and Empodisma minus.
Population estimate for 1985	Not known.
Population estimate for 2005	400–800 (2004) in total. Within the Ramsar area 80–160 approximately.

C. Distribution and habitat associations within the Ramsar area

Within the Ramsar area the species is found at the following locations with the Tributary wetlands system unit (see Figure 15 below).

These sites are classified as Tp - Permanent freshwater marshes/pools ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season, by the Ramsar Convention (see Section 4).

Survey data provided by the Mount Lofty Ranges Southern Emu-wren Recovery team (M. Pickett, 2005, pers. comm.) indicates the following vegetation associations were found at sites at which the bird was

- Juncus kraussii, Gahnia filum wet sedgeland and samphire low closed wet shrubland
- · Baumea rubiginosa closed wet sedgeland
- Leptospermum lanigerum tall open wet shrubland
- Muehlenbeckia florulenta tall open wet shrubland.

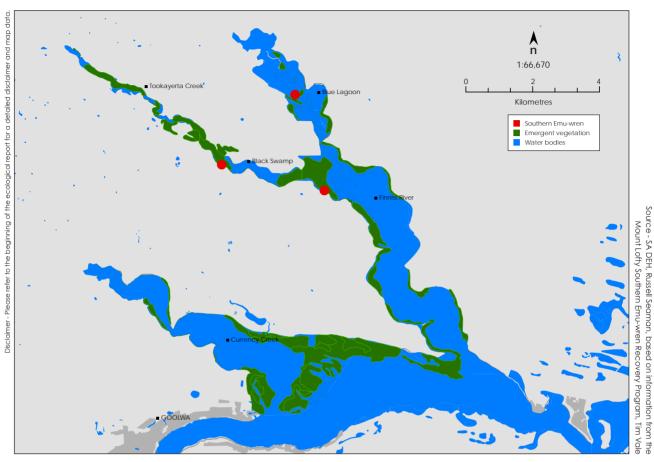


Figure 15 - Distribution of the Mount Lofty Ranges Southern Emu-wren within the Ramsar site

D - Key ecological components and processes					
Ecosystem components and processes	Description				
Physico-chemical—salinity	One of the vegetation associations listed as habitat for the MLR Southern Emu-wren occurs in samphire marshes, however a preference of vegetation associated with saline systems compared to freshwater systems is not known.				
Water regime	Reductions in quality and quantity of water through poor catchment management activities may also pose a threat to the declining habitat although direct links with reduced populations of the wren have not been established.				
Habitat availability (connectivity and competitive extent)	Most (80%) of existing sub-populations are now confined to swamp habitats on private property on the Fleurieu Peninsula. This habitat was once more extensive but is now reduced to small patches in the order of 5 ha or less (Littlely and Cutten, 1994 cited in Environment Australia 1998). It is unclear whether the MLR Southern Emu-wren has a preference for wet habitats or that this habitat is the only type in the region that offers the structural features it requires at the 0–1 m level (Mount Lofty Ranges Southern Emu-wren Recovery Team 1998).				
	Wilson and Paton (2004) investigated habitat differences in three sub species of <i>Stipiturus</i> malachurus, including the MLR Southern Emu-wren S. m. intermedius. They concluded that the differences in habitat usage reflected habitat availability rather than any preference for particular types by the birds. Structural features are more important than floristic composition, although further work is required to establish a clearer understanding of dietary requirements (Wilson and Paton, 2004).				
	Competition with similar species does not appear to be significant in determining habitat selection.				
	Dietary requirements and relationship to habitat use and/or preference is poorly understood.				
Reproduction	Dispersal of juveniles may be a factor limiting polulation sustainability and colonisation of new areas.				
Predation	Little information is available regarding the susceptibility of the species to predation. Native predators are likely to include the Red-bellied Black Snake, Tiger Snake, Water Rat, and possibly predatory birds. Introduced predators (fox, cat) may also pose a threat to the populations (Mount Lofty Ranges Southern Emu-wren Recovery Team 1998).				

Limits of acceptable change and traffic light assessment

It is not possible to establish the size of the population of this species or the Fleurieu Peninsula swamp habitats it relies upon (see preceding section) at or around the time the site was Ramsar-listed. Even today there are strong caveats placed on the estimated areal extent of the Fleurieu Peninsula swamp habitat currently (see preceding section). Further work is needed to confirm both the population size and extent of the habitats required by this endangered species within the Ramsar site so that appropriate planning and management can be provided. From the perspective of setting limits of acceptable change there are four primary considerations as follows:

1. Population size—the estimate is 80–160 and natural variability of this within the population is not known at present. Until such time as a more precise population estimate is possible and natural variations are better understood, the precautionary approach suggests a 0% limit of acceptable change. In this context this is intended to mean that no actions should be permitted that may threaten this small population.

- 2. Areal extent of Fleurieu Peninsula swamp habitat—see preceding section.
- 3. Condition of the Fleurieu Peninsula swamp habitat —see preceding section.
- 4. Connectivity between wetland remnants or pockets —no further loss of dryland habitats connecting these should be allowed.

Traffic light assessment



While there remain caveats on the estimated areal extent of this ecological community within the Ramsar site, this rating is given taking into consideration that the community is listed as critically endangered and that recovery actions are underway. Without the latter, the rating would be 'red'.



Orange-bellied Parrot						
Common name Scientific name Ramsar criteria National Status IUCN Status SA Status						
Parrots - Family Psittacidae						
Orange-bellied Parrot	Neophema chrysogaster	2, 3, 4	E	CE	E	

5.1.4 Orange-bellied Parrot

Qualitative details

The Orange-bellied Parrot (OBP) is listed as an endangered species under the Commonwealth EPBC Act and critically endangered by IUCN through the 'red list' process.

A. Summary life history details Extracts from the Orange-bellied Parrot Recovery Plan 1998-2002

Note: a new recovery plan is to be released for public comment in the near future. An advance copy of this draft was kindly provided to the authors and some notable information from it is provided below.

'The Orange-bellied Parrot has a single breeding population containing less than 200 mature adults in the wild. When breeding, the species occupies an area of approximately 1,600 km², but during winter migration is otherwise dispersed widely along the coastline of south-eastern Australia.

'The species forages for the seeds of low vegetation in a variety of coastal plant communities and roosts in shrubland usually within 10km of the coast of southeastern Australia. It breeds only in south-west Tasmania and migrates to Victoria and South Australia to spend winter in saltmarsh and strandline habitats. Threats



Orange-bellied Parrot in samphire

are loss of critical winter habitat and food supply from development or damage, competition from feral species for food, predation from foxes and cats, disease and possibly stochastic factors such as inbreeding depression.

'Most adults depart the breeding range in February, leaving juveniles to follow in March and April. Adults first reach Victoria in late March and disperse east as far as coastal South Gippsland and as far west as Lake Alexandrina in South Australia by April, Most of the population over-winters in saltmarsh habitat in central Victoria while the remainder moves west to the coast of South Australia. In September, the first adults leave the Australian mainland for Tasmania with the last birds departed by November.

'In Victoria, the species mainly uses natural saltmarshes dominated by Beaded Glasswort (Sarcocornia quinqueflora) and Shrubby Glasswort (Sclerostegia arbuscula), as well as associated grassy or weedy pastures. In South Australia, as on migration in western Victoria, they also use beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores where they feed on the seeds of strandline plants (e.g. Sea Rocket Cakile maritima). Critical winter habitat for the species is saltmarsh along the western shore of Port Phillip Bay at the Murtcaim Wildlife Area. Lake Connewarre and Swan Bay, including Swan Island. Other suitable habitat in Victoria is located at Jack Smith Lake, Corner Inlet, Western Port, French Island, Port Fairy, Nelson and Discovery Bay Coastal Park and in South Australia at Canunda National Park, Lake Bonney, Nora Creina, Robe, Butchers Gap, Blackford Drain, Woods Well, Magrath Flat and Lake Alexandrina, where birds tend to spend less time and occur in smaller flocks than in the key sites in Port Phillip Bay.

'In South Australia, strandline plants are as important as saltmarsh and pasture plants for Orange-bellied Parrots (Gibbons, 1984; Casperson, 1995).'

As indicated above, an advance copy of the revised Recovery Plan was provided to the authors of this report. Of note in this context are the following quotes taken from the draft:

'The current total population is unlikely to exceed 150 individuals (Mark Holdsworth pers. comm.)'

'The Orange-bellied Parrot is endemic to south eastern Australia. Formerly, the species' range on the mainland extended from Adelaide, and possibly Yorke Peninsula, southeast through the Coorong, Robe, Beachport and Port MacDonnell in South Australia, east through southwestern coastal Victoria, Port Phillip Bay to South Gippsland, and north to near Sydney. In Tasmania the species extended along the west and south coasts, east to Bruny Island (North, 1912; McGill, 1960; Jarman, 1965; Loyn & Kinhill Planners, 1980; Brown & Wilson, 1982, 1984; Higgins, 1999).'

'The Orange-bellied Parrot is now rarely recorded in large numbers from west of the Murray River in South Australia or east of Jack Smith Lake in South Gippsland, Victoria (Higgins, 1999).'



Orange-bellied Parrot

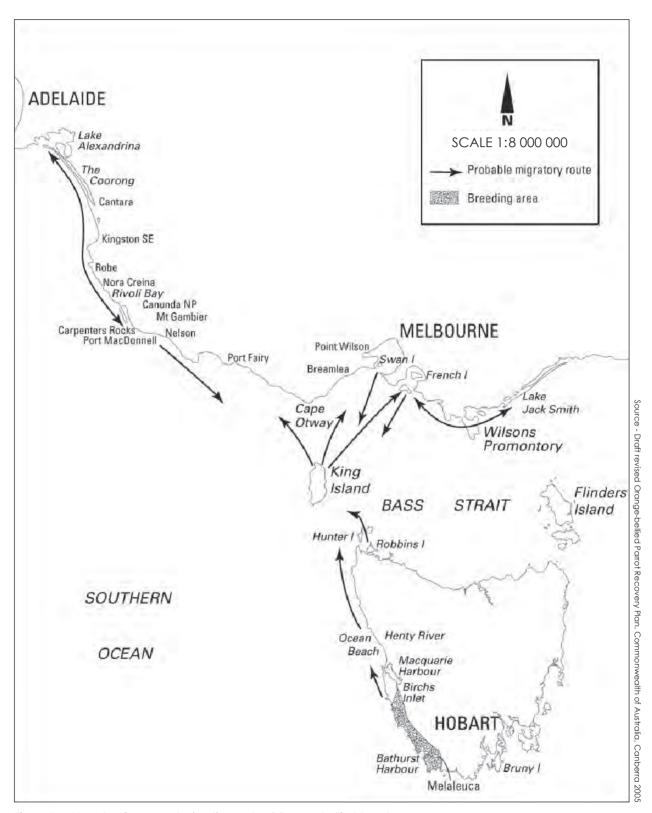


Figure 16 - Map showing annual migration route of Orange-bellied Parrots

Habitat critical to the survival of the species

Saltmarshes, coastal dunes, pastures, shrublands, estuaries, islands, beaches and moorlands, usually within ten kilometres of the coast, make up the diverse habitats used by OBPs.

In Victoria, the species mainly uses saltmarshes dominated by Beaded Glasswort, Southern Sea-heath Frankenia pauciflora and Shrubby Glasswort Sclerostegia arbuscula, as well as associated grassy or weedy pastures. Key sites are along the western shore of Port Phillip Bay, particularly the Spit Nature Conservation Reserve, and on the Bellarine Peninsula at Lake Connewarre Wildlife Reserve and Swan Bay, including Swan Island. In South Australia, beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores are favoured. Little is known of the species' habitat preferences in NSW.



Spoonbills

Ecologically	Species migrates from Tasmania annually and uses overwintering habitats within the Ramsar area (see Figure 16).
Habitat requirements	Habitat requirements: The species uses beaches, dune frontages and adjacent dune systems, saltmarshes and sheltered areas along rocky foreshores within 10km of the coast where they feed on the seeds of strandline plants (e.g. sea rocket Cakile maritima). In Victoria, the species mainly uses natural saltmarshes dominated by Beaded Glasswort (Sarcocornia quinqueflora) and Shrubby Glasswort (Sclerostegia arbuscula).
	In his report, Seaman (2003) includes the following information, and used this to base a habitat prediction for the species within the Coorong and Lakes (see below): • mainland, mostly within three kilometres of the coast, bays, lagoons, estuaries • low samphire herbland dominated by Beaded Glasswort Sarcocomia quinqueflora, Sea heath Frankenia pauciflora or Sea-blite Suaeda australis. Also in taller shrubland dominated by Shrubby glasswort Sclerostegia arbuscula; sometimes in low samphire shrubland dominated by Grey Glasswort Halosarcia halonemoides, or in Chenopodium herbfields. (Belcher, 1914; Watson, 1955; Yugovic, 1984; Hewish & Starks 1988; Stephenson, 1991) • beaches, amongst patches of colonising plants (Watson, 1955) • heath vegetation (Loyn & Kinhill Planners, 1979b) rarely in cultivated sunflower crops (Eckert, 1990)
	When migrating in South Australia, and in western Victoria, they also use beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores where they feed on the seeds of strandline plants, e.g. sea rocket Cakile maritima (OBPRT, 1998).
Population estimate for 1985	Not known.
Population estimate for 2005	Approximately 150 nationally. Population using Ramsar site during overwintering period unknown.

C. Distribution within the Ramsar area Not known.

Predicted available habitat in the Ramsar area (Seaman, 2003)

As noted by Seaman (2003), while the prediction adjacent (Figure 17) indicates extensive suitable habitat (approx. 35,000 ha), it is known that not all of this is used by the species. The low population number is likely to be one factor. Seaman did a more restricted prediction

using only beaches and rocky shores; having been identified as providing unique feeding areas for this species (OBPRT, 1998). This identified close to 1,300 ha as offering habitat for this species.

Note: a large proportion of the areas highlighted in the map lie outside the Ramsar-listed area.



Figure 17 - Predicted habitats: Orange-bellied Parrot within and surrounding the Ramsar-listed area

C - Distribution within the Ramsar area						
Ecosystem components an processes	Description					
Physico-chemical - salinity	Knowledge gap.					
Water regime	Knowledge gap.					
Habitat availability	Habitats close to coast (usually within 3 kms) including areas of low samphire herbland, Chenopodium herbfields or shrublands dominated by Shrubby Glasswort or Grey Glasswort. Sometimes found in patches of colonising plants on beaches or dune frontages or along rocky shores feeding on strandline plants such sea rocket Cakile maritime, competition and predation are poorly understood.					

Limits of acceptable change and traffic light assessment

It is not possible to establish the size of the population of this species using the Coorong and Lakes Ramsar site at or around the time the site was Ramsar-listed. While there has been work done to estimate the extent of likely habitat (see above), the authors have not been able to gain authoritative advice on the veracity of this modeling, nor the size of the population that overwinters in the site today. Further work is needed to determine both the population size and extent of the habitats required by this endangered species within the Ramsar site so that appropriate planning and management can be provided. From the perspective of setting limits of acceptable there are four primary considerations as follows:

- 1. Population size—no estimate of the population using the site today is available. Until such time as a precise population estimate is possible and natural variations within that population are better understood, the precautionary approach suggests a 0% limit of acceptable change. In this context this is intended to mean that no actions should be permitted that may threaten this small population.
- 2. Areal extent of primary habitats—no advice has been forthcoming on the primary habitat areas. Once this information is collected or provided, then this can be used to establish a robust limit of change. For an endangered species with a total national population estimated at 150 birds, a 0% limit of acceptable change would be indicated.
- 3. Condition of the primary habitats—no suitable limits of acceptable change can be indicated until these habitats are known.
- 4. Connectivity between primary habitats—this may or may not be a factor. No suitable limits of acceptable change can be indicated until these habitats are known.

Traffic light assessment While the population size and areal extent of its primary habitats within the Ramsar site remains unknown, this rating is given taking into consideration that the species is listed as endangered nationally and that recovery actions are underway. Without the latter, the rating would be 'red'.

Southern Bell Frog					
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status
Southern Bell Frog	Litoria raniformis	2, 3, 4	V	E	V



Southern Bell Frog

5.1.5 Southern Bell Frog

Qualitative description A. Summary life history details Extracts from DEH web site (www.deh.com.au):

'Litoria raniformis is usually found in association with dams, ponds and marshes, either amongst sedges and other semi-aquatic vegetation, or sheltering under logs and rocks (Gillespie et al., 1995). The species appears to be associated with permanent waterbodies though it is unclear whether, like L. aurea, the species also utilises ephemeral pools (Mahony, 1999). The species occurs both in woodland and areas of improved pasture (Gillespie et al., 1995). Adults are opportunistic predators, preying on other frogs and are also known to be cannibalistic (Hero et al., 1991; Gillespie et al., 1995).

In SA the species is known to occur along the lower River Murray valley, the lower South East to near Keith, and a small, apparently introduced population, in the Adelaide Hills (Tyler 1978 in Mahony, 1999).

Declines have occurred in sections of the species range (Mahony, 1999) ... It is currently widespread throughout the River Murray valley, but has disappeared from a number of sites along the Murrumbidgee River (Mahony, 1999).

Little is known about the biology of this species, however it is likely to be similar to that of L. aurea (Gillespie et al.,

1995). Males call from August–April. (Hero et al., 1991). The species breeds in permanent ponds or swamps, usually with extensive areas of sedges and rushes from which adults call (Gillespie et al., 1995). About 1698 eggs are laid in a loose clump (Hero et al., 1991; Hero & Warrell unpublished). Tadpoles are free-swimming and develop over summer and autumn (Gillespie et al., 1995). Metamorphosis takes place between late summer and autumn, although tadpoles may overwinter and metamorphose the following season (Gillespie et al., 1995).'

According to the South Australian EPA, the distribution of this species in the State is as shown in Figure 18. This map is derived from the Frog Census data collected through the EPA's community program since 1998. This species has also been recorded at Tolderol by the Wetlands Baseline Survey (RMCWMB, 2004).

The report from the 1999 Frog Census (EPA, 2000) indicates that in that year only eight Southern Bell Frogs were recorded throughout the Murray Valley and in the South East of the State. The number of recordings increased to 41 after the wet conditions that prevailed between 1999 and 2000; all of these being wet habitats such as rivers, swamps and wetlands.

It is noted that at present a national Recovery Plan is being prepared for this species and this will need to be taken into consideration with future investigations into the management requirements of the species within the Ramsar-listed area.

B - Importance of the Co	B - Importance of the Coorong and Lakes Ramsar site							
Ecologically	It is apparent from the Frog Census and Wetland Baseline Survey data referred to above that this species continues to exist within the Ramsar site, although precisely where and in what numbers is not known at present.							
Habitat requirements	Surveys have shown that the species has a preference for permanent freshwater areas usually associated with swamps and marshes with sedges and other semi-aquatic vegetation. It has also been recorded in dams and drains (irrigation drains, it is assumed).							
Population estimate for 1985	Not known.							
Population estimate for 2005	Not known.							

C. Distribution and habitat associations within the Ramsar area

Given the paucity of survey data from within the Ramsar site the distribution cannot be indicated. With the apparent preference of the species for permanent freshwater marshes and swamps with fringing sedges and other semi-aquatic vegetation, it is likely the species will be found (once surveys are undertaken) associated with these habitats around Lakes Albert and Alexandrina and their tributaries.

D. Key ecological processes

Without more specific information about the microhabitat needs of the species these cannot be specified.

E. Summary conceptual model and limits of acceptable change:

As above. Priority should be given to surveys to establish the distribution, population size, micro-habitat and other needs of this species so that the key ecological processes can be specified and limits of acceptable change provided. Given the national decline of this species across much of its former distribution it is likely there will be very narrow limits of change indicated.

Limits of acceptable change and traffic light assessment

There is so little known about the distribution, abundance and habitat preferences of this species in the Ramsarlisted area to be able to make any recommendations on limits of acceptable change at this time. Once this information is available, there are four primary considerations as follows:

- 1. Population size—a precise population estimate is needed and some understanding of the natural variations within that population.
- 2. Areal extent of primary habitats—mapping of the primary habitat areas is needed to ensure appropriate management of these.

- 3. Condition of the primary habitats—maintaining the condition of the primary habitats is vital for protecting this species within the Ramsar site.
- 4. Connectivity between primary habitats—this may or may not be a factor.

Traffic light assessment











Despite the lack of comprehensive data, this rating is recommended taking into consideration the vulnerable status of the species concerned and applying the precautionary approach. The traffic light assessment for many of the likely habitats of this species within the Ramsar site (see Section 4.1) is also a factor. Surveys are recommended as a high priority to clarify the situation and, if indicated, to introduce specific management interventions.

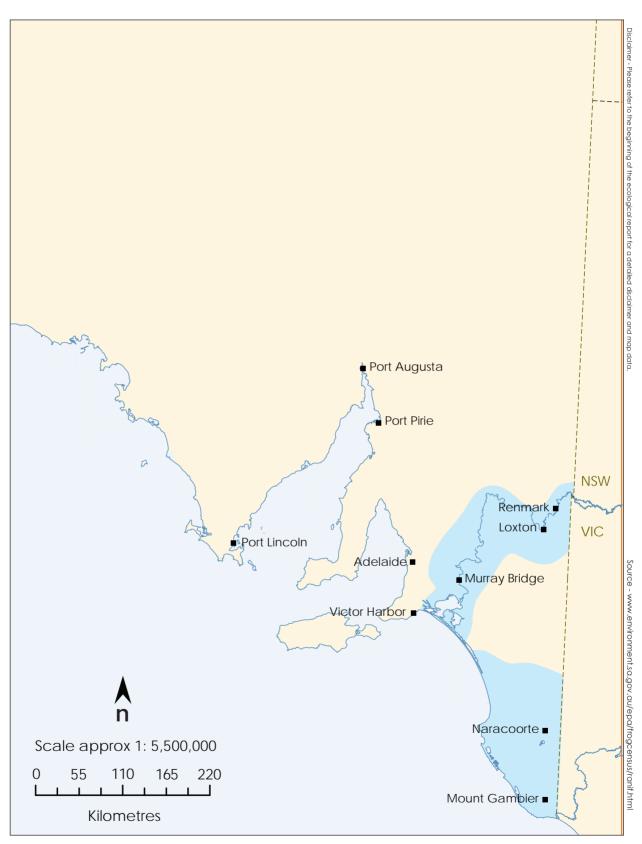


Figure 18 - Distribution of Southern Bell Frog in South Australia

■ 5.2 The site supports a high diversity of species and assemblages important for conserving biodiversity at the bioregional scale (Ramsar Criteria 3)

The draft revised RIS for this Ramsar site (Appendix C) indicates that there are a number of plant and animal species that can be considered important for conserving biodiversity at the bioregional scale (Ramsar Criterion 3). Naturally, this also includes those species and ecological communities that qualified the site under Ramsar Criterion 2, being either globally or nationally threatened, endangered etc. These are considered in Section 5.1 and so not reconsidered here.

The decision rules applied in relation to Criteria 3 indicate that the species or communities of significance are those that are listed as vulnerable or endangered (but not rare) under South Australian legislation and/or those (plant species) listed as threatened, vulnerable or endangered regionally for the Southern Lofty or Murray botanical regions. Included also is the provisionally listed (by SA DEH) threatened ecosystem of Gahnia spp. For native fish, those included are those that are listed at the State level as P—protected under the Fisheries Act 1982 or C—provisional State conservation concern under the draft Threatened Species Schedule NPWSA are included (for now). It is understood that the status of some of the latter species is still being discussed among government departments in South Australia.

Based on these decision rules, there is one vegetation association, one plant species, 20 fish species and five bird species that contribute to the site qualifying against this Criterion (see Tables 4, 6 and 7). Consideration of the plant species is provided in Section 5.1.1, the fish species in Section 5.6 and the bird species in Section 5.4, leaving only the vegetation association to examined below.



Complex aquatic vegetation is being simplified by static lake levels and lack of flows

5.2.1 Gahnia vegetation association

Gahnia vegetation association								
Common name	Scientific name	Ramsar criteria	National Status	IUCN Status	SA Status			
Cutting-grasses	Gahina filum, Gahnia trifida	3			V			

As advised in Section 3.5.1, the South Australian Department for Environment and Heritage has compiled a provisional list of threatened ecosystems. The vegetation association of Gahnia spp. is identified as a vulnerable ecosystem within the agricultural district of South Australia.

Qualitative description

A. Summary life history details

Gahnia filum is a tussock sedge that flowers throughout the year and has tall stems with several nodes and long, smooth leaves tapering into purple bracts (Black, 1986). Gahnia trifida is extremely similar and can be distinguished by the sharp cutting edges to its leaves. They both grow in swampy areas with G. filum preferring more saline areas and G. trifida preferring fresher, creek habitats. Both plants form bands of tussocks at or near the high water level mark and tend to occur in association with other sedges and reeds, samphire communities and Melaleuca halmatuorum, Swamp paperbark depending on water regime. They are salt-tolerant and able to survive extended periods of drought. Work by the Goolwa to Wellington Local Action Planning Board shows that the seeds germinate readily, particularly following exposure to smoke (unpubl. data).

G. filum and G. trifida vegetation associations have been included by SA DEH on their provisional list of threatened ecosystems (Seaman, 2005). These vegetation associations or communities are sedgelands located in drainage lines and depressions. Within the agricultural district of the State, they are mostly confined to a number of small areas within NPWSA Reserves. The entire occurrence of Gahnia filum and Gahnia trifida (cuttinggrass) sedgelands in the SA Murray-Darling Basin (SA MDB) is within the Coorong and Lakes region (Kahrimanis et al., 2001).

Seaman (2005) used the Coorong and Lakes Habitat Database to document occurrences of these Gahnia spp. vegetation associations within the Ramsar area. This found approximately 471 hectares of the association distributed along the northern shoreline of the Finniss River, the western shoreline of Lake Alexandrina, with other scattered remnants around the Lakes. Seaman reports

that within the Coorong National Park, good remnants remain south of Parnka Point comprising of approximately 421 hectares (see Figure 19). Many of the remnant Gahnia spp. sedgelands in the Coorong and Lakes area are grazed and it is currently unknown what impacts this may have on the communities. During the 'peer review' of this report other sites with Gahnia associations were mentioned and these are yet to be verified.



Gahnia filum, Coorong National Park

B - Importance of the Coorong and Lakes Ramsar site							
Ecologically	The only occurrence of <i>Gahnia filum</i> and <i>G. trifida</i> in the South Australian portion of the Murray-Darling Basin is within the Coorong, Lakes and tributaries. It is thought that 96% of the remaining population is contained within these sites (Kahrimanis et al., 2001). This is considered important habitat for Mount Lofty Ranges Southern Emu-wren (see Section 5.1.3).						
Habitat requirements	High water level tussocks that are salt-tolerant but require frequent freshwater inundation. Details on timing, frequency and duration of these freshwater flushes are poorly understood.						
Population estimate for 1985	Knowledge gap.						
Population estimate for 2005	900 ha approximately.						

C. Distribution and habitat associations within the Ramsar area

Within the Ramsar area, the species is found at the following locations within the Lake Alexandring, Lake Albert, Tributary wetlands and South Lagoon system units (see Section 4). Gahnia spp. tend to occur with other sedges and reeds in fresher areas such as Finniss River (Black Swamp) and Hindmarsh Island. In more saline areas, Gahnia spp. often form bands around saline depressions containing samphire and grade into Melaleuca halmaturom woodlands as elevation increases. Gahnia spp. tussocks can provide protection from grazing for other plants such as Stipa spp.

D. Key ecological components and processes

Gahnia spp., particularly G. filum, are relatively salttolerant and able to withstand several years of drought. However, little is known about the specificities of Gahnia spp. water regime and recruitment requirements thus key ecological processes are difficult to define. The Coorong and Lakes Ramsar site is thought to contain 96% of the remnant populations of Gahnia spp. in the South Australian Murray-Darling Basin.

Some insights into the ecological needs of this species can be gained from the information relating to wetland types M and W in Section 4.2.4, pages 76 and 79, respectively.

Limits of acceptable change and traffic light assessment

It is not possible to establish the areal extent of this wetland type at or around the time the site was Ramsar-listed, and even today the area indicated (900 ha) is considered an estimate until further detailed ground surveys are completed. From the perspective of setting limits of acceptable change, there are three primary considerations as follows:

- 1. Areal extent—while the full areal extent is yet to be confirmed the association is provisionally listed as a vulnerable ecosystem within the agricultural district of South Australia, Given this, the precautionary approach indicates that a limit of acceptable change of 0% is appropriate until further information is obtained that may or may not alter this.
- 2. Condition of the vegetation association—no suitable limit of change can be recommended at present.
- 3. Connectivity between the vegetation association —this may or may not be a consideration depending on the findings of future research to establish the full ecological roles.

Traffic light assessment









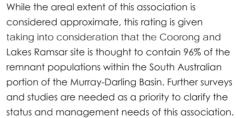




Figure 19 - Currently mapped distribution of Gahnia plant association

■ 5.3 The site supports animal taxa at critical stages of their life cycle breeding, wetland-dependent birds

Ramsar Criterion 4 seeks to identify those species that are supported by the site at critical stages of their life cycle. For the Coorong and Lakes Ramsar site, there are a large number of fish and wetland-dependent bird species of note in this regard. These are detailed in Attachment 3 of the draft revised Ramsar Information Sheet (Appendix C) and also shown in Tables 6 and 7 of this report.

Among the 20 fish that help qualify the site under this criterion there are diadromous species that move between the freshwater, estuarine and marine parts of the system for spawning, and also those species known to spawn in the Ramsar site itself. Detailed consideration of these significant fish species can be found in Section 5.6.

Among the wetland-dependent bird species of note in this context there are:

- 1. Those species regularly using the site that are listed under the JAMBA or CAMBA migratory bird agreements Australia has with Japan and China, respectively.
- 2. Some other species that have more localised migrations within Australia (among these is the Orange-bellied Parrot—see Section 5.1.4).
- 3. Several species that have been regularly recorded using the site in numbers exceeding their 1% population or sub-population level. These are; Pied Oystercatcher, Red-capped Plover, Red-necked Avocet, Fairy Tern and Caspian Tern. (These qualify against Ramsar Criterion 6—see Attachment 5 -Appendix C).
- 4. Those species that use the site on a regular basis (at least three years in five on average, or better) for breeding.

For the purposes of this description of ecological character, it is only this latter group of species that breed at the site which are considered below. Migratory and other birds of note are considered in Section 5.4.

Breeding wetland-dependent birds Qualitative description

The following table lists 40 wetland-dependent bird species that are known to breed (or it is suspected they might) within the Coorong and Lakes Ramsar site. This very high number reflects the diversity of species and habitats that this system supports; making it possibly one of the most important waterbird breeding areas in the Murray-Darling Basin, and possibly in southern Australia.

The Mount Lofty Ranges Southern Emu-wren is also found within the Ramsar area and breeds there, but has been considered elsewhere in this report (see Section 5.1.3).

Examination of the summary life history information about the species (Table 10) shows a wide range of breeding and feeding habitat preferences and preferred prey items, thus making this part of the ecological character benchmarking exercise very challenging. In general terms, these species can be grouped as follows based on their preferred breeding habitats:

- 1. Coastal beach, dune or islands breeders: Pied Cormorant, Pied Oystercatcher, Hooded Plover, Fairy Tern, Caspian Tern, Silver Gull and Australian Pelican (not always coastal).
- 2. Inland shrublands, reedbeds, rushes and tussocks, grasslands or tree breeders. This group includes ground-nesting species, those that prefer to be secluded in rushes or reedbeds and also those that use tree hollows. The common theme running through this group is their preference (in most cases) to be near freshwater wetlands in general. One exception to this group of more inland breeders is the Red-necked Avocet that typically breeds at inland salt lakes, on the ground.

Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Pelicans - Fam	ily Pelecanidae						
Australian Pelican	Pelecanus conspicillatus	4, 5.1, 5.2, 5.3	R	1, 2, 3, 4, 5, 6	Breeds on low, secluded sandy islets or shores among scattered vegetation (HANZAB)	Open water in terrestrial, estuarine marine waters (HANZAB)	Fish, aquatic invertebrates
Darters - Family	y Anhingidae						
Australian Darter	Anhinga melanogaster	4?	R/M	4, 1 mainly	Nests in trees or shrubs over water (HANZAB)	Open water	Fish, aquatic invertebrates
Cormorants - F	amily Phalacrocoracida	e	•			1	
Little Pied Cormorant	Phalacrocorax melanoleucos	4	R	1, 2, 3, 4, 5, 6	Shrubland, mainly freshwater wetlands (HANZAB)	Open water	Aquatic invertebrates fish
Pied Cormorant	Phalacrocorax varius	4	R	1, 2, 3, 4, 5, 6	Coastal rocky or sandy islands, or in estuaries, in trees (HANZAB)	Open water	Fish
Little Black Cormorant	Phalacrocorax sulcirostris	4, 5.1, 5.2	R	1, 2, 3, 4, 5, 6	Shrubland in freshwater wetlands, favouring flooded trees in larger systems (HANZAB)	Open water	Fish, aquatic invertebrates
Great Black Cormorant	Phalacrocorax carbo	4, 5.1, 5.2	R	1, 2, 3, 4, 5, 6	Shrubland or trees in or near water. Sometimes on coastal cliffs (HANZAB)	Open water	Fish
Geese, swans	and ducks - Family Ana	idae				1	
Black Swan	Cygnus atratus	4, 5.1, 5.3	R	1, 2, 3, 4, 5, 6	Reedbeds, floating vegetation, open water; in fresh, brackish or saline, but not tidal waters (HANZAB)	Grass and weeds, bare margins, open water	Pasture plants, aquatic plants (submerged macrophyte (Scholz, 2001
Australasian Shoveler	Anas rhynchotis	4	R	1, 2, 3, 4, 5, 6	Grass and weeds near freshwater wetlands, either temporary or permanent (HANZAB)	Grass and weeds, bare margins, open water	Aquatic invertebrate
Musk Duck#	Biziura lobata	4?, 5.3	R	1, 2, 3, 4, 5, 6	Tussocks, reedbeds	Open water	Aquatic invertebrate: fish, aquatic plants

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Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Australian Shelduck	Tadorna tadornoides	4, 5.1, 5.2, 5.3	R	1, 2, 3, 4, 5, 6	Shrubland, grass and weeds, sometime in trees or beneath shrubs in saltmarsh (HANZAB)	Bare margins, open water	Aquatic invertebrates and plants, some mollusc (Scholz, 2001)
Chestnut Teal	Anas castanea	4, 5.1, 5.2, 5.3	R	1, 2, 3, 4, 5, 6	Mostly in tree hollows mainly in coastal regions, or on islands or shores (HANZAB)	Bare margins, open water	Aquatic invertebrates and plants
Rails, crakes, swo	amphens, coot - Famil	y Rallidae		•			
Spotless Crake#	Porzana tabuensis	4, 5.3	ŝ	?4, 5, 6	Shrubland, reedbeds, tussocks	Forage on mud or shallow water near to reeds (HANZAB)	Aquatic invertebrates and plants
Dusky Moorhen	Gallinula tenebrosa	4	R	4, 5, 6	Reedbeds	Grass and weeds, bare margins, open water	Aquatic invertebrates and plants
Purple Swamphen	Porphyrio porphyrio	4, 5.3	R	2, 4, 5, 6	Reedbeds	Shrubland, reedbeds, rushes, floating vegetation, grass and weeds, bare margins, open water	Aquatic plants and pasture plant
Herons, egrets, b	itterns - Family Ardeid	ae	•	<u>'</u>	<u>'</u>	'	
Australasian Bittern*	Botaurus poiciloptilus	2, 3, 4?	ę	4, 5, 6	Breeds in deep, dense vegetated rushes over shallow water (HANZAB)	Terrestrial wetlands and occasionally estuaries; prefers wetlands with tall dense vegetation and forages in still shallow water. (HANZAB)	Knowledge gap
Little Egret	Ardea garzetta	4	R	1, 2, 3, 4, 5, 6	Nests in trees near vegetated wetlands; fresh, brackish, marine or saline (HANZAB)	Shrubland, grass and weeds, bare margins	Fish, aquatic invertebrates and vertebrates
Cattle Egret	Ardea ibis	4	М	4, 5	Nests in densely wooded areas in or near swamps (HANZAB)	Terrestrial wetlands, and also grasslands; often forage on grasslands or pasture (HANZAB)	Grasshoppers insects mostly (HANZAB)

Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Great Egret	Ardea alba	4	R	1, 2, 3, 4, 5, 6	Shrubland or flooded trees (HANZAB)	Rushes, floating vegetation, grass and weeds, bare margins	Fish, aquatic invertebrates and vertebrates
White-faced Heron	Ardea novaehollandiae	4, 5.3	R	1, 2, 3, 4, 5, 6	Shrubland or trees not necessarily near water (Scholz, 2001)	Floating vegetation, grass and weeds, bare margins	Fish, aquatic vertebrates, crustaceans (Scholz, 2001)
Rufous Night Heron	Nyctocorax caledonicus	4, 5.3	R	4, 5, 6	Nests in various locations; trees, off-shore islands on the ground etc. (HANZAB)	Littoral, estuarine or inland wetlands; mainly nocturnal foraging in still or slow-moving shallow water (HANZAB)	Carnivore, mostly fish also insects and crustaceans (Scholz, 2001)
Ibises, spoonbill	s - Family Threskiornida	e					
Glossy Ibis	Plegadis falcinellus	4	R	4, 5	Breeds in fresh or brackish wetlands; among reeds, lignum, rushes, shrubs or trees (HANZAB)	Forage in shallow waters over soft substrate or muddy edges of wetlands, either freshwater or sheltered marine (HANZAB)	Aquatic invertebrates and insects (HANZAB)
Straw-necked Ibis	Threskiornis spincollis	4, 5.1	R	1, 2, 4, 5, 6	Shrubland, reedbeds; can form large colonies, breeding often triggered by flooding (HANZAB)	Grass and weeds	Fish, aquatic invertebrates and vertebrates
Australian White Ibis	Threskiornis molucca	4, 5.3	R	1, 2, 3, 4, 5, 6	Shrubland, reedbeds	Grass and weeds	Fish, aquatic invertebrates and vertebrates
Royal Spoonbill	Platalea regia	4, 5.3	R?	1, 2, 3, 4, 5, 6	Shrubland over or near water (HANZAB) or trees (Scholz, 2001)	Open water	Fish, aquatic invertebrates
Yellow-billed Spoonbill	Platalea flavipes	4, 5.3	R?	4, 5, 6	Shrubland in freshwater wetlands (HANZAB) or trees (Scholz, 2001)	Open water	Aquatic invertebrates fish

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Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Oystercatchers -	Family Haematopodid	lae					
Pied Oystercatcher	Haematopus longirostris	4, 5.3, 6	R	1, 2, 3	Nests on sand, shell-grit or shingle just above high- water mark on beaches or sand- bars. (HANZAB)	Feeds on exposed sand, mud, rock or coral (HANZAB)	Knowledge gap
Lapwings, plove	s, dotterels - Family Ch	aradriidae					
Hooded Plover	Charadrius rubricollis	3, 4, 5.3, 6	R	1, 2, 3	Breeds at similar locations to where they feed, typically close to the fore-dune vegetation. (HANZAB).	Prefers wide, flat ocean beaches, especially those with seaweed present (HANZAB).	Knowledge gap
Red-capped Plover	Charadrius ruficapillus	4, 5.3, 6	RŞ	1, 2, 3, 4, 5	Breeds in open areas or low vegetation around the margins of terrestrial wetlands, exposed sandy shorelines or on mats of weeds. (HANZAB)	Feeds on sand and mudflats along the edges of estuaries, lagoons and lakes, and even at times gravel or shellgrit (HANZAB).	Knowledge gap
Masked Lapwing	Vanellus miles	4, 5.3	R	1, 2, 3, 4, 5, 6	Nests on ground in short grass (<12 cm) or stony ground on small islands, floating reeds (Scholz, 2001)	Forages around natural (and modified) inland wetlands, either freshwafer or saline, and both permanent and temporary wetlands. (HANZAB)	Molluscs, worms, insects, crustaceans, and occasionally seeds (Schol: 2001)
Stilts, avocets - F	amily Recurvirostridae						
Black-winged Stilt	Himantopus himantopus	4, 5.3	R/M	1, 2, 3, 4, 5	Nests on islets or hummocks surrounded by shallow water. (HANZAB)	Forages in shallow water, fresh or saline, on sandflats often where there is dense vegetation of grass or other emergents. (HANZAB)	Molluscs, crustaceans, and occasionally vegetative matter and seeds (Scholz, 2001

Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Red-necked Avocet#	Recurvirostra novaehollandiae	4?, 5.3, 6	M/R	1, 2, 3 4, 5	Breeds mostly at inland salt lakes; nesting on bare ground or in low vegetation. (HANZAB)	Found in ephemeral inland, fresh, saline and hyper-solline wetlands, especially drying salt lakes. Feeds in soft mud areas, wading to their belly (HANZAB).	Molluscs, crustaceans, and occasionally vegetative matter and seeds (Scholz, 2001) occasionally small fish
Gulls, terns etc.	- Family Laridae						
Fairy Tern	Sterna nereis	3, 4, 5.1, 5.2, 5.3, 6	R	1, 2, 3	Nests above high water on sheltered beaches, spits or sand bars often in estuaries and on islands (HANZAB)	Sheltered coasts and estuaries; fresh or saline near-coastal wetlands (HANZAB)	Small fish
Crested Tern	Sterna bergii	4, 5.1, 5.2	R	1, 2, 3	Breeds on islands, sandy cays and banks; gregarious when breeding (HANZAB)	Feed from surface of sea, mainly in in-shore waters (HANZAB)	Fish
Caspian Tern	Hydropogne tschegrava (Hydroprogne caspia)	4, 5.3, 6	R	1, 2, 3, 4, 5	Breeds on islands, sandy cays and banks (HANZAB)	Forages in open wetlands, often in sheltered water areas near the margins (HANZAB)	Fish, crustaceans
Whiskered Tern#	Chlidonias hybridus	49, 5.1, 5.2, 5.3	R	1, 2, 3, 4, 5, 6	Often nests in temporarily flooded inland wetland flats, claypans; among inundated vegetation (HANZAB)	Inland wetlands with emergent and submerged vegetation (HANZAB)	Fish, insects, crustaceans, carnivorous
Pacific Gull*	Larus pacificus	4?	R	1, 2, 3	Breeds on off- shore rocky islets mostly; sometimes on sandy islets or sandflats (HANZAB)	Forages along coast between high and low-fide shallow waters, sandy beaches and exposed mudflats	Knowledge gap
Silver Gull	Larus navaehollandiae	4, 5.1, 5.2, 5.3	R	1, 2, 3, 4, 5	Prefers off-shore islands, but will breed in many habitats (HANZAB)	Cosmopolitan; found across a range of natural and built environs (HANZAB)	Omnivorous, scavenger

Common name	Scientific name	Ramsar criteria	Resident (R) migratory (M) or occasional visitor (O)	System units where found [†]	Preferred breeding habitat*	Preferred feeding habitat*	Preferred food*
Old world warble	rs - Family Sylviidae						
Great (Oriental) Reed-Warbler	Acrocephalus arundinaceus	4	М	4, 5, 6	Knowledge gap	Knowledge gap	Invertebrates
Little Grassbird	Megalurus gramineus	4	М	1, 2, 3, 4, 5, 6	Knowledge gap	Knowledge gap	Invertebrates
Golden- headed Cisticola#	Cisticola exilis	4?	М	1, 2, 4, 5, 6	Knowledge gap	Forages in reedbeds, tussocks and floating vegetation; in shallow swamps and even shorelines of deeper wetlands (Seaman, 2003)	Invertebrates

The order used above follows that of Field Guide to the Birds of Australia, 6th Edition by Simpson and Day, 1999

Shrubland - Melaleauca halmaturom; Reedbeds—stands of Typha spp. and Phragmites australis; Rushes—Diverse beds; Tussock—mainly Gahnia filum; Floating vegetation—Triglochin procerum and other plants in fresh water; Bare margins—subject to inundation or dry; Open water—area of water with no emergent or overhanging vegetation

- 1 Murray Mouth and Estuary; 2 North Lagoon; 3 South Lagoon; 4 Lake Albert; 5 Lake Alexandrina; 6 Tributary wetlands
- * Information (mostly) from Earthtech, 2003, cited as P.A.Paton based on Jaensch, 1982 and personal observations, and HANZAB, 1990, 1993 and 1996
- † For these species there has been no confirmation that they breed within the Ramsar site, although it is considered likely. Where found: System units

Source - Earthtech, 2003, cited as P.A. Paton based on Jaensch, 1982 and personal observations, and HANZAB, 1990, 1993 and 1996 (unless otherwise indicated).



Crested Tern

Key drivers, levers, components and processes

Given the diversity of species, and, as highlighted above, their range of breeding, feeding and dietary preferences, it is not possible here to detail the key drivers, levers, components and processes for each of the 40 species, or even for assemblages.

While past surveys have identified some areas of the Coorong and Lakes where waterbirds breed, there has not been a full inventory or any on-going monitoring to allow an appreciation of how breeding patterns or success rates vary seasonally or over longer periods. Some of the breeding observations documented in relation to the various wetlands types of the system in Section 4 have been summarised in the following table. Clearly these do not reflect the full range of habitats used by the wetland-dependent birds of the Coorong and Lakes Ramsar site, however, they do provide some insights.

This lack of specific data limits the opportunities for setting limits of acceptable change for these various species (see the following page), although Paton (2005b) provides some further data that is notable for some of these species.

Wetland type	System Unit	Breeding observations
Freshwater system units		
D – Rocky marine shores ; includes rocky offshore islands, sea cliffs	Lake Alexandrina	This habitat type is likely to be an important nesting site for some bird species and the complex shorelines are likely to be important for fish and other aquatic biota. These rocky areas are located: • eastern shore of Lake Alexandrina below Wellington (Poltalloch Plains) • southern edge of Point Sturt • in patches along lakeshore between Clayton and Point Sturt.
Tp – Permanent freshwater marshes/ pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water- logged for at least most of the growing season	Lake Alexandrina, Lake Albert	The areas of reedbeds that were recorded as waterbird rookeries pre-barrage construction still exist and support seasonal breeding colonies. Waterbird breeding areas on Lake Alexandrina include: Tolderol Point, Snake Island; Mosquito Point, Boggy Lake area, South of Milang; Kindaruar Corner, Reedy Point; Opposith Clayton, Goat Island; Goose Island, Finniss River mouth; Currency Creek mouth, Salt Lagoo islands; Coolindawerh Lagoon, Rat Island; and Rushy Island (EarthTech, 2003). Other areas of extensive and dense emergent vegetation include: Loveday Bay, connection between Mud Island and Long Island, Pelican Lagoon, River Murray confluence near Wellington and tributary confluences. The reedbeds in the Narrung Narrows and other areas have become noted as long-term rookery sites for several species of ibis, spoonbill and cormorants. The protected shallow wetland areas on the inshore areas of the reedbeds are important habitat for small fish species (MDBC, 2003). In Lake Albert, this habitat is identified as critical bird habitat in the following areas (from Paton, 2000): Narrung Narrows—waterbirds and ibis (area incorporates Tp, O, W and Ss habitats) Reedy Point—waterbirds, pelicans (Tp, O) Waltowa Swamp—waterfowl, waterbirds, waders (Tp, Ss, W) Waringee Point—waterfowl, waders (Tp, O).
W - Shrub-dominated wetlands; shrub swamps, shrub- dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	Lake Alexandrina, Lake Albert	Remnant samphire communities support diverse faunal assemblages. When combined will lignum or paperbarks they become important rookery sites, and also offer sheltered feeding grounds in semi-permanent lagoons (MDBC, 2003). For example, Coolinderwerh Lagoon is a Swamp Paperbark-fringed samphire wetland representing habitat that is now considered very rare in the Lakes. Samphire wetlands Type W occur in a number of areas which are considered as critical habitat for waterbirds (from Paton, 2000): Hindmarsh Island and other barrage islands—waterfowl, waders, waterbirds, and Cape Barren Geese (includes habitat types W, 4) Milang shore—waterfowl, waders, waterbirds (W, Ts, 4, Tp) Milang Town—Latham's Snipe (W) Wellington Point—Darters, waterbirds (W) Poltalloch—waterfowl, waders, waterbirds (W, Ss) Yalkuri and Salt lagoon—waterfowl, waders (Tp, W, Xf) cormorant nesting site, Salt Lagoon Conservation Park, Lucerne Island (W, Xf).
Xf – Freshwater, treedominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	Lake Alexandrina, Tributaries	Coolinderwerh Lagoon and Dunn's Lagoon are Swamp Paperbark-fringed wetlands representing habitat that is now considered very rare in the lakes. The wetland flora at the sites is complex, driven by variation in soil salinity levels and topography. These habitats support diverse faunal assemblages, with the paperbarks being important rookery sites an nesting and foraging grounds for a wide range of waterbirds (Jensen et al., 2000). They also offer sheltered feeding grounds in semi-permanent lagoons (MDBC, 2003).
Saline - estuarine system	units	
D – Rocky marine shores ; includes rocky offshore islands, sea cliffs	Murray Mouth and Estuary, North Lagoon, South Lagoon	Isolated patch of rocky inland shores of approximately 40 ha in the Mundoo Channel comprised of exposed calcrete outcrops, plus a thin band along the north western shoreling of North Lagoon and isolated patches on the northern part of South Lagoon. These areas are important for bird foraging, especially egrets and larger waterbirds. As water recedes in the spring these areas becomes important nesting sites for waterfowl such as pelicans and Caspian Tern, particularly in the island areas (Oborne, 2003).

Wetland type	System Unit	Breeding observations
Saline - estuarine system	units	
H - Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes	Murray Mouth and Estuary, North Lagoon	These wetlands are areas that are inundated diurnally with tidal flow along the Goolwa channel and into the North Lagoon. They also receive some freshwater inputs from local catchments and groundwater. These areas are considered important foraging areas for rails, crakes and waterhens, nesting habitats for a range of waterbirds as well as refuge areas for small native fish (Brandle, 2002).
I – Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	Murray Mouth and Estuary	Small area (approximately 4ha) in the Mundoo Channel near the confluence of Hunter's Creek and Murray Mouth Estuary. The trees represent an important nesting site for a range of waterbirds (Jensen et al., 2000). In addition, the reedbeds provide nesting and foraging habitat for some waterbird species and, when inundated habitat for aquatic invertebrates
K – Coastal freshwater lagoons; includes freshwater delta lagoons	Murray Mouth and Estuary, North Lagoon	Isolated patches of discharging fresh groundwater appear along the dunes, particularly the southern shore of North Lagoon. Often associated with samphire communities, these patches of reeds provide a range of birds with nesting and foraging habitat.

Paton (2005) provides detailed data on the distribution and abundance of aquatic birds (that is, not only wader species) in the Coorong for the period 2000–2005 and he concludes that several of the fish-eating bird species had reduced numbers and breeding activities in the South Lagoon, due, it is assumed to the reduced availability of food items and Small-mouthed Hardyhead (Atherinosoma microstoma) in particular. This includes species such as Australian Pelican, some waterfowl species, Fairy Tern and Hoary-headed Grebe. This reflects a significant change in the ecological character of this part of the site. Section 5.4 examines other aspects of the Paton (2005) report also.

In particular Paton (2005b) notes the following:

- 1. Australian Pelicans—numbers substantially lower in 2003-2005 than 2000-2002, with these declines occurring mostly in the South Lagoon. There has been little or no pelican breeding on the islands near Policeman's Point despite there being a large breeding colony there in the past. This decline probably reflects reduced availability of small fish, as recorded in the food items research reported on in Section 5.4.
- 2. Other predominantly fish eating species—there have been reductions in the numbers of Fairy Tern, Caspian Tern and various egrets and herons. Paton notes the following to illustrate the ecological changes in the South Lagoon.
 - a) Fairy Tern—(Paton 2005b) notes the case of Fairy Tern, a species for which hardyhead fish is the key prey item. He notes as follows: 'In the 1980s in excess of 1300 Fairy Terns used the South Lagoon

alone. In 2000–2001, between 600 to 700 Fairy Terns were counted throughout the Coorong, but since then the numbers have been consistently below 400 and dropping below 200 in January 2004. Furthermore the numbers of juvenile birds have accounted for less than 5% of the Fairy Terns in recent counts, suggesting reproductive success has been low in recent years. Fairy Terns, like other piscivorous species, have largely vacated the southern Coorong during 2004 and 2005, reflecting the reductions in the abundances of hardyhead fish in this part of the Coorong. No breeding colonies of Fairy Terns have been detected in the southern Coorong during the last two years, although small numbers of birds have bred near the Murray Mouth.'

b) Hoary-headed Grebe—'Although the total numbers of Hoary-headed Grebes in the Coorong have been reasonably consistent since 2001, they have largely vacated the southern Coorong in the last two years. In January 2005 they were virtually absent from the southern Coorong and concentrated in the middle sections of the North Lagoon where hardyhead fish were more abundant. For comparison, in January 2000 over 8,000 Hoary-headed Grebes were using the South Lagoon, and in the 1980s over 60,000 were counted just in the South Lagoon."

Supporting the above notes about declines in breeding effort and presence of some species in the Coorong are the following observations from the Ngarrindjeri community and three of the long-term fishing families of the Coorong (see Section 7 for full accounts).

Naarrindieri community

Bird numbers, both resident and migratory species, have declined dramatically and breeding of all species is very low, even for pelicans and sea gulls. Of particular note is the loss of Black Swans and Eastern Curlews. In the 1960s, the water of the Coorong lagoons was black with swans and now they are rarely seen due to the lack of their preferred 'swan weed' food. Today they stay in the freshwater areas around the lakes in order to get food from the submerged plant beds on the fringes of the lakes. Swans are also seen in paddocks getting green feed now because of the lack of swan weed in the Coorong. Similarly, Eastern Curlews were seen every year in large numbers in the Coorong Lagoons but now only a few are seen near the Murray Mouth.

Neil and Nancy Ferguson—long-term residents of South East South Australia and Coorong fishing for 30 years The pelicans are still breeding on Pelican Island but there are not many at all now and they have to fly to the lakes to get food so lots of the young ones are dying from lack of food. Not many at are making it now.

2003 was the major turning point, before then pelicans would move around here in mobs of 40 to 50, Oystercatchers stopped nesting about two years ago too, no feed.

Bob Hera-Singh—Coorong fisher and hunter, 1940s to present

Swan Island used to be covered in swan nests. The last swan nests on the Coorong. They haven't nested there for 12 years. There are still a few swans breeding around the lakes but nowhere near what there were and none on the Coorong. If you go south of Pelican Point you might see 50 pelicans on a good day, there used to be thousands.

Right up until a few years ago, pelicans were still breeding in good numbers on Pelican Island but now there are very few and unlikely to successfully fledge. Seagulls also used to nest so densely on the islands that you couldn't walk for eggs.

Frank Gibbs—Coorong fisher and hunter from the 1930s to present

We used to hear swans flying all night—it kept us awake.

Limits of acceptable change and traffic light assessment

At present there is no systematically collected information to indicate the size, distribution, annual or seasonal variations and success of these breeding populations within the Ramsar site, thus making it impossible to set meaningful limits of acceptable change across this range of species. Once more systematic surveys are conducted to map and assess the full extent of breeding areas it should be possible to set limits of acceptable change. Depending on the species this may set limits of acceptable change of between 0 and 10%. For species such as Australasian Bittern and Hooded Plover, that are threatened species either nationally or at state level, it is expected the limits of acceptable change would be 0%. An important element of these surveys will be to determine if species breed there every year, do so two or three years out of five or only very occasionally. This will allow limits of acceptable change to be developed that can indicate when managers need to be concerned should a certain species discontinue breeding activities at the site.

Surveys will also identify the primary breeding habitats and allow limits of acceptable change to be developed that consider, for example the areal extent and condition of inland shrublands, reedbeds, rushes, tussocks and grasslands etc. At present, limits of acceptable change have been set for each wetland type found within the Ramsar site (in Section 4) and these will provide an interim indication for managers until more detailed breeding habitat data is collected.

The data from Paton (2005b) suggest that for several fish-eating species, breeding effort in the South Lagoon has declined considerably in recent years, apparently coincident with declines in the population of hardyhead fish. This includes the Australian Pelican, Fairy Tern and Hoary-headed Grebes. Oral history accounts from the Ngarrindjeri community and three of the long-term fishing families also raise concerns about pelicans, Black Swans, Oystercatchers and Silver Gulls. On face value these may seem not to allow for the setting of robust 'limits of acceptable change'. However, the reduction and possible cessation of pelican breeding in the South Lagoon is notable in this context, as are Paton's (2005b) observations for Fairy Tern and Hoary-headed Grebe,



Pelicans. An icon of the Coorong have reduced their breeding effort in the South Lagoon over recent years, as have several other waterbird species dependent on fish and aquatic plants as food items

Traffic light assessment



Urgent action is needed to provide the ecological conditions that support waterbird breeding, in particular, to arrest the declines of the key food items Ruppia tuberosa and Small-mouthed Hardyhead (see Section 6).



indicative as they seem to be of the loss of hardyhead fish from this part of the Coorong. Equally, the observed reduction in swan numbers and breeding success, linked to the documented decline in 'swan weed' (Ruppia tuberosa) (see Sections 5.4 and 6) is also strongly indicative of a major change in the ecological character of the South Lagoon.

For these species, the limits of acceptable change need to reflect a continuation of their breeding effort and success at or near that witnessed around the time the site was Ramsar-listed in 1985. It has not been possible for this project to source any such data and so it is recommended that this be part of the follow-up actions. At the very least it should be recognised that the decline or cessation of breeding activities by these species in the South Lagoon indicates the need for urgent remedial action to recover the former ecological character.

■ 5.4 The site supports significant numbers and diversity of wading birds, including migratory species listed under the JAMBA and CAMBA agreements

The preceding section noted that among the wetland-dependent bird species of the Coorong and Lakes Ramsar site, there are those that migrate, either internationally or within the country, and those that use the site on a regular basis for breeding. There is some overlap between these two groups. Section 5.3 considers those that breed within the site. In this section, the focus is on the so-called waders. This group of 30 species being those that have been regularly observed in the wader surveys undertaken along the Coorong units of the Ramsar site (the South and North Lagoons and the Murray Mouth and Estuary) by various observers, some of this work dating back to 1981. While these species are not restricted to the more saline and estuarine system units of the Ramsar site, their regular presence together identifies them as species that share strong similarities in their foraging habitat preferences. Five species from the waders group also breed at the site and so they are considered in both Sections 5.3 and below.

With the breeding and migratory birds considered in Sections 5.3 and here, this leaves, from among the notable bird species of the site, a further seven species and these are considered in Section 5.5.

Qualitative details

The species considered here are those waders, many of which are listed under Australia's bilateral migratory bird agreements with Japan and China, that have been regularly recorded as using the Coorong components of the Ramsar site in surveys conducted from 1981 onwards (AWSG Wader Surveys, Gosbell and Christie, 2005). Reference to Table 12, listing these 30 species, indicates that in broad terms they forage in, on or near the waterline in shallow water areas or on sandy or muddy surfaces nearby. While each exhibits differences in their foraging preferences and behaviours, they have been for many years strongly attracted to the Coorong, as shown by the large numbers that aggregate there at times. Table 13, taken from Gosbell and Christie (AWSG, 2005), shows these large numbers; exceeding 160,000 in 1981, approximately 140,000 in 1982 and close to 235,000 in 1987. The survey for 1981 did not include the South Lagoon system unit. Notable also are the survey results from more recent years showing greatly reduced totals of 60-85,000, although these need to be interpreted with care (see below under 'interpreting the data').

Table 12 below also indicates that many of these species are not restricted to the Estuary and lagoons of the Coorong and Lakes Ramsar site. More generalist species are found at times around the lakes as well. It is also important to note that Lakes Albert and Alexandrina have significant areas of mudflats, seasonal saline marshes, salinas, samphire and saltmarsh communities that are also suitable habitat for many wader species (see Section 4.1.4). Examples include Waltowa Swamp on the eastern edge of Lake Albert; a series of separate salina basins, interconnected at high lake levels with each other and the Lake. Around Lake Alexandrina, Polltaloch Plains (near Wellington), Hindmarsh Island and Mundoo Island have the greatest concentration of these salinas and are considered key habitat.

Common name	Scientific name	Ramsar criteria	J/CAMBA or CMS	SA Status	System units where found	Habitat and other life history information (based on species accounts in the HANZAB)
Curlews, sandpipers, snipe	es, godwits, phalaropes - Fo	ımily Scolopac	idae			
Sharp-tailed Sandpiper	Calidris acuminata	4, 5.3, 6	J/CAMBA, CMS		1, 2, 3, 4, 5, 6	Forage mainly in shallow water up to 5cm deep on bare, wet mud or sand in intertidal areas. Also use areas with saltmarsh, grasses or sedges.
Curlew Sandpiper	Calidris ferruginea	4, 5.3, 6	J/CAMBA, CMS		1, 2, 3, 4, 5	Feeds mainly in shallow water or mudflats or sandflats.
Common Sandpiper	Tringa hypoleucos	4	J/CAMBA, CMS		1, 2, 3	Uses both coastal and inland wetlands. Generally forages in shallow water with bare mud and near protruding obstacles such as rocks or roots.
Marsh Sandpiper	Tringa stagnatilis	4	CAMBA, CMS		2, 3, 4, 5	Prefers intertidal mudflats although does also use a range of habitat types including shallow freshwater areas. Feeds among mud and vegetation.
Terek Sandpiper	Xenus cinereus (Tringa terek)	4	J/CAMBA, CMS		1, 2, 5	Forages in saline intertidal mudflats in sheltered estuaries. Usually feeds in the open on soft intertidal mudflats, near mangroves and at times in samphire.
Pectoral Sandpiper	Calidris melanotos	4	JAMBA, CMS		5	Prefers shallow water or soft muc typically close to low fringing or emergent vegetation.
Red-necked Stint	Calidris ruficollis	4, 5.3, 6	J/CAMBA, CMS		1, 2, 3, 4, 5, 6	Forages mainly in shallow water up to 2cm deep over sand and mudflats
Sanderling	Crocethia alba	4, 6	J/CAMBA, CMS		1, 2	Forages on sandy beaches, exposed sand bars in the wavewash zone. At times also uses the edges of shallow pools on sandspits and near to mudflats.
Common Greenshank	Tringa nebularia	4, 5.3, 6	J/CAMBA, CMS		1, 2, 3, 4, 5	Uses both inland and coastal wetlands, foraging in the soft mud near the water's edge and also around emerging vegetation such as saltmarshes. Often found in deeper water (10–20cm deep in Coorong region) (D. Paton pers. comm.)
Eastern Curlew	Numenius madagascariensis	3, 4, 5.3	J/CAMBA, CMS	V	1, 2	Mainly forages on soft, intertidal sand or mudflats, without seagrass cover. Sometime also uses saltmarshes.
Bar-tailed Godwit	Limosa lapponica	4	J/CAMBA, CMS		1, 2	Feeds near water's edge or shallow water, preferring exposed sandy substrates on intertidal flats. Also feeds in soft mud, often with beds of eelgras or other seagrasses.

» continued overleaf »

Common name	Scientific name	Ramsar criteria	J/CAMBA or CMS	SA Status	System units where found	Habitat and other life history information (based on species accounts in the HANZAB)
Black-tailed Godwit	Limosa limosa	4, 5.3	J/CAMBA, CMS		1, 2	Feeds on wide intertidal mudflats or sandflats, and occasionally in shallow estuaries, saltmarshes, saltflats or river flats.
Great Knot	Calidris tenuirostris	4	J/CAMBA, CMS		1, 2	Forages on intertidal flats, in soft sand and mud, usually at the edge of shallow water as the tide falls.
Red Knot	Calidris canutus	4	J/CAMBA, CMS		1, 2	Feed on soft sand and mudflats, and occasionally on sand beaches, rock platform, reefs.
Ruddy turnstone	Arenaria interpres	4	J/CAMBA, CMS		1, 2, 3	Tends to be found on exposed rock or reefs, often in shallow tidal water, and on shingle or sand beaches. Only occasionall forages in saltmarsh or exposed seagrass areas.
Ruff	Philomachus pugnax	4	J/CAMBA, CMS		5	Feeds on exposed mudflats, in shallow water.
Oystercatchers - Family H	aematopodidae				·	
Pied Oystercatcher (see Section 4.6 also)	Haematopus longirostris	4, 5.3, 6			1, 2, 3	Feeds on exposed sand, mud, rock or coral, near water's edge
Sooty Oystercatcher	Haematopus fuliginosa	5.3			1	Prefers rocky intertidal shorelines, coral reefs or sandy beaches near mudflats.
Lapwings, plovers, dottere	ls - Family Charadriidae					
Grey Plover	Pluvialis squatarola	4	J/CAMBA ,CMS		1, 2	Mostly a coastal species found foraging on tidal mud and sandflats. Inland it uses the edges of salt lakes and pans.
Pacific Golden Plover	Pluvialis fulva	4, 5.3	CMS		1, 2, 4, 5	Feeds mostly on beaches and mud and sand flats, although at times uses saltmarshes and pasture grasses.
Double-banded Plover	Charadrius bicinctus	4	CMS		1, 2, 4, 5	Uses a wide range of freshwater and coastal wetlands, river and estuarine flats included.
Lesser Sand Plover	Charadrius mongolus	4	CMS		1, 2	Mostly a coastal species, preferring beaches, wide intertidal flats, and sometimes saltmarshes or mangroves.
Oriental Plover	Charadrius veredus	4	CMS		1, 2	Mostly an inland species found associated with open grasslands Only occasionally uses estuarine areas.
Hooded Plover (see Section 4.6 also)	Charadrius rubricollis	3, 4, 5.3	CMS	V	1, 2, 3	Prefers wide, flat ocean beaches, especially those with seaweed present.

Table 12 - Significant wader species found within the Ramsar site and summary life history information (continued)							
Common name	Scientific name	Ramsar criteria	J/CAMBA or CMS	SA Status	System units	Habitat and other life history information (based on species accounts in the HANZAB)	
Red-capped Plover (see Section 4.6 also)	Charadrius ruficapillus	5.3, 6	CMS		1, 2, 3, 4, 5	Feeds on sand and mudflats along the edges of estuaries, lagoons and lakes, and even at times gravel or shellgrit.	
Masked Lapwing (see Section 4.6 also)	Vanellus miles	5.3	CMS		1, 2, 3, 4, 5, 6	Forages around natural (and modified) inland wetlands, either freshwater or saline, and both permanent and temporary wetlands.	
Red-kneed Dotterel	Erthrogonys cinctus	5.3	CMS		1, 2, 3, 4, 5	Forages around the muddy edges of freshwater wetlands in general or can wade up to 30 cm deep.	
Stilts, avocets - Family Rec	urvirostridae						
Banded Stilt	Cladorhynchus leucocephalus	5.3, 6	CMS		1, 2, 3,	Feeds in shallow saline or hyper- saline water or by wading or swimming into deeper water.	
Black-winged Stilt (see Section 4.6 also)	Himantopus himantopus	5.3	CMS		1, 2, 3, 4, 5	Forages in shallow water, fresh or saline, on sandflats often where there is dense vegetation of grass or other emergents.	
Red-necked Avocet	Recurvirostra novaehollandiae	5.3, 6	CMS		1, 2, 3, 4, 5	Found in ephemeral inland, fresh, saline and hyper-saline wetlands, especially drying salt lakes. Feeds in soft mud areas, wading to their belly.	

System units where found:
1 – Murray Mouth and Estuary; 2 – North Lagoon; 3 – South Lagoon; 4 – Lake Albert; 5 – Lake Alexandrina; 6 – Tributary wetlands

Species	Year								
	1981	1982	1987	2000	2001	2002	2003	2004	2005
Black-tailed Godwit	133	185	105	210	115	0	21	98	
Bar-tailed Godwit	15	0	3	8	0	0	20	5	58
Eastern Curlew	17	24	8	15	16	2	2	13	15
Marsh Sandpiper	0	2	30	0	0	68	1	2	1
Greenshank	600	717	596	557	305	323	312	355	616
Terek Sandpiper	0	0	0	0	0	1		0	
Common Sandpiper	13	1	1	0	1		2	0	
Ruddy Turnstone	0	1	0	1	0			0	
Great Knot	3	4	0	1	0				
Red Knot	57	67	0	80	0	30		12	
Sanderling	113	929	308	512	53	10	120	165	235
Sharp-tailed Sandpiper	24871	55739	22898	10697	5718	17067	6992	6535	10447
Pectoral Sandpiper	0	1	0	0	0	0			
Red-necked Stint	54743	63794	54710	30145	18368	44544	46067	28772	29265
Curlew Sandpiper	39882	22614	22512	13124	4309	9177	13430	3304	7052
Cox's Sandpiper	0	0	1	0	0	0			
Pied Oystercatcher	108	297	84	92	9	208	149	255	58
Sooty Oystercatcher	0	0	3	3	3	24			12
Black-winged Stilt	238	991	291	340	183	712	282	238	180
Banded Stilt	13782	77149	18692	11299	15611	24552	8602	12055	29195
Red-necked Avocet	1449	5401	3589	93	260	3856	4122	5687	3331
Pacific Golden Plover	289	230	144	84	103	43	43	30	91
Grey Plover	1	0	0	12	0	2	3	1	11
Red-capped Plover	4677	5152	2533	1089	1288	968	2897	817	803
Double-banded Plover	0	0	1	0	0		1		
Black-fronted Plover	0	2	0	0	0		1		
Lesser Sand Plover	0	0	0	0	0	2			
Hooded Plover	0	0	12	3	4	12	7	8	15
Red-kneed Dotterel	14	17	0	0	0	1	3	18	9
Oriental Plover	18	0	0	0	0				
Banded Lapwing	0	248	130	0	0				
Ruff	0	0	0	1	0				
Masked Lapwing	591	978	765	233	355	337	423	284	328
Red-necked Phalarope	0	0	3	0	0				
Unidentified small			3064		1724	1912	539	103	55
TOTALS	141614	234543	130483	68599	48425	103851	84039	58757	81777

^{*}Data from the Australian Wader Study Group (Gosbell and Christie, AWSG, 2005)



Waders feeding in the shallow water of the Coorona

Interpreting the data

In terms of total numbers recorded, Table 13 suggests a decline in the number of waders visiting the Coorong portion of the Ramsar site in more recent years. From numbers ranging between 140,000 and 235,000 in the 1980s, more recent surveys have been in the range of 60–85,000. Closer examination reveals that these large numbers are attributable to a relatively small number of species, with Sharp-tailed Sandpiper, Red-necked Stint, Curlew Sandpiper and Banded Stilt dominating the counts. Species such as Greenshank, Red-necked Avocet, Red-capped Plover, Sanderling and Masked Lapwing make up a second group of species commonly recorded, but in lesser numbers. For the species that have dominated the counts, despite some variability, there does appear to have been declines over time. For example, Sharp-tailed Sandpipers, recorded in the 1980s at levels of around 25,000–55,000, has in the surveys of 2003–2005 been recorded at levels between 7,000-10,000. A similar trend is evident for Curlew Sandpipers.

Broad-scale surveys provide some indications of local population numbers for these species, although they are limited to the Coorong lagoons and Estuary units, and there is great variability of the data. The reduction in total numbers observed, and even for some species, may reflect either a reduction in the suitability of the habitat for these species, or population declines for the species more generally. While the latter cannot be discounted, extensive surveys and other studies by Paton and Geddes (see following page), in particular, have reinforced this decline in numbers, attributing it to reduced availability of food items. This results from the combined impact of reduced freshwater inflows to the Coorong over the barrages, from the South East of South Australia and

from groundwater inputs. This has seen the former salinity gradient from the mouth of the Murray to the southern end of the South Lagoon disrupted, increases in salinity levels and reductions in the tidally driven fluctuations in water levels. All of these factors contributing to reductions in the area of suitable intertidal flats for wader forgaina.

The reduced freshwater inflows into the lagoons, coupled with evaporation, has seen escalating salinity in the South Lagoon, in particular to above the tolerances of many forage species (see Section 6.1). This could be dampened to some extent by less saline water from the Upper South East Drainage Scheme discharging into the lagoon at Salt Creek, however, these flows to date have been too low to induce widespread or sustainable decreases in salinity.

Another factor is that the higher than normal water levels that occur in winter (due to local runoff, groundwater inflows etc.) deleteriously impact on the growth of the aquatic angiosperm Ruppia tuberosa, as does the drop in water levels that occurs during spring (before this essentially annual plant has been able to reproduce). These occur under the current regime of reduced inflows (see Section 6.4). Ruppia tuberosa is the keystone species of the ecology of the South Lagoon which once formed dense stands across the lagoons. It is now limited to shallower areas (<0.8m) due to the turbidity of the water column and further constrained by high water levels in winter and spring (Paton, 2003) affecting reproductive processes. Section 6 considers these various key determinants of ecological character in detail.

Table 14 - Comparison of the abundances of key food resources for waders in the South Lagoon in 1985 and 2005. Taken from Paton (2005b)

Resource	Section 1		Sect	ion 2	Section 2		
	1985	2005	1985	2005	1985	2005	
Ruppia tuberosa seeds	1.5	0.3	6.8	0.6	19.7	1.3	
Ruppia tuberosa turions	1.8	0.1	12.9	0.8	9.1	5.1	
Chironomid larvae	0.2	0.2	3.0	0.7	3.0	2.1	

Paton (2005b) observes that 'In the South Lagoon of the Coorong, chironomid larvae, Small-mouthed Hardyheads (Atherinosoma microstoma) and the seeds and turions of Ruppia tuberosa are important food items for aquatic birds during January. In the northern parts of the North Lagoon where salinities are lower, polychaete worms are an important food source.' Paton (2005) divided the Coorong into seven 15km sections and plotted the distribution and abundance of these key food items along the system for the years 2001–2005. The data are based on annual sampling within each section, from dry mudflats, at the waterline and where the water level was 30 cm. As noted by Paton (2005b), these represent the typical feeding niches of the wader species. To summarise, the findings were as follows:

- the abundance of both Ruppia tuberosa (seeds and turions) and hardyhead fish has declined considerably in the South Lagoon, and in particular in the two southern-most sections
- abundances of chironomid larvae were higher in the 2005 sampling than in previous years, which Paton suggests may reflect the lower numbers of hardyhead fish that feed on these
- the abundance and distribution of polychaete worms in the North Lagoon has also declined. Paton (2005) notes that sites where polychaetes were very abundant in 2001–2003 had few worms in 2004–2005.

Paton (2005) also provides a comparison for the South Lagoon sections of the Coorong of the densities of Ruppia tuberosa (seeds and turions) and chironomid larvae as recorded in January 1985 (the year this site was Ramsar-listed) and January 2005. This table has been reproduced below. The numbers represent means per core sample, based on 30-50 cores taken at the sampling sites of which there were 2-3 per 15km section.

The data in the table above show clearly the severe decline in Ruppia tuberosa in the South Lagoon over the past 20 years.

Paton (2005b) also provides detailed data on the distribution and abundance of aquatic birds (that is, not only wader species) in the Coorong for the period 2000-2005 and he concludes that several of the fish-eating bird species had reduced numbers and breeding activities in the South Lagoon, due, it is assumed to the reduced availability of food items, hardyhead in particular. This includes species such as Australian Pelican, some waterfowl species, Fairy Tern and Hoary-headed Grebe. This is considered further in Section 5.3.

Of the prominent wader species referred to earlier in Table 13, Paton (2005b) makes the following observations based on his surveys:

- Red-capped Plovers—signs of continuing decline with less than 500 recorded for the first time in 2005.
- Curlew Sandpipers—numbered 40,000 in 1981, but in 2005 this was 2,000; approximately what it has been in surveys in more recent years.
- Banded Stilts—numbers substantially higher in 2005 with these birds feeding mostly on chironomid larvae, whose numbers are high due to reduced foraging pressure from hardyhead fish (see above).
- Red-necked Avocets—same as for Banded Stilts.

Paton (2005b) concludes that the lack of spring flows over the barrages over the past five years has seen a continued decline of Ruppia tuberosa from the more southern parts of the Coorong. This has also seen a rise in salinities, and the loss of another waterbird food item, the hardyhead fish. It seems likely that the loss of Ruppia tuberosa has contributed to the loss of hardyheads. The reduction in the population of hardyheads has seen a reduction in the numbers of several fish-eating birds (see above and Section 5.3). Paton (2005b) notes that while Ruppia tuberosa and hardyheads have declined, chironomid larvae have not, and these have become a staple food item for most of the waders. The conclusion is that this increase in the numbers of chironomid larvae is due to the reduced predation pressure because of the declining hardyhead population.

Geddes (2005) reports on the ecological health of the Coorong based on monitoring done in 2003 and 2004. This study considered issues of water levels, water quality and biological components. From his earlier studies Geddes also draw comparisons with the condition of the system in the 1980s. His findings in relation to water levels and water quality are considered further in Section 6, however, here it is notable to examine his conclusions in relation to the overall ecological health of the Coorong, as follows:

'The biota of the Coorong was of similar limited diversity, distribution and abundance to that recorded in 2003. The aquatic plants were represented only by Ruppia tuberosa. Filamentous algae and macroalgae (both of which are 'nuisance' algae) were also present in the Murray Mouth and north of the North Lagoon. No R. megacarpa or seagrass was collected at any site.

The estuarine-lagoonal fauna of the North Lagoon was restricted to the Murray Mouth and the most northern sections of the North Lagoon, in a similar way to that recorded in 2003. Most of the North Lagoon locations did not have the estuarine-lagoonal crustaceans, polychaetes and molluscs that would be expected in the area. The absence of these invertebrates is probably the result of high salinities in summer and autumn, before the May/June inflow of seawater. These animals would take some time to disperse and establish viable populations in newly 'refreshed' areas. In the South Lagoon very few species were collected. The chiromonid Tanytarsus barbitarsus was low in abundance and salt lake isopods were present in some collections; the hypermarine microcrustaceans that occurred previously in the South Lagoon (Geddes, 1987) were not collected. Surprisingly, brine shrimp Parartemia zietziana were collected, representing the first time this salt lake brine shrimp has been collected in the Coorong.

It appeared that fish numbers were low and distributions restricted in the North Lagoon. In the South Lagoon only hardyheads, Atherinosoma microstoma, were collected and these were in low numbers. At the southern end of the South Lagoon, the abundance of hardyheads seemed to be lower than in 2003." (Geddes, 2005).



The abundance and distribution of polychaete worms in the North Lagoon has declined

Key drivers and levers	
Drivers and levers	Description
Winds and tides	Coorong: Mixing in the Murray Mouth Estuary is driven by tidal signals which are in turn dependent on the Murray Mouth Opening Index (Lamontagne et al., 2004). The tidal signal terminates at Pelican Point thus little tidal energy reaches the Corong Lagoons and mixing in the North and South Lagoons is primarily caused by winds which cause water to 'slosh' back and forth (Lamontagne et al., 2004). This results in a well-mixed water column and lower probability of stratification and associated anoxia and nutrient release from sediments. The ingresses of sea water that do occur into the North Lagoon act in concert with the wind induced mixing to create relatively uniform salinity along the North Lagoon. Tidal fluxes determine the extent of exposed mud and sand flats in the Estuary, around the Murray Mouth whilst the wind may cause daily changes in water level of c. 30 cm across the Coorong Lagoons which is an impediment to Ruppia growing in the more shallow waters where light is not limiting. Water can be pushed into the South Lagoon from the North Lagoon when tides and strong winds coincide. Lakes: There is no tidal influence now that barrages are in place, although seawater intrusions do occur caused by reverse head over the barrages. Wind, combined with shoreline erosion, can cause increased
	freshwater intrusions or splashing on saline-samphire areas. Wave action exacerbates erosion of the alluvial layers that overly the sand deposits on the lake shoreline.
Opening of the Murray Mouth	Coorong: The penetration of tides into the Lagoons is strongly dependent on the degree of Murray Mouth Opening (Lamontagne et al., 2004). The tidal fluxes are not great enough to flush the Coorong Lagoons (tidal signal terminates at Pelican Point) and only act to flush the Murray Mouth Estuary area itself. Sea water that enters the North Lagoon counters the salinity rise from evaporation to some extent but also adds to salt loads in the Coorong system given the paucity of freshwater inflows from either the River Murray or the southeastern end of the system.
	Lakes: Lake levels are managed to provide water to Murray Mouth and Coorong and thus hydrology of the lake is impacted upon by releases. The 'fill and spil' philosophy that has governed barrage operation is being replaced with a risk management approach that will deliver water in a more ecologically sensitive manner.
River Flows— freshwater inflows	Coorong: River flows provide freshwater inputs to freshen the estuarine and lagoon environments. They are critical for the life cycles of many macroinvertebrates, fish, and hence birds. Flows contribute to maintaining the opening of the Mouth (supplementing the dredging effort) and play a major role in the salinity, carbon and nutrient cycles of the Estuary and lagoons.
	Upper South East Drainage Scheme water releases: Redirected groundwater is stored in Morella Basin for controlled release into the South Lagoon via Salt Creek. Inflows are capped at 40,000 ML per year with a 10-year rolling average. To date flows have been in the order of 5–15GL per year, it is unknown whether volumes approaching 40 GL are likely to be available. Inflows from the South East occurred under natural conditions, but extensive drainage schemes constructed from European settlement onwards have modified inflows to the Coorong and redirected surface and groundwater flows to the sea. Freshwater inflows directly into the Coorong lagoons from freshwater soaks is thought to have also declined significantly since the 1940s (see Section 6).
	Lakes: Maintaining little variation in lake levels in order to service irrigation needs has reduced exposure of wader habitat along the shorelines and is contributing to lakeshore erosion and freshening of the saline-samphire communities surrounding the lakes. Species dependent on variable water regime, such as some emergent plants important for nesting, are now under-represented in the lakes environment.

Ecosystem components and processes	Description
Salinity	Coorong: Variation in salinity from marine to hypersaline. Salinity in the Lagoons is a product of freshwater flows through the barrages, marine water exchange from the Southern Ocean along the dredged channel, evaporation, discharges from the Upper South East Drainage Scheme into the South Lagoon, groundwater inflows (e.g. freshwater soaks) rainfall on the lagoon surfaces and the movement of hypersaline water from the South Lagoon into the North.
	Lakes: Variation in salinity is a product of River Murray and tributary inflows, rainfall on the lakes, groundwater dynamics, water extraction and evaporation. Since the year 2000 onward, salinity levels in Lake Alexandrina have ranged between 400 EC to nearly 1,500 EC and in Lake Albert fror about 1,300 EC to nearly 2,300 EC (See Appendix H)—see Section 6.
Dissolved oxygen	Coorong: The shallow water depth and the wind-induced mixing in the Estuary generally result in a well-mixed, oxygenated water column in the North Lagoon (MDBC, 2002). However, thermal or salinity induced stratification can occur and result in nutrient releases and negative effects to benthic organisms (Lamontagne et al., 2004).
	Lakes: As shallow water bodies it is likely that wind-induced mixing prevents stratification in the lakes most of the year. This is not well understood at present.
Turbidity	Coorong: Turbidity causes a reduction in light available for photosynthesis for submerged aquatic plants and changes the conditions to favour the growth of phytoplankton over aquatic macrophytes. High levels of turbidity can also reduce the success of visual feeders such as waterbirds and carnivorous fish that require adequate visibility to see prey. High turbidity levels restrict growth for Ruppia spp. to shallower waters.
	Lakes: As above, except the affected plants are freshwater macrophytes such as Valiisneria americana, Myriophyllum and Ceratophyllum spp.
Sedimentation, sediment size and erosional processes	Coorong: Sedimentation needs to be balanced between the amounts needed to replenish the organic matter and nutrients for the sand and mudflats and the amounts that will not cause decline in aquatic plant growth due to light limitation and biofilm growth. Excess sedimentation may also change the topography of the floor of the lagoons, filling-in holes and covering sand, mud and stony flats that are important for fish feeding and spawning. Another consideration here is the loss of the finer sediments previously deposited by semi-regular riverine flooding and the replacement of these substrates with coarser marine sands.
	Decomposing algae is depositing on the rocky shorelines (5–15cm thick at Woods Well), smothering and infilling the micro-topographical features, thereby reducing rocky shoreline pool habitats.
	Lakes: As for the Coorong, submerged aquatic plants in the lakes are being adversely impacted upon by high turbidity. Shoreline erosion adds to the River Murray sediment loads and breaks down fringing reedbeds which tends to increase the opportunities for freshwater intrusion into the saline samphire communities behind (see above).
Water levels	Coorong: Water levels in the Estuary are lowest in February–April, and highest July–September, changing seasonally by approximately 0.7m (Lamontagne et al., 2004). This variation and tidal fluxes in the North Lagoon are important for exposing mudflats. In addition, submerged aquatic vegetation requires water levels between 0.3 and 0.8m in winter and spring for reproduction and growth (Oborne, 2003). Ruppia tuberosa requires this for the whole of spring. Changes in water level need to be gradual to allow for biota to adapt (e.g. setting of seeds for aquatic plants or laying of eggs for invertebrates).
	Lakes: Maintaining relatively constant water levels in the lakes increases the freshwater intrusion from wave and splash actions) into samphire communities that fringe the lakeshore that were formerly less-frequently flushed and more saline areas and therefore favoured by waders. The lack of medium and large floods means salinas and samphire communities etc. that lie behind the fringing vegetation and higher on the floodplain do not receive the fresh waters they need on a semi-regular basis. Thus some samphire communities are receiving too much freshwater and others are not receiving enough. Extensive areas of these communities are now grazed (EarthTech, 2003).
Biological	
Nutrient and carbon cycling	Coorong: Nutrient concentrations in the North Lagoon are typically higher than those near the Mouth and lower than the South Lagoon (MDBC, 2002). However, nutrient cycling and the nutrier requirements of aquatic plants in the Coorong is not well understood (Lamontagne et al., 2004; Nichols, 2005). Carbon cycling similarly has been poorly studied but it is likely that the increasing salinity levels and highly labile carbon loads from algae (cf. relatively refractile carbon from plants) will favour anaerobic over aerobic decomposition, particularly sulphate reduction.
	Lakes: Nutrient and carbon cycling in the lakes is poorly understood.

» continued overleaf »

Biological	
Habitat availability	Coorong: The dominant primary producers, and thus habitat foundation, in the lagoons are Ruppia spp. Ruppia megacarpa has now gone from the North Lagoon (Nicol, 2005). Ruppia tuberosa has declined in the South Lagoon and begun to colonise the North Lagoon presumably due to the increasing salinity found there. Ruppia forms the basis of the food chain for waterfowl which fed on seeds, leaves and turions and provide detritus for stimulating nutrient cycling in the sediments and food for detritivores such as fish and macroinvertebrates. R. tuberosa is not being replaced by another plant species in the South Lagoon but rather by algae as the dominant primary producer indicting a fundamental shift in ecological character.
	Lakes: Submerged aquatic plants such as Vallisineria americana, Myriophyllum sp. and Ceratophyllum sp. once grew out several kilometres into the lakes from the shoreline (Sim and Muller, 2004). They are now confined to the near-shore environment (c. 25m from shore), channels, drains and fringing wetlands that provide suitable light climates and substrate stability.
Reproduction	See Section 5.3 regarding bird breeding.
Competitive extent	Coorong: Ruppia spp. is an important food source for plovers, sandpipers, stints, silts, avocets, ducks and swans. Whilst the Small-mouthed Hardyhead fish that depend upon the Ruppia are major food sources for grebes, pelicans and terns (Paton, November 2004 presentation by Geddes, Goolwa, November 2004). Greenshank, Banded Stilts and Red-necked Avocets will also take small fish at times (D. Paton pers. comm.). Both plant and fish food sources are now severely depleted and competitive pressure is high.
	Lakes: Submerged aquatic plants such as Myriophyllum sp., Lepileana sp. and Vallisineria americana are direct food sources for herbivorous birds such as swans and ducks. Whilst the small native fish that depend on the macroinvertebrates living in the submerged plant beds are important food sources for piscivorous birds and larger fish species such as Golden Perch. Submerged aquatic plants and small native fish tend to be dependent on variable water regime and thus are now under-represented in the lakes environment, placing competitive pressure on the waders.

Limits of acceptable change and traffic light assessment

For this assemblage of wading species within the wetland-dependent bird community of the Coorong and Lakes Ramsar site, there are a number of limits of acceptable change that need to be considered, as follows:

1. Population size—survey data to date can be used only to indicate trends and it is not possible to use it to set robust limits of change. The data is also, in most cases, highly variable and this wide natural variation also hinders the setting of LAC. It is recommended

that future surveys focus on the following wader species; Sharp-tailed Sandpiper, Red-necked Stint, Curlew Sandpiper, Banded Stilt, Greenshank, Rednecked Avocet and Red-capped Plover, to establish meaningful LAC. In the interim, the LAC should be to see these populations retained at or better than their 2000 levels as recorded in Paton (2005). For these species, those population estimates for the Coorong were as shown below. It is recognised that these are somewhat arbitrary but they are provided in the interest of providing an interim LAC until more systematic surveys can provide stronger data on which to base them.

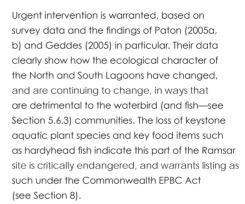
Prominent wader species of the Coorong	2000 population estimate (Paton, 2005b)
Sharp-tailed Sandpiper	13,089
Red-necked Stint	25,524
Curlew Sandpiper	8,157
Banded Stilt	2,354
Greenshank	579
Red-necked Avocet	163
Red-capped Plover	1,243



Red-necked Stints

- 2. Distribution and breeding success of certain species—See Section 5.3.
- 3. Habitat/food availability and condition—There are a number of levers, components and processes that impact on the availability and condition of habitat and food items for these species. These are considered in Section 6.

Traffic light assessment



■ 5.5 The site supports a diverse community of wetland-dependent bird species

Qualitative description

As outlined in the introduction to the preceding section. once wetland-dependent bird species that breed at the site (Section 5.3) and the wader species are addressed (Section 5.4) this leaves a short list of other significant wetland-dependent species to be considered. These are listed in the table below, along with some summary life history information and an indication of where within the Ramsar site they are known to occur.

Examination of this information shows that with one exception (Cape Barren Goose, see following page) these seven species, and their ecological needs and roles have been addressed indirectly in this report in either Sections 5.3 or 5.4. While they are neither wading species nor breed at the site, these species, to a large extent, have ecological needs that mirror those considered in these earlier sections. As such, no attempt has been made here to provide detailed profiles of these habitat requirements and the underlying processes and drivers, or to set limits of acceptable change. It is assumed that if the limits of acceptable change for these other bird assemblages are applied then the species under consideration below will also benefit.

It is assumed that if the limits of acceptable change for these other bird assemblages are applied then the species under consideration below will also benefit.



Cape Barren Geese

Common name	Scientific name	Ramsar criteria	J/CAMBA or CMS	SA Status	System units	Habitat and other life history information
Grebes - Family Po	odicipedidae			ı		
Great Crested Grebe	Podiceps cristatus	5.3, 6		R	1, 2, 4, 5	Found in rivers, lakes, swamps etc. preferring large, open water areas. Non-breeding groups form on saline lakes, estuaries and bays (HANZAB). Eats primarily aquatic arthropods, fish, mollusks, vegetative matter and seeds (Scholz, 2001).
Hoary-headed Grebe	Podiceps poliocephalus	5.1, 5.2, 5.3, 6			1, 2, 4, 5	Prefers large, permanent or semi-permanent, and open waterbodies; coastal up to approx. 1001 m ASL. Seems to avoid waters covered with dense vegetation, preferring water 0.5–3.0 m deep with some submerged vegetation (HANZAB). Eats primarily aquatic arthropods and fish (Scholz, 2001).
Geese, swans and	l ducks - Family Anal	idae				
Cape Barren Goose	Cereopsis	6	CMS	R	1, 2, 4, 5	Grasslands and terrestrial wetlands; grazing on vegetation, such as grass, pasture, cereals, and sometimes the fringing aquatic vegetation (HANZAB).
Grey Teal	Anas gracilis	5.1, 5.2, 5.3	CMS		1, 2, 3, 4, 5, 6	Feeds in shallow open waters of less than 1 m depth. Widespread, from terrestrial wetlands to sheltered estuaries etc. (HANZAB). Eats mostly seeds and vegetative matter, sedges, smartweeds and grasses (Scholz, 2001).
Rails, crakes, swar	mphens, coot - Famil	y Rallidae		ı	ı	l
Lewin's Rail	Rallus pectoralis	3		V	4, 5, 6	Densely vegetated, freshwater to saline wetlands usually with areas of still water. Eats molluscs, earthworms, arthropods and occasionally frogs o birds' eggs (Scholz, 2001).
Curlews, sandpipe	ers, snipes, godwits, p	halaropes - I	amily Scolopa	cidae		
Latham's Snipe	Gallinago hardwickii	3, 4	J/CAMBA, CMS	V	4, 5, 6	Prefers marshy areas, feeding mostly on invertebrates found in soft muddy soils around low vegetation such as sedges and herbs (HANZAB).
Gulls, terns etc F	amily Laridae					
Little Tern	Sterna albifrons	3, 4	J/CAMBA	V	1, 2, 3	Sheltered coastal areas; forages in shallow water of estuaries and coastal lagoons. Breeds on sandspits, banks and ridges of lakes or estuaries (HANZAB).

System units where found:
1 – Murray Mouth and Estuary; 2 – North Lagoon; 3 – South Lagoon; 4 – Lake Albert; 5 – Lake Alexandrina; 6 – Tributary wetlands
The Ramsar criteria are provided in Table 3

5.5.1 Cape Barren Goose

As noted above, the Cape Barren Goose, due to its unique ecological niche is worthy of note in this description of ecological character. While a generalist in terms of where it feeds, the species is considered rare in South Australia and has somewhat of an iconic position to the people of this region. It therefore seems appropriate to consider applying a limit of acceptable change to this species, purely in terms of its population size within the Ramsar site, to ensure that this area remains a refuge for it and this rather unique part of the bird fauna of the Ramsar site is monitored.

Limits of acceptable change and traffic light assessment

The species breeds away from the Coorong, on Kangaroo Island and other offshore islands further to the west.

It is not possible to establish the size of the population of this species at or around the time the site was Ramsarlisted in 1985. In recent years the population size of the Ramsar site and immediately adjacent areas has been estimated at approximately 4,000 (Tim Wilson, pers. comm.).

Further work is required to determine both the population size and extent of the habitats required by this rare species within the Ramsar site so that appropriate planning and management can be provided. From the perspective of setting limits of acceptable change there are four primary considerations as follows:

1. Population size—the estimate is approximately 4000 however natural variability of this figure is not known at present. Until such time as a more precise population estimate is possible and natural variations are better understood, the precautionary approach suggests a 5% limit of acceptable change, noting the generalist foraging behaviour of the species.

- 2. Areal extent of primary habitats used by the species. Not known at present.
- 3. Condition of the primary habitats used by the species. Not known at present, although see wetland Type 4 in Section 4.1.4.
- 4. Connectivity between primary habitats used by the species assuming this is an important factor in sustaining the population. Not known at present.

Traffic light assessment



There are no indications at present that this species, despite being rare in South Australia, is facing any immediate threat, or that the population has declined over recent years. Being a generalist feeder, less reliant on aquatic resources than other birds from this site, and breeding on off-shore islands may have insulated this species from some of the impacts noted for other bird species in the preceding sections. Further investigations are needed to set robust

LAC for the aspects referred to above.





■ 5.6 The site supports significant numbers and diversity of native fish, including migratory species

The Coorong and Lakes Ramsar site is significant for 49 native fish species which between them contribute to qualifying the site against five of Ramsar's eight criteria (see Appendix C, Attachment 6). Among these species are the followina:

- · five species that are listed as vulnerable at either global or national levels
- 20 further species that are classified as protected or have been provisionally listed as of conservation concern within South Australia
- 20 species that utilise the site at critical stages of their life cycle, such as, diadromous species, estuarine species that spawn or have large populations and any freshwater species that spawn or recruit within the
- a further four species of note because they contribute to the overall biodiversity and biodisparity within the fish community.

For the purpose of this description of ecological character, these species have been broken up into the following groups based on their life history strategy:

5.6.1 Obligate freshwater species

5.6.2 Diadromous species

5.6.3 Euryhaline and estuarine species

5.6.4 Marine stragglers.

5.6.1 Obligate freshwater fish species

Qualitative description

Table 6 (in Section 3) provided details of those obligate freshwater native fish considered 'significant' in the Ramsar Information Sheet for this site (see Appendix C). As is to be expected, these species occupy the freshwater parts of the Ramsar site; Lake Albert and Lake Alexandrina and its tributaries. On occasion some of these species may move through the barrages during release events but these more saltwater environments are not preferred. Added to the fish community of the Lakes at times are the diadromous species that move into freshwater environments for spawning (see the following section for consideration of these species).

Wedderburn and Hammer (2003) in their survey of the fish fauna of the Lakes noted the diversity of this community from a South Australian and Murray-Darling Basin perspective. They noted the mix of diadromous

and obligate freshwater species, among these (as shown below) are several considered threatened, protected or of conservation concern nationally or within South Australia.

To quote Wedderburn and Hammer (2003):

A large proportion of the total native species of the Murray-Darling Basin were captured in the Lakes (18 of 41 species), including about a third (11 of 30) of the freshwater obligate species. The area is the exclusive habitat in the Basin for several species, notably the Yarra Pygmy Perch, and also houses rare populations of other threatened species such as the Murray Hardyhead and Southern Pygmy Perch. Similarly, from a South Australian perspective, species richness accounts for a third of the State's species with a number of those only recorded in the Murray Drainage. Hence the biological significance placed upon the Lakes as a Ramsar Convention Wetland of International Importance extends to an important fish fauna, with the area a localised hotspot for fish diversity. On a negative note, there is indication that historically this uniqueness was even more pronounced, as several species no longer appear to be represented.



Murray Hardyhead



Yarra Pygmy Perch

Wedderburn and Hammer (2003) also noted that this fish community could be divided into two sub-sets; those more mobile and generalist species that were frequently encountered on the open exposed lake edge, and those more specialist demersal species that prefer the fringing wetland areas with more cover. They noted that 'wetlands that provided habitat for threatened species invariably had dense submerged or emergent vegetation and were characterised by some form of flow (e.g. Mount Lofty Ranges stream discharge, through channel water movement).'

Below more detailed information is provided on where each of these species occurs in the Coorong and Lakes Ramsar site, plus habitat information sourced from Wedderburn and Hammer (2003) and the SKM report of 2003 that reviewed freshwater fish species of the Murray-Darling Basin. Tables taken from the SKM (2003) report providing summary information of the habitat and other needs of these species during spawning and for larval and juvenile forms are provided in Appendix D.



Typical fish habitat

	Currency	Finniss	Hindmarsh	River Murray	Lake	Lake
Species	Creek	River	Island	Confluence	Alexandrina	Albert
Common Galaxias	Х	Х	X	Х	Х	Х
Mountain Galaxias		*				*
Australian Smelt	Х	Х	X	Х	Х	Х
Bony Herring	Х	Х	X	Х	X	Х
Sandy Sprat					X	
Murray Rainbowfish		*				
Small-mouthed Hardyhead	X	X	Х		X	Χ
Flyspecked Hardyhead	Х	Х	X			Х
Murray Hardyhead		*	Х		*	Х
Southern Pygmy Perch		Х	Х		Х	
Yarra Pygmy Perch	*	Х	Х		*	
Chanda Perch		*				
Purple-spotted Gudgeon		*				
Murray-Darling Carp Gudgeon		х	Х		Х	
Midgley's Carp Gudgeon					Х	
Western Carp Gudgeon		*			*	
Flathead Gudgeon	Х	Х	Х	Х	Х	Х
Dwarf Flathead Gudgeon	Х	Х	X	Х	Х	Х
Lagoon Goby	Х	Р	X	Х	Х	Х
Tamar Goby			Р		Х	Х
Western Blue-spot Goby	X	Х	X	Х	Х	Х
Congolli	X	Х	X		Х	Х
Short-finned Eel					*	
Murray Cod		*			*	
Estuary Perch			*		*	
Golden Perch		X	P		P	X
Silver Perch					*	
Freshwater Catfish		*			*	
Pouched Lamprey			P		*	
Shortheaded Lamprey			P		*	
Introduced species						
Tench	*					
Gambusia	X	X	X	X	X	X
Goldfish		X	X	X	X	X
Carp	X	X	X	,	X	X
Redfin	X	X	X	X	X	X
	^	^	^	^	^	^
Total native (and exotic)	10 (3)	14 (4)	18 (4)	7 (3)	15 (4)	13

X-current record, * historical record, P-recorded recently, but not found during this survey.

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Olive Perchlet (Chanda perch, Agassiz's glassfish) Ambassis agassizii	1, 4, 5, 6	'This fish is a lowland to mid-slope species with habitat preference for slow, warm waters in rivers, creeks and floodplains and relies on instream cover such as aquatic vegetation and woody debris. Spawning is probably induced by rises in water levels and water temperature.' Temperature: Prefers warm water Salinity (mg/L): DD Dissolved oxygen: Can probably tolerate low DO	'Similar historic accounts as for the Murray Rainbowfish, occurring in the Finniss arm historically except disappearing in the early 1970s. Unfortunately, detailed studies of their habitat requirements and ecology to help assess reasons for decline were not conducted in the Lower River Murray region prior to their presumed local extinction. The variability and extent of habitat in the Finniss arm still offers some hope of small refuge populations of these species.'		
Murray Hardyhead Craterocephalus fluviatilis	1, 4, 5, 6	'Murray Hardyheads have a patchy occurrence in lowland rivers, lakes, billabongs and wetlands in the southern Basin. Adults are often associated with aquatic vegetation in lakes, billabongs and wetlands and are occasionally found on inundated floodplains.' Temperature: DD Salinity (mg/L): <43,800 Dissolved oxygen: DD	'The Coorong and Lakes Ramsar site support a self-sustaining population, and is the only region where the species is currently known to inhabit extensive freshwater habitats. In other states it is mostly found in deflation basins. In the Coorong and Lakes Ramsar site the species lives sympatrically with two other Atherinids, the Small-mouthed Hardyhead and Fly-specked Hardyhead.' Environmental conditions at survey sites: Habitat types: drains, river channel, lake, wetland Submerged cover (%): 1–90 Emergent cover (%): 0–20 Secchi depth (m): .01–>0.43 Conductivity (µS): 1210–2700 Flow environment: Permanent Flow condition: Low flow Habitat specialist* (M. Hammer, pers. comm.		
Fly-specked Hardyhead Craferocephalus stercusmuscarum fulvus	1, 4, 5, 6	'Pools and areas of still or low flowing water are often a preferred habitat and fish are often associated with aquatic vegetation, which is used as cover.' Temperature: 9.3–36°C Salinity (mg/L): <43,700 Dissolved oxygen: DD	'This species is generally patchily distributed in Murray wetlands, with a similar pattern shown for the Lakes. It was patchily distributed and restricted in range in the Lakes (12 sites) generally in low numbers (e.g. only three recorded for the Lake Albert sampling area) being abundant at one site within the Currency Creek arm (130 fish at site R18). Abundances were higher than one or two individuals only at sites with dense submerged aquatic vegetation, usually Myriophyllum spp. Some taxonomic confusion between the three Lakes hardyheads limits reliable understanding of historic distribution, however, the Fly-specked Hardyhead is likely to have been associated with more long-term fresh sections such as wetlands at the mouths of tributary streams (e.g. Currency Creek, Angas River, Finniss River, Tookayerta Creek).'		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Bony Bream (Herring) Nematalosa erebi	1, 4, 5, 6	'Bony Herring inhabit still and slow-flowing rivers, streams and floodplains of the foothill and lowland zones. Often associated with snags and muddy substrates, it also swims in open water. Spawning may be induced by rising water levels or flooding but there is limited information on spawning triggers for this species.' Temperature: 9–38°C Salinity (mg/L): <35,000 Dissolved oxygen: DD	'Widespread in Lake Alexandrina and Lake Albert (17 sites) generally over sandy substrates, but mostly absent from more sheltered sites in the Hindmarsh Island, Currency Creek and Finniss River regions where vegetation was thickest. High number of larval fish were recorded on the northern shore of Lake Alexandrina. The species has probably increased in abundance with the stable and permanently fresh lake conditions now existing.'		
Purple-spotted Gudgeon Mogurnda adspersa	6	'The Southern Purple-spotted Gudgeon has a patchy occurrence throughout the Basin. They prefer habitats with slow-flowing waters with suitable hard substrates such as cobbles, boulders and wood as well as aquatic vegetation.' Temperature: 19–34°C Salinity (mg/L): <17,100 Dissolved oxygen: DD	'Similar historic accounts as for the Murray Rainbowfish, occurring in the Finniss arm historically except disappearing in the early 1970s. Unfortunately, detailed studies of their habitat requirements and ecology to help assess reasons for decline were not conducted in the Lower River Murray region prior to their presumed local extinction. The variability and extent of habitat in the Finniss arm still offers some hope of small refuge populations of these species.'		
Dwarf Flathead Gudgeon Philypnodon sp.	1, 4, 5, 6	'This species tends to inhabit slow-flowing streams, lakes and reservoirs and is also found in brackish estuaries. Habitat preferences include muddy and rocky substrates and areas of aquatic vegetation and snags.' Temperature: DD Salinity (mg/L): DD Dissolved oxygen: DD	'Represented in all sampling regions, generally in low numbers, at 26 sites. They were unusually abundant at a drain connected to Hunter's Creek (44 fish at site D2) and a drain on the eastern edge of the Finniss River wetland complex (33 fish at site R20). This species seemed strongly associated with cover, being mostly recorded in small to medium-sized, well-vegetated waterbodies associated with Lake Alexandrina and the Finniss River. Little is known of the ecology of this species, however its benthic nature and habitat preference suggest that it would be a slow coloniser under variable conditions, and that populations in the Lakes may have gradually built up following construction of the barrages.'		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Midgley's Carp Gudgeon Hypseleotris sp.	5		'The carp gudgeon species complex (Bertozzi et al., 2000; Hammer and Butler, 2001) has historically caused considerable confusion within species lists of the region. The current survey benefited from identification experience as part of the SA Museum's genetic studies into the group, and hence two species were positively identified: the Murray-Darling Carp Gudgeon occurred in wetland and drain habitats with dense submerged cover, and Midgley's Carp Gudgeon was identified in a single drain (it is an otherwise common river edge species in the main channel of the Murray).		
			Again, given taxonomic confusion, little is known of the historic distribution, with a more in-depth morphological revision of museum specimens required. Lloyd and Walker (1986) listed the Western Carp Gudgeon for several sites, but without reviewing voucher specimens it is likely the same species from the current survey were detected. Although not detected, further collecting is required to determine the status of the Western Carp Gudgeon (Hypseleotris klunzingeri sensu stricta), in the Lakes as other collecting seems to suggest that this species is now rare or absent below Morgan within the Murray system (M. Hammer pers. obs.).' (Wedderburn and Hammer, 2003)		
Murray-Darling Carp Gudgeon Hypseleotris sp.	1, 5, 6		See Midgley's Carp Gudgeon above Habitat specialist* (M. Hammer, pers. comm.)		
Hybrid Carp Gudgeon (e.g. Lakes Carp Gudgeon) Hypseleotris spp.	1, 5, 6		See Midgley's Carp Gudgeon above		
River Blackfish Gadopsis marmoratus	6	'They prefer habitat such as pools and slow-flowing water with abundant cover in the form of logs, boulders, overhanging and aquatic vegetation and undercut banks and sand and gravelly substrates. Hollow logs are particularly important as areas for egg laying and attachment.' Temperature: 5–28°C Salinity (mg/L): <10,000 Dissolved oxygen: Intolerant of low DO.	Habitat specialist* (M. Hammer, pers. comm.)		
Mountain Galaxias Galaxias olidus	6	'This species occurs from southern Queensland to eastern South Australia in small mountain streams that are well- shaded and contain abundant cover from woody debris and overhanging banks and vegetation. The substrate usually consists of sand and gravel.' Temperature: 1.7–32°C Salinity (mg/L): <1,500 Dissolved oxygen: DD	'Probably only a rare inhabitant historically as a straggler from extended periods of freshwater dominance in the Lakes. A record from the Point Mcleay Jetty near Narrung in 1928 suggests that it might have constantly occupied select wetland or swamp habitats in the region.' Habitat specialist* (M. Hammer, pers. comm.)		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
	O mis	Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Murray (Crimson-spotted) Rainbowfish Melanotaenia fluviatilis	1, 4, 5, 6	'Murray-Darling Rainbowfish inhabit streams and backwaters of large rivers, drainage ditches, ponds and reservoirs. They prefer still littoral zones and backwaters with cover provided by submerged macrophytes and woody debris. Spawning occurs during low-flow periods, thus river regulation with increased summer flows may reduce recruitment potential.' Temperature: >18.4°C Salinity (mg/L): <30,000 Dissolved oxygen: DD	'Early 1900 records for the lower Finniss River at the top of the region included in the study (Rutherford, 1991); also museum specimens up to the 1980s. Last recorded in the region by Lloyd and Walker (1986), disappearing shortly after (Sim et al., 2000). Still occurs at Wellington in main channel habitat, so an absence from the Lakes is surprising given that there are seemingly suitable wetlands in various locations, especially the Finniss arm and Hindmarsh Island.'		
Southern Pygmy Perch Nannoperca australis	1, 4, 5, 6	'This species prefers slow-flowing areas of rivers and backwaters with abundant aquatic macrophytes and areas of overhanging vegetation.' Temperature: 3.4-38°C Salinity (mg/L): <3.800 Dissolved oxygen: Tolerant of concentrations below 1 mg/L	'The Southern Pygmy Perch was historically widespread throughout the Lower River Murray and its tributaries, wetlands and backwaters. Populations now only occur in four MLR tributaries and small sections of Lake Alexandrina that represent genetically distinct subpopulations (Hammer 2001, 2002). All populations are threatened with extinction and the species is soon to be lister as 'endangered' in South Australia under the NPWSA Threatened Species Schedule. Lloyd and Walker (1986) recorded the species from two sites in the survey region both in the Finniss arm—they remain at Black Swamp (site R21) but have apparently disappeared from further upstream (site 19). In the early 1900s they were also reported as common in the lower Finniss River region (Rutherford, 1991).' Environmental conditions at survey sites: Habitat types: drains, backwater, wetland Submerged cover (%): 5–45 Secchi depth (m): .01–>0.43 Conductivity (μS): 1200–3040 Flow environment: Permanent		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Yarra Pygmy Perch Nannoperca obscura	1, 4, 5, 6	'Yarra Pygmy Perch are found in small streams and lakes and prefer habitat with abundant cover from aquatic vegetation.' Temperature: 10–30°C Salinity (mg/L): Tolerant of brackish water Dissolved oxygen: DD	'The presence of the species in the Murray-Darling Basin has only recently been recognised, however, SA Museum specimen document a long-term presence in the Lake region (e.g. Lake Alexandrina and Currency Creek collections from 1928). The natural population dynamics of the species is likely to have involved expansion and contractior in range according to local conditions, with refuges at wetlands at the lower region of streams. An overall range has included the Lake Alexandrina and Currency Creek regions (as above) and distribution in the Finniss Region was likely more extensive (i.e. a core population; supported by museum specimens between 1961–1992). Specific rapid field investigation targeting Southern Pygmy Perch (Hammer 2001) also detected three individuals on channel edge habitat downstream from Wally's Wharf on the Lowe Finniss River. Further survey is required to moraccurately map the range in the Finniss Region, with an overall close monitoring of population trends with response to cover density and environmental conditions.' Environmental conditions at survey sites: Habitat types: drains, river channel, wetland, lagoon Submerged cover (%): 5–95 Emergent cover (%): 5–95 Emergent cover (%): 5–90 Secchi depth (m): .011–>0.43 Conductivity (μS): 740–3040 Flow environment: Permanent Flow condition: Low flow (mostly) Habitat specialist* (M. Hammer, pers. comm.		
Murray Cod Maccullochella peelii peelii		'Preferred habitat is pools or holes with abundant cover such as boulders, logs, undercut banks and overhanging vegetation The reduced frequency, extent and duration of spring flooding in the Basin has lead to an overall reduction in larval recruitment, and this is considered to be a major cause of the decline in the abundance of Murray Cod (Rowland 1998a).' Temperature: 10–37°C			

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)			
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Golden Perch Macquaria ambigua ambigua	1, 4, 5, 6	'This species is usually found in warm, slow-flowing river habitats with turbid water, backwaters and anabranches. They are often associated with woody debris in mid-water sections of rivers close to banks or in deeper pools, particularly during the day. Adult fish may undergo a significant upstream migration prior to spawning. Migration is induced by increased flow and temperature. Pelagic larvae are then dispersed downstream, carried by floodwaters.' Temperature: 40–37°C Salinity (mg/L): <33,000 Dissolved oxygen: DD	'Sub-adult fish were recorded from single sites in the Finniss and Lake Albert regions. Other individuals were also captured in supplementary sampling at Hunters Creek on Hindmarsh Island. Other methods would be required to better assess local range of adult fish; local knowledge indicates they are occasionally angled from Lake Alexandrina (e.g. Sim et al., 2000) and they are the targe of commercial fishing, with over 1100 Tonnes of callop being taken as part of the Lakes and Coorong Fishery in the past ten years (Knight et al., 2003). The Lakes appear to provide suitable habitat for the species, but it is unknown if recruitment occurs locally or that fish persist in the area as a population sink from upstream in the Murray.'		
Freshwater Eel-tailed Catfish Tandanus tandanus	1, 5, 6	'Freshwater Catfish are benthic feeders preferring lakes and slow flowing rivers with fringing vegetation.' Temperature: <38°C Salinity (mg/L): <17,000 Dissolved oxygen: DD			
Silver Perch Bidyanus bidyanus	1, 4, 5, 6	'Silver Perch tends to be found in slow-flowing, warm waters in lowland river reaches and is able to tolerate a range of turbidities and temperatures. It utilises cover provided by macrophytes and woody debris but is also found in open waters and is often found below rapids and weirs.' Temperature: 2–38°C Salinity (mg/L): <15,000 Dissolved oxygen: >2mg/L			
Australian Smelt Retropinna semoni	1, 4, 5, 6	'Australian Smelt is most commonly found in river edge and backwater habitats with cover provided by debris and macrophytes.' Temperature: <28°C Salinity (mg/L): <59,000 Dissolved oxygen: Cannot survive <1 mg/L	'Widespread but patchily distributed (28 sites), particularly abundant in the Currency Creek arm and open areas of Lake Albert. They typically occurred in larger waterbodies (open-water) with a sandy substrate and sparse submerged vegetation rather than densely vegetated wetlands. Their distributio and abundance in the lakes probably remains unchanged with respect to historic conditions; several early SAM collections and Zietz (1902) mentioned smelt as a Lake resident. Genetic research in progress at the SAM suggests that Lakes populations might be unique (as per the Southern Pygmy Perch).'		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (quoted extracts from SKM, 2003 and Wedderburn and Hammer, 2003)		
		Source: Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)	
Flat-headed Gudgeon Philypnodon grandiceps	1, 4, 5, 6	'Flat-headed Gudgeon has a wide distribution throughout coastal drainages from Queensland through to South Australia. Basin populations extend inland along the Murray River and some of its southern tributaries in Victoria and has also been recorded in the Murrumbidgee, Lachlan and Macquarie Rivers in NSW (Harris & Gehrke, 1997b2). It is more common in the northern part of its range than in the south or inland areas (Allen et al., 2002b2). Adults reach up to 115 mm in size when mature (Larson & Hoese, 1996b2).'	'Common and widespread throughout the Lakes (37 sites), generally more abundant at sites with high levels of cover. They were captured in all regions of the Lakes, with no apparent habitat preference except that they were abundant in the Finniss River around well-vegetated habitats. They show some resilience to degradation (e.g. grazing impacts) and seem able to negate some of the impacts of exotic species such as Gambusia, Redfin and goldfish co-existing a a number of sites. It is likely that the historic and current status are similar.'	
		Temperature: DD Salinity (mg/L): <40,000		
		Dissolved oxygen: Tolerant of concentrations below 1 mg/L		

DD – Data deficient

PREFERRED SYSTEM UNITS

1 - Murray Mouth and Estuary; 2 - North Lagoon; 3 - South Lagoon; 4 - Lake Albert; 5 - Lake Alexandrina; 6 - Tributary wetlands Note: Unit 1 (Murray Mouth and Estuary includes the freshwater flood channel on Hindmarsh Island).

Some of these species may at times move into parts of the Coorong lagoons during barrage openings, however this is not their preferred habitat.

^{*} Habitat specialist, preferring habitats with physical cover like snags and aquatic vegetation; not often encountered in more open water areas (M. Hammer, pers. comm.)

Key drivers and levers	
Drivers and levers	Description
Freshwater inputs - river flows	Flow events can be important as cues for certain native fish species, whether for migration, spawning etc. (see Table re spawning behaviour in Appendix D). Historically, the more natural patterns of river flow into the lakes were highly seasonal. Peak flows typically came in spring with lower flows in late summer and autumn. As a result of this, prior to the construction of the barrages, the Lakes were mostly freshwater with occasional periods of higher salinity when flows were low. While some of this variability is still evident (at times) today, discharges from the River Murray have decreased in terms of water quantity by about two-thirds. Zero flows now occur 1 in 2 years compared to 1 in 20 as it was in the past (MDBC, 2004c). While it is generally accepted that the barrages have had a negative impact on the Coorong and Lakes ecosystem, ' the construction of the barrages has inadvertently led to the fixation of small sections of wetland habitat as refuge for certain freshwater species. These populations surely would not have otherwise persisted, as conditions in the Murray-Darling Basin and the local region have deteriorated as the result of human agency' (Wedderburn and Hammer, 2003). Average water residence time has increased in the Lakes due to lower inputs and closure of the barrages in summer. This has increased sedimentation and reduced outflow of both sediments and freshwater into the Coorong and Encounter Bay (Lamontagne et al., 2004, cited in DWLBC, 2005). While appropriate flows from the River Murray are seen as vital, it is also important to acknowledge the role
Barrage operations	played by the streams of the Eastern Mount Lofty Ranges, especially the Finniss River and Tookayerta Creek. Freshwater inputs and the operation of the barrages are the key drivers of the ecological character of the Lakes and the Coorong (see Section 6). The low flows from the river have been offset by the closure of the barrages in summer, thus maintaining water in the lakes for a longer period of time, at very stable levels. These static conditions have led to the establishment of significant lakeshore reedbeds, but also a loss of plant species in the deeper regions of the lakes (due to increased turbidity). Lake surcharge events behind the barrages in late winter and spring inundates shallow and floodplain habitat that appears to be important for the spawning and recruitment of species such as Southern Pygmy Perch. Water balance of the Lakes and Coorong (groundwater inputs, evaporation losses, local tributary inputs) is considered an important knowledge gap (DWLBC, 2005) and potentially has a significant role in
Habitat availability— geomorphology	the hydrology of the system. See discussion following regarding habitat connectivity. The location of seasonal inflows and intermittent habitat inundation is likely to have a key role in determining the location and continuity of fish habitats. The tributaries, confluence areas, fringing wetlands, drains and channels often provide suitable flow regimes and habitat inundation patterns to support fish.



Less variable water levels have led to the establishment of significant reedbeds

Key ecosystem components and	processes
Ecosystem components and processes	Description
Physico-chemical	
Salinity	From the information above (and found in Appendix D), most freshwater fish species prefer salinities of less than 10,001 mg/L, with Southern Pygmy Perch and Mountain Galaxias being the notable exceptions with salinity tolerances of less than 3,800 and 1,501 mg/L, respectively. A significant proportion of the fish fauna of the Lakes are highly mobile and able to recolonise areas during favourable conditions or alternatively occupy areas subject to a wide range of salinities (e.g. smelt, gobies, common galaxias) (Wedderburn and Hammer, 2003). The other component of the fauna, the demersal species (including Southern Pygmy Perch) are adapted to, and to a degree depend on, the more variable and natural flow regimes of the fringing tributary wetlands and confluence areas and the artificially induced flow regimes found in irrigation drains and channels.
Dissolved oxygen	The table above shows that little data has been collected on dissolved oxygen in relation to fish.
Temperature	The SKM (2003) report, quoted from above (and in Appendix D), indicates that most species can tolerate a wide range of water temperatures as adults at least. Upper limits are typically 34–37°C. Harasymiw (1983) found that the upper limit for Southern Pygmy Perch was approx. 28°C.
Nutrient cycling	Knowledge gap.
Turbidity	Turbidity has a strong controlling influence on both algal and macrophyte growth in the lakes and this can in turn impact on the native fish populations. Macrophytes and aquatic plants are strongly favoured by most obligate freshwater fish species.
	Increased erosion and sediment re-suspension has increased turbidity in the Lakes. Inflows dominated by water from the Darling River, or periods of low flow can also contribute to increased turbidity. Associated with this is the potential for algal blooms as nutrient levels change and favour blue-green algae (Lamontagne et al., 2004, cited in DWLBC, 2005). The areas on and around Hindmarsh Island and the tributary wetlands that currently have low suspended colloidal material, and thus low turbidity, are considered key habitats for demersal fish species and submerged aquatic plants. Vallisineria americana is a submergent plant that was believed to be widespread in the Lakes. Studies have shown that for positive plant growth, light penetration into the water is a critical
	factor. At 500 NTU the critical depth is between 20–30cm below the surface, at 200 NTU the plant would be able to grow to depths of around 60 cm and at 90 NTU the plant can grow to depths of 110 cm (Ganf, 2000). Myriophyllum spp., Milfoil, that forms extensive beds, is also quite important (e.g. majority of
	habitat in tributary wetlands and parts of Hindmarsh Island).
Movement of water into and out of the lakes	See above under drivers and levers.
Sedimentation and erosional processes	Due to increased residence times of water in the lakes and reduces outflow, sediment loads have increased in the lakes. Erosional processes have increased as a result of the static water levels, with wave action causing erosion of the shoreline soils. Shoreline erosion potentially threatens fringing vegetation of importance for native fish. Deposition of sediment also changes the substrates that are important for certain fish species (feeding, spawning etc.).
Habitat availability and connectivity	One of the critical abiotic factors that structure fish communities is habitat availability and diversity. Lake bed and stream morphology influence ecological interactions/processes such temperature and oxygen regimes, lake surface area influences wave action which can lead to the formation or loss of habitat important for different life stages, with areas with more complex habitats being shown to enhance food resources, foraging opportunities and refuge from predation—all of which can lead to increased diversity (Jackson et al., 2001). Within the lakes themselves, some threatened and less mobile species (Southern Pygmy Perch, for example) survive in small remnant populations. These isolated populations are vulnerable to local extinction unless dispersal can be assisted through habitat re-establishment, and the protection of
	existing habitats. For example the population of Yarra and Southern Pygmy Perch on Hindmarsh Island may benefit from the careful management and potential enhancement of the drain system at Wyndgate. The wetland environments that many of the smaller, less mobile species found are also considered important for predator avoidance (Wedderburn and Hammer, 2003). Allowing passage past the barrages is of critical importance for diadromous fish, such as Congolli. It is also noted that allowing such passage needs to be carefully designed to exclude potential predator species (Mulloway, for example) of the threatened fish taxa residing in the lakes.

Ecosystem components and processes	Description	
Biological		
Maintaining and connecting habitat refugia	See adjacent re habitat connectivity. For some species it is possible that drains have provided additional shelter, well-vegetated permanent aquatic habitats which can act as refuges (e.g. Pygmy Perch species) (Wedderburn and Hammer, 2003). The fish populations supported on Hindmarsh Island and surrounding areas (Dunn's Lagoon, Mud Island, and Jacobs Bight) reflect the diversity and extent of habitat available, with the critical elements being the rich submergent vegetation. Other significant area within the Lakes include the upper reaches of the Finniss River, the entrance to Waltowa Swamp, and drains entering Lake Alexandrina. Consideration of both the high value natural sites and the habitats created by the altered hydrological regime (drains) is important in developing targets for conservation and regional management (Wedderburn and Hammer, 2003).	
Reproduction	Flow events can be important as cues for certain native fish species, whether for migration, spawning etc. (see table re spawning behaviour above). The reedbeds and other fringing vegetation provide protected wetlands on the inshore areas which allow the establishment of more diverse aquatic growth in the shallow wetland areas. Thes are important for the breeding of many species.	
Predation	Predation is an important factor affecting fish communities, although the relative importance is not clearly understood. Some work suggests that in larger lake systems (>200 ha) populations of predators and prey can coexist due to increased habitat heterogeneity and inherent spatial components in the population dynamics of the species (Jackson et al., 2001).	
Competition	Carp are believed to play a role in the loss of submerged aquatic plants and increased turbidity which in turn has impacts on other biota. The arrival of Carp into the Lakes was reported to have occurred in the 1970s, which has been noted to have coincided with the loss of submergent vegetation (Sim et al., 2000 cited in Wedderburn and Hammer, 2003). Whilst redfin have been recorded from the lakes, they tend not to have the same habitat requirements of many native fish. Other exotic species found in the lakes include goldfish and Gambusia (Wedderburn and Hammer, 2003).	
	Hammer, 2003). It is likely that the habitat diversity and predation are more important than competition in structuring the fish community of the Lakes.	

Population trends

Apart from the observations above in relation to species such as the Southern Pygmy Perch and its now restricted distribution in the freshwater system units, there is evidence to suggest declines in other species (see Table 17). The emerging view is that habitat simplification due to reduced variability of water levels is a primary cause. This impacts on the growth of macrophytes, a keystone group in these habitats, with the result being increasing loss of habitat connectivity also. Sections 6.3, 6.4 and 6.5 consider these issues further.

Commercial fishing data

EconSearch (2004) note that there have been declines in the quantities of commercial fish species caught in the Coorong and Lakes over the past 20 years (see Section 5.6.3). It is acknowledged by the authors of this description of ecological character that a more detailed analysis of commercial fishing data would enhance the understanding of population trends for some the larger species. However, such an analysis was beyond the scope of this study. The authors wish to note that no

inference should be drawn about the management of commercial fishing in the Ramsar site because of the apparent declines in some species. Further, it is noted that sustainable commercial fishing is fully consistent with Ramsar's wise use principle and practised in many Ramsar sites around the world.

In addition to the above views, there is also anecdotal advice from the Ngarrindjeri community (see Section 7.1 for the full oral history account) supporting the view that the populations of a number of these larger obligate freshwater species have declined markedly over the past few decades.

Naarrindieri community

There has been a widespread loss of large fish particularly Murray Cod, Callop, Blackfish, Tench (introduced) and Catfish since the 1970s. Carp are the only fish that are now caught consistently in the lakes. Callop appear to have returned in small numbers about 3-4 years ago presumably because the carp are targeted and fished out of the lakes.

Bony Bream are almost gone from the lakes; very few are still seen, whereas they were once plentiful. When the barrage gates have been open in recent years, Bony Bream have been caught in the Coorong but only small ones, the big ones are not caught anymore. Bony Bream are important in Ngarrindjeri lore and the creation story associated with how the Bony Bream was created tells of the need to not be greedy and is an important lesson.

Limits of acceptable change and traffic light assessment

It is not possible to establish the population sizes for these species either around the time the site was Ramsar-listed or today. Further survey work is needed to provide robust estimates of population sizes and extent of the habitats each rely upon. From the perspective of setting limits of acceptable change there are four primary considerations as follows:

- 1. Population size—these cannot be determined at present although of concern are the suggestions by Wedderburn and Hammer (2003) that a number of the smaller species either have patchy or quite restricted distribution, making them potentially vulnerable. Until such time as a more precise population estimate is possible and natural variations are better understood, the precautionary approach suggests a 0% limit of acceptable change for those species with restricted or patchy distribution, and 5% for those are more widespread and less specialised in niche requirements.
- 2. Areal extent of primary habitats—see Section 4.1 where these are identified by wetland type and LAC indicated.
- 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively.
- 4. Connectivity between primary habitats—as noted above, for some of these species there is concern that habitat patches are becoming isolated and some types are becoming less common due to the simplification of the lake environments caused in large part by the lack of flow and water level variations. This means that areas showing greater habitat diversity, such as the upper reaches of the Finniss River, the entrance to Waltowa swamp, and drains entering Lake Alexandrina, are becoming more and more important for some species. In Sections 4.1.4 (and se also Sections 6.3–6.5) this is noted under the relevant wetland types and LAC have been indicated.

Traffic light assessment

Population numbers are not confirmed although some of the smaller species have restricted distributions and increasingly isolated habitats. This assessment level is therefore recommended to reflect a precautionary approach and that some of the important key habitat areas (see above) are known to face threats (see Section 4.1.4).



Wetland type N (Section 4.1.4). Such channels are now prime habitat for some of the smaller native fish species

5.6.2 Diadromous fish species

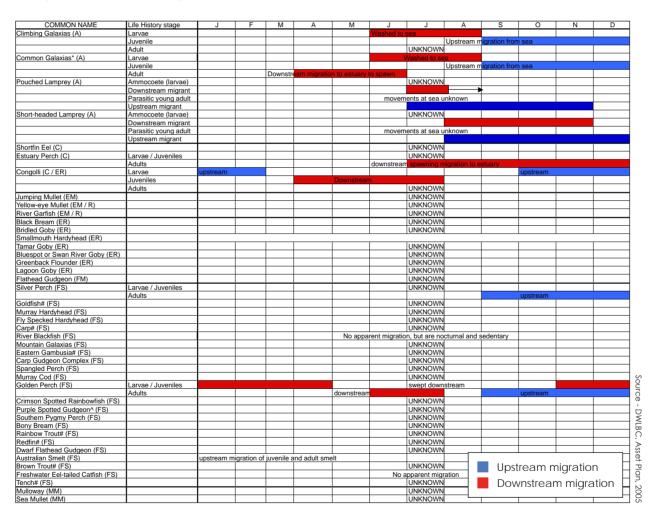
Qualitative description

There are seven diadromous species found in the Coorong and Lakes site that contribute to the Ramsar status of the site (see Table 6). All but one of these species is included on the South Australian provisional list of species of conservation concern. It is understood that this status is yet to be agreed within government, and so this may require review depending on the outcome of that consideration.

Among these species, migration is a pre-spawning behaviour, with four of the species moving downstream to the Estuary or to sea and the other three moving upstream from the sea. Allowing this passage through the barrages is an important management consideration.

The timing of these migrations also differs slightly between species, thus providing a management challenge. These differences in timing of migrations can be seen in see Figure 20 below.

Below in Table 11 more detailed information is provided on where each species occurs in the Coorong and Lakes Ramsar site, plus habitat information sourced from Wedderburn and Hammer (2003) and the SKM report of 2003 that reviewed freshwater fish species of the Murray-Darling Basin. Tables giving summary information of the habitat and other needs of these species during spawning and for larval and juvenile forms are provided in Appendix E.



KEY

(A) Anadromous – (C) Catadromous – (C / ER) Catadromous / Estuarine Resident – (EM) Estuarine Migrant – (EM / R) Estuarine Migrant / Resident (ER) Estuarine Resident – (FM) Freshwater Migrant – (FS) Freshwater Straggler – (MM) Marine Migrant

Figure 20 - Timings and other details of fish migrations in the Coorong and Lakes Ramsar site

^{*} If landlocked, G. maculatus can reproduce entirely in freshwater – # denotes exotic taxa – ^ denotes locally extinct taxa

Common name, scientific name	Preferred system units	Preferred habitat information - adults (See Appendix E for information relating to spawning and for larval and juvenile forms)			
	Offits	Source: Habitat requirements of native fish of the Murray-Darling Basin-wide (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Short-finned Eel Anguilla australis	1,6	'Habitat ranges from oceans to estuaries to rivers but they are mainly found in coastal wetlands. Adults have been found in rivers, creeks, lakes and swamps with few reported from the Murray-Darling River system. In rivers, adult eels are usually associated with accumulations of woody debris.' Temperature: DD Salinity (mg/L): High tolerance Dissolved oxygen: DD	'The entrance to the Murray-Darling system represents part of the most westerly distribution for the migration of larval eel along the Australian coast, with occasional SAM specimens recorded in drains and pumping areas around the fringes of Lake Alexandrina. Barrages and reduced flows through the Murray Mouth likely impede the migratory requirements of this species.'		
Climbing Galaxias Galaxias brevipinnis	1, 2, 4, 5, 6	'Climbing Galaxias are most often found in small, fast-flowing, rocky streams with abundant overhanging vegetation. They can travel long distances inland, being able to negotiate waterfalls and other barriers due to their ability to 'climb' vertical obstacles (McDowall & Fulton, 1996b2). Coastal populations are normally diadromous thus this species can readily form landlocked populations.' Temperature: <23°C Salinity (mg/L): <35,000 Dissolved oxygen: DD	'Adult habitat: recorded from one stream tributary, but probably more widespread prior to barrages (Hammer, 2004). Spawn in lower stream reaches with larvae drifting to sea. Juveniles would enter system and move through Lakes and/or potentially recruited in lake environments with pelagic larvae.' (M. Hammer, pers. comm.)		
Common Galaxias Galaxias maculatus	1, 2, 4, 5, 6	'This species is an important commercial fish and is a mainstay of the whitebait fishing industry in the Southern Hemisphere. Common Galaxias are migratory and found at low elevations in rivers, streams and estuaries from Queensland to South Australia, Tasmania and south-eastern Western Australia. They are found in the lower reaches of the River Murray in South Australia. They are tolerant of a range of salinities and prefer habitats with slow flowing water, fringing vegetation and areas of deep slack water.' Temperature: <10->24.5°C Salinity (mg/L): <45,000 Dissolved oxygen: DD	'Widespread in the Lakes (43 sites) and occupied a range of habitat types generally in open-water alongside littoral (edge) vegetation. They now exist as at least a partly landlocked population as is common in other landlocked lake environments (e.g. Pierce, 1985, Hammer, 2002). The current and historic range for the species appears similar, although abundances are likely mucl reduced with the interruption of diadromous whitebait runs entering freshwater environments.'		
Pouched Lamprey Geotria australis	1, 5, 6	'Pouched Lamprey is a migratory species with downstream migration of young adults to the sea where they mature and eventually return to freshwater to spawn. Habitat preferences include upper reaches of coastal streams, estuaries and the sea depending on the stage of their life cycle.' Temperature: DD Salinity (mg/L): DD Dissolved oxygen: DD	'Cryptic species rarely encountered today without specialised survey techniques. Individuals of both species were recently caught below the Goolwa Barrage (SAM specimens from winter 2002 lodged by SARDI Aquatic Sciences). Historically, large migrations were witnessed on weirs along the River Murray. The lakes probably only offer a conduit upstream into the Murray and to a limited extent to smaller tributary streams most of which have significant natural migration barriers.'		

Common name, scientific name	Preferred system units	Preferred habitat information - adults (See Appendix E for information relating to spawning and for larval and juvenile forms)			
	55	Source: Habitat requirements of native fish of the Murray-Darling Basin-wide (SKM, 2003)	Source: Lakes Fish Inventory (Wedderburn and Hammer, 2003)		
Short-headed Lamprey Mordacia mordax	1, 5, 6	'The Short-headed Lamprey is a migratory species that spends the majority of its adult life in the sea or in estuaries. Its preferred habitat varies depending on its life cycle from fast flowing streams with muddy, sandy and silty substrates during spawning migration to slow flowing, muddy streams during the larval stage and coastal seas during adulthood.' Temperature: DD Salinity (mg/L): DD Dissolved oxygen: DD	'Cryptic species rarely encountered today without specialised survey techniques. Individuals of both species were recently caught below the Goolwa Barrage (SAM specimens from winter 2002 lodged by SARDI Aquatic Sciences). Historically, large migrations were witnessed on weirs along the River Murray. The Lakes probably only offer a conduit upstream into the Murray and to a limited extent to smaller tributary streams most of which have significant natural migration barriers.'		
Estuary Perch Macquaria colonorum	1, 2, 5, 6	'Estuary Perch are most common in estuaries and tidal reaches of rivers, although they can extend upstream into freshwater reaches. They can tolerate a range of habitats but are typically found in deeper channels, often in association with submerged objects.' Temperature: DD Salinity (mg/L): Prefer >2,000 Dissolved oxygen: DD	Habitat and ecology little known in region. Thought to be more common prior to the barrages (Sim et al., 2000) and has also likely suffered from broader ecosystem changes. (M. Hammer, pers. comm.)		
Congolli (Tupong) 1, 2, 3, 4, 5, 6		Tupong are usually found near the coast and are common in the coastal drainages from the River Murray in South Australia to Bega in NSW. Habitat preferences of adults in rivers include slow-flowing water among leaf litter and woody debris and under overhanging banks. As this species is primarily marine, habitat in estuaries such as sea grasses is also important for breeding. Tupong are osmoregulators and are able to withstand a range of salinities. They have been recorded 120km inland and are known to move considerable distances up the River Murray (Andrews, 1996b2). It is common in the lower reaches of the River Murray including the Lakes but few are found above Lock 1 in South Australia (Lloyd, 1987c). Temperature: 5–20°C Salinity (mg/L): <17,000 Dissolved oxygen: DD			

PREFERRED SYSTEM UNITS

DD – Data deficient

1 - Murray Mouth and Estuary; 2 - North Lagoon; 3 - South Lagoon; 4 - Lake Albert; 5 - Lake Alexandrina; 6 - Tributary wetlands Note: Unit 1 (Murray Mouth and Estuary includes the freshwater flood channel on Hindmarsh Island).

Key drivers and levers			
Drivers and levers	Description		
Winds and tides	Tides near the Murray Mouth are semi-diurnal and vary between 0.2m (neap) and 1 m (spring tides) (MDBC, 2005). Tidal exchange drives a number of processes including mixing of the water column (and consequently nutrient release from bottom sediments), salinity balance with freshwater inflows, and wetting and exposing of mudflats and intertidal marshes for the maintenance of ecosystem health of habitat for native fish. It also plays a role in controlling water clarity by the flushing of river sediments to the ocean.		
Opening of the Murray Mouth	The Murray Mouth opening determines habitat connectivity for fish that move between the Estuary and the sea, including those that have a marine phase in their life cycle. In addition, the extent of the Murray Mouth opening controls salinity, nutrients and turbidity by providing flushing to the ocean.		
River Flows—Barrage operations	Freshwater inputs triggers spawning for a number of species. These provide nutrients, turbidity and especially zooplankton food items that are washed into the Estuary with outflow from Lake Alexandrina. River flows also play a role in maintaining the opening of the Mouth and in the salinity and nutrient cycles of the Estuary.		



Congolli typically inhabit the sandy, rocky fringes of the Lakes

Ecosystem components and processes	Description
	Description
Physico-chemical	
Salinity	As diadromous species, these seven can clearly tolerate a wide range of salinities at particular life stages. However, most rely on salinities in the range of fresh to <50 ppt and as such cannot tolerate hypersaline conditions and likely require lower salinites (<5 ppt) for optimum growth and survivorship in adult habitat in the Lakes. In addition, changes in salinity can promote spawning success in estuarine fish (Geddes, 2000).
Dissolved oxygen	Stratification, increased nutrient concentrations and high phytoplankton growth can all contribute to the lowering of dissolved oxygen concentrations within the water column. While stratification is not common in the Coorong, it has been recorded in the North Lagoon (Lamontagne et al., 2004). All seven fish species are reliant on oxygen in the water column for survival and could not survive periods of anoxia.
Nutrient cycling	This is only a factor when it affects productivity, especially of zooplankton.
Turbidity	Species such as the Estuary perch are predatory and visual feeders. Excessive turbidity would affect their ability to feed.
PAR	Likely to effect productivity and especially the establishment of littoral vegetation.
Temperature	Need to maintain seasonal temperature patterns.
Movement of water into and out of the lakes	See above under drivers and levers.
Moon phase	For Common Galaxias and Short-finned Eel (and possibly Lamprey species too) moon phase triggers pre-spawning migrations.
Sedimentation and erosional processes	Excessive sedimentation and deposition in the Murray Estuary and associated channels has significantly reduced the estuarine habitat and passage for these fish species.
Habitat connectivity	Allowing passage through the Murray Mouth and past the barrages is of critical importance for these diadromous fish, although it is also noted that allowing such passage needs to be carefully designed to exclude potential predator species (mulloway for example) of the threatened fish taxa residing in the Lakes.
Substrates and habitats	Among these species some display a preference for certain substrate/habitat types. For example, Short-headed lamphrey spend the day buried and among loose stones and Congolli prefer to live among leaf litter, near logs and buried in sand.
	Most of these species also occupy areas that contain large woody debris, overhanging vegetation or submerged objects. All except the Climbing galaxias seem to prefer slower flowing waters.
Biological	
Reproduction	See above re movement of water, moon phase, habitat connectivity and substrates.
Competition	Concentrations of diadromous fish (e.g. below barriers) may be vulnerable to predation.
Primary production	Knowledge gap.
Food sources	Small and larval fish feed on zooplankton. Conditions that limit zooplankton production/ abundance will limit larval and juvenile fish survival. Abrupt changes in salinity may cause mortality in freshwater and estuarine zooplankton (M.Geddes, pers. comm.).

Limits of acceptable change and traffic light assessment

It is not possible to establish the population sizes for these species either around the time the site was Ramsar-listed or today. Further survey work is needed to provide robust estimates of population sizes and extent of the habitats each rely upon. From the perspective of setting limits of acceptable there are four primary considerations as follows:

- 1. Population size—these cannot be determined at present although, as noted above, six of these seven species are being considered for inclusion on the South Australian list of species of conservation concern. Given this, the precautionary approach suggests a 0% limit of acceptable change for these species, meaning they warrant consideration in the operations of the barrages and fishways to ensure passage, either upstream or down, when it is required.
- 2. Areal extent of primary habitats—too little is known of the habitat needs of these species at present to allow a LAC to be recommended.
- 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively.
- 4. Connectivity between primary habitats—as noted above, the primary consideration for these species is to be able to move through the barrages at certain times. The fishway (see adjacent) and Barrage Operating Strategy make some allowance for these needs at present.

Traffic light assessment

Population numbers are not known although six of these seven species are being considered for inclusion on the South Australian list of species of conservation concern. This assessment level is therefore recommended to reflect a precautionary approach and that being able to move through the barrages is a critical life history strategy for these species.



Fishway—designed to allow diadromous fish and other species to move through the barrage

5.6.3 Euryhaline or estuarine species

Qualitative description

There are 12 euryhaline or estuarine native fish species deemed 'significant' in the draft revised Ramsar Information Sheet for this site (see Appendix C), as listed in Table 6. Excluded from consideration here are diadromous species; these being considered separately (see Section 5.6.2), as have those significant species considered 'marine stragglers' (see Section 5.6.4).

Among the 12 species listed below, none are considered threatened or of conservation concern nationally or in South Australia. Notable, however, are the four species of Goby for which this site is considered significant as it is the only location in the Murray-Darling Basin where they occur.

Although classified as estuarine residents and breeding in the estuarine waters, most of these species of fish move between the system units of the Coorong, the Southern Ocean and the Lakes (when access is provided). Gobies (except for the Bridled Goby) however, are equally 'comfortable' living, breeding and recruiting in fresh and estuarine habitat.

Below more detailed information is provided on where each species occurs in the Coorong and Lakes Ramsar site, plus habitat information sourced from Wedderburn and Hammer (2003) and other sources as indicated.



The unusual life cycle requirements of Lamprev species are under threat

Common name, Preferred system units		Preferred habitat information - adults Note: Information cited from the report Lakes survey by Wedderburn and Hammer (2003) infers that it applies to the freshwater (lake) side of the barrages.			
Small-mouthed Hardyhead Atherinosoma microstoma	1, 2, 3, 4, 5, 6	'Widespread (22 sites) and generally common throughout all habitat types of the regions of the Lakes (although not recorded at the Murray confluence), particularly common in Lake Albert and around Hindmarsh Island. Generally associated with some edge or submerged vegetatio Current and historic distribution likely remains similar.' (Wedderburn and M. Hammer, 2003). See also Molsher et al., 1994.			
Sandy Sprat Hyperlophus vittatus	1, 2, 4, 5	'A new record for the freshwater section of the region, albeit in low numbers at two Lake Alexandrina sites. They are most likely a marine vagrant that have passed through the barrage (common in the Coorong; Eckert and Robinson, 1990), rather than a resident capable of completing its life cycle in freshwater.' (Wedderburn and M. Hammer, 2003). Little is known of the status of this species in system components 1 and 2 (M. Hammer, pers. comm.).			
Bridled Goby Acentrogobius bifrenatus	1, 2, 3	On the lake-side of the barrages, occurs over mud and silt, generally in areas of structure (e.g. rocks). Limited information on range and abundance in the region. (M. Hammer, pers. comm.)			
Tamar Goby Afurcagobius tamarensis	1, 2, 4, 5, 6	'A rare species for the survey (three sites), found in muddy and rocky habitats. Locations where it was found were widespread, but it may not form reproductively viable populations in the lakes, unlike the aforementioned gobies. There have probably been declines in abundance since construction of the barrages.' (Wedderburn and Hammer, 2003). Reasonably common in the Murray Mouth region over varied substrates, seems to occur in areas that receive freshwater.			
Western Blue-spot (Swan River) Goby Pseudogobius olorum	1, 2, 3, 4, 5, 6	'The species is essentially estuarine, however they are widespread and commonly encountered in the freshwater habitats of the Lakes (30 sites), apparently forming landlocked populations (although migration to and from the Coorong could still occur). They are generally located in low numbers over sand or mud with little cover, however, they were in high abundance (>50 individuals) at shallow sites at Nalpa Station (Lake Alexandrina) and Nindethara (Lake Albert). Current distribution would be similar to that occurring historically, perhaps with reduced abundance.' (Wedderburn and Hammer, 2003).			
Lagoon Goby Tasmanogobius lasti	1, 2, 4, 5, 6	'Essentially an estuarine species that can tolerate freshwater, appearing to have a wide range throughout both lakes. They were found in high abundance in some lake and lagoon habitats (e.g. Lake Alexandrina near Narrung and Raukkan, and Pelican Lagoon), generally in areas with some cover such as rocks or Vallisineria americana. They appear to breed in freshwater habitats in Lake Albert. Probably more common in-line with estuarine conditions historically.' (Wedderburn and Hammer 2003). Little is known of the status of this species in system components 1 and 2 (M. Hammer, pers. comm.).			
River Garfish Hyporhamphus regularis	1, 2	Knowledge gap.			
Yellow-eye Mullet Aldrichetta forsteri	1, 2, 3, 5	'Populations of Yellow-eye Mullet, Aldrichetta forsteri are distributed in bays, estuaries and open coastline from Shark Bay in Western Australia, throughout the southern coastline including Tasmania, to Newcastle in NSW (Kailola et al., 1993). A. forsteri also inhabit shallow bays and inlets around New Zealand. A. forsteri live in brackish and inshore coastal waters and beaches overs sandy and muddy bottom in depths to about 20m (Kailola et al., 1993). The estuarine waters of the Coorong offer an ideal habitat for this species. Two separate genetic populations are considered to exist between the western and eastern seaboard (Thomson, 1957). South Australian populations are considered to form part of western stocks (Thomson, 1957; Pellizzari 2001).			
		Yellow-eye Mullet are categorised as estuarine opportunists (Wakefield 1999) that is, they regularly utilise estuaries during part of their life cycle but do not need access to complete their life cycle (Potter and Hyndes 1994). However the importance of the Coorong estuarine system of South Australia to the life history of yellow-eye mullet is presently uncertain due to conflicting information about gonad condition and early life history from the region (Higham and Ye, 2004).			
		Generally Yellow-eye Mullet are considered to be omnivorous, eating detritus, seagrass, micro and macro-algae as well as small animals and epiphytes (Kailola et al., 1993; McDowall 1996). In the majority of cases, food items were ingested in direct proportion to their relative abundance within the Estuary sampled (continued)			

Table 19 - Euryhaline or	estuarine fis	th, their preferred habitats and other life history information (continued)		
Common name, scientific name	Preferred system units	Preferred habitat information - adults Note: Information cited from the report Lakes survey by Wedderburn and Hammer (2003) infers that it applies to the freshwater (lake) side of the barrages.		
Yellow-eye Mullet Aldrichetta forsteri	1, 2, 3, 5	'In the Lakes and Coorong region, recreational catch of Yellow-eye Mullet during 2001–2002 was 82,519 fish, with a total estimated harvest of 8,830 kg. A further 31,763 Yellow-eye Mullet were released during this period, with 34,343 hours of effort expended to catch these fish using a range of techniques. Of this total catch, the majority (95%) was caught from private boats, while approximately 4% was caught from beach and/or rocks and less than one percent was caught from other platforms. Of the total catch of Yellow-eye Mullet, 96% was caught using the line method, while 4% was caught using gill nets (Higham & Ye, 2004).' Extracts from the Management Plan for the South Australia Lakes and Coorong Fishery, Paper No. 44 April 2005, PIRSA.		
Jumping Mullet Liza argentea	1, 2	Knowledge gap.		
Greenback Flounder Rhombosolea tapirina	1, 2, 3	1 Hall (1984) documented that Greenback Flounder were rarely captured in marine waters outside of the Coorong, suggesting that the Coorong population is estuarine resident (MDBC, 2002), completing its life cycle in the sheltered waters of the Coorong lagoons. Based on this understanding of movement patterns and the limited information available on stock structure, the greenback flounder population in the Coorong is managed as a distinct unit stock, reliant on local spawning events within the Coorong lagoons for successful recruitment.		
		Greenback Flounder are usually found over non-vegetated, sandy or muddy bottom where they are well camouflaged (Connolly, 1994). Larvae are fully settled on this type of habitat about 65 days after hatching, at less than a centimetre in length (Crawford, 1984; Crawford, 1986). Greenback flounder have a large temperature and salinity tolerance (Kailola, et al., 1993). In their natural state, the Coorong lagoons provide an ideal habitat for greenback flounder. Larvae feed during daylight hours (Chen, et al., 1999; Cox & Pankhurst, 2000), in contrast to juveniles and adults, which feed on rising tides at night on shallow mud banks (Kailola, et al., 1993).		
		Limited information is available of the reproductive biology of greenback flounder in South Australia. A Tasmanian study indicated that the species has a protracted spawning season from March to October and that spawning occurs in the deeper regions of estuaries, tidal rivers and offshore waters (Kurth, 1957). Maturity is reached at between 19 and 30 cm (Kailola, et al., 1993). Female greenback flounder are capable of ovulating several times within a reproductive season (Barnett and Pankhurst, 1999).		
		In the Coorong lagoons, temperature-dependent freshwater inflows are thought to provide a critical spawning stimulus for greenback flounder and other estuarine dependent species (MDBC, 2003). In addition to spawning success, the magnitude, timing and duration of freshwater flows effect larval survival and development (Hall, 1984; Pierce and Doonan, 1999). There is potential for greenback flounder stock production levels to be significantly improved in the Coorong lagoons under an improved barrage flow strategy (Hall, 1984; Pierce and Doonan, 1999; MDBC, 2003a). Future management of this species must focus on increasing the number of successful annual spawning events and maximising the opportunities for larvae survival and development, through improved barrage flow manipulation.'		
		Extracts from the Management Plan for the South Australia Lakes and Coorong Fishery, Paper No. 44 April 2005, PIRSA.		

Common name, scientific name	Preferred system units	Preferred habitat information - adults Note: Information cited from the report Lakes survey by Wedderburn and Hammer (2003) infers that it applies to the freshwater (lake) side of the barrages.			
Mulloway Argyrosomus japonicus	1, 2, 3, 5	'Mulloway, Argyrosomus japonicus are distributed throughout southern Australia, however, there is currently only a limited understanding of stock structure for the species (Hall 1986; Ferguson and Ward, 2003). In the absence of reliable quantitative scientific data to support an alternative stock hypothesis, the South Australian Mulloway population is managed using a precautionary approach as a self-recruiting population, with recruitment considered to be dependent upon local spawning within South Australian waters. The first stock assessment of Argyrosomus japonicus in South Australia was completed in 2003 (Ferguson and Ward, 2003).			
		The spawning behaviour and locations used by Mulloway in South Australia are unclear, as is the proportion of the total population that use the Coorong Estuary as juvenile habitat (Ferguson and Ward, 2003). Adult Mulloway aggregate around the River Murray Mouth during the summer months, attracted by freshwater outflows and an abundance of food (Hall 1986; Ferguson and Ward, 2003). It is currently unclear to what extent these aggregations form part a reproductive strategy.			
		Juvenile Mulloway utilise the waters of the Coorong Estuary as a nursery habitat for at least five years after which time they are thought to migrate out of the Estuary and into marine waters. A present, separate size limits are in place for Mulloway taken inside estuarine waters and outside estuarine waters on the ocean beaches. This management strategy was implemented after the completion of a targeted research project undertaken by Hall (1986), mainly to protect adult Mulloway aggregating near the Murray Mouth on the ocean beaches. Hall (1986) suggested that Mulloway do not reach a size of sexual maturity until five years-of-age, or a size of 75 cm.			
		Historical Mulloway population production was far greater than current levels, due mainly to the significant reduction in available nursery habitat following the introduction of the barrage network in the 1940s. Figure 10 represents the total commercial catch of Mulloway by all sector in South Australia over the period 1984 to 2001. The total commercial catch of Mulloway in the 2001/02 financial year was 114 tonnes. Of this, 96% was taken by Lakes and Coorong fishers. The remaining 4% was taken in the marine scalefish fishery. In addition to this catch, Commonwealt southern shark fishery licence holders took an estimated 2.7 tonnes.'			
		Extract from the Management Plan for the South Australia Lakes and Coorong Fishery, Paper No. 44 April 2005, PIRSA.			
Black Bream Acanthopagrus butcheri	1, 2, 3, 4, 5	'In South Australia, Black Bream are common in estuaries from the Victorian border to Port Lincoln on the west coast, including the small estuaries on Kangaroo Island (Hall, 1984). Movement between estuaries and other sheltered bays is limited and usually only occurs during periods of flooding (Hall, 1984; Kailola, et al., 1993; Cashmore, Conron and Knuckey, 2000). Black Bream are considered to be an estuarine resident species that complete their life cycle within estuarine waters (MDBC, 2002).			
		Black Bream are a bottom dwelling species that occur in areas where hard substrates, snags or structures provide shelter (Kailola, et al., 1993), although they are also captured over more exposed sandy bottom and seagrass beds in the Victorian Gippsland Lakes (Cashmore, Conro and Knuckey, 2000). They can withstand a wide range of salinities and often move into the freshwater Lakes and the lower reaches of the River Murray.			
		In the Coorong lagoons, temperature dependent freshwater inflows are thought to provide a critical spawning stimulus for black Bream and other estuarine dependent species (MDBC, 2003). In addition to spawning success, the magnitude, timing and duration of freshwater flows effect larval survival and development (Hall, 1984; Pierce and Doonan, 1999). There is potential for black Bream stock production levels to be significantly improved in the Coorong lagoons under an improved barrage flow strategy (Hall, 1984; Pierce and Doonan, 1999; MDBC 2003a). Future management of this species must focus on increasing the number of successful annual spawning events and maximising the opportunities for larvae survival and developmen through improved barrage flow manipulation.			
		There has been a significant reduction in the total commercial catch of black Bream from the Coorong lagoons since the early 1940s when the barrage network was completed. This decrease in production is largely due to reduced spawning success and lower survival rates of larvae caused by limitations on the availability of estuarine habitat, disrupted natural flow regimes and changes to estuarine conditions.'			
		Extract from the Management Plan for the South Australia Lakes and Coorong Fishery, Paper No. 44 April 2005, PIRSA.			

PREFERRED SYSTEM UNITS

1 – Murray Mouth and Estuary; 2 – North Lagoon; 3 – South Lagoon; 4 – Lake Albert; 5 – Lake Alexandrina; 6 – Tributary wetlands Note: Unit 1 (Murray Mouth and Estuary includes the freshwater flood channel on Hindmarsh Island).

Key drivers and levers			
Drivers and levers	Description		
Winds and tides	Tides near the Mouth are semi-diurnal and vary between 0.2m (neap) and 1m (spring tides) (MDBC, 2005). Tidal exchange drives a number of processes including mixing of the water column (and consequently nutrient release from bottom sediments), salinity balance with freshwater inflows, and wetting and exposing of mudflats and intertidal marshes for the maintenance of ecosystem health of habitat for native fish. It also plays a role in controlling water clarity by the flushing of river sediments to the ocean.		
Opening of the Murray Mouth (Geomorphology)	The Murray Mouth Opening determines habitat connectivity for fish that have a marine phase in their life cycle. In addition, the extent of the Murray Mouth opening controls salinity, nutrients and turbidity by providing flushing to the ocean.		
River Flows	Provide freshwater inputs, and trigger spawning for a number of species. River flows also play a role in maintaining the opening of the mouth and in the salinity and nutrient cycles of the Estuary.		

Key ecosystem components and processes				
Ecosystem components and processes	Description			
Physico-chemical				
Salinity	Estuarine fish species are adapted to fluctuating salinity, and most are tolerant of periods of freshwater but they cannot tolerate salinities above about <50–60 ppt (Geddes, 2000). However, Small-mouthed Hardyheads are extremely tolerant of both high and low salinities and have been reported in waters up to 94 ppt (Boon, 2000). There is evidence that changes in salinity can promote spawning success in estuarine fish and that many of the estuarine fish of the Coorong rely on variations in salinity to maintain optimum health (Geddes, 2000). Southern Bream for example, spawn when salinity is 11–18 ppt (Boon, 2000).			
Dissolved oxygen	Stratification, increased nutrient concentrations and high phytoplankton growth can all contribute to the lowering of dissolved oxygen concentrations within the water column. While stratification is not common in the Coorong, it has been recorded in the North Lagoon (Lamontagne et al., 2004). All twelve fish species are reliant on oxygen in the water column for survival and could not survive periods of anoxia.			
Nutrient cycling	Only a factor when it affects productivity, especially of zooplankton.			
Turbidity	Turbidity causes a reduction in light available for photosynthesis for submerged aquatic plants and change the conditions to favour the growth of phytoplankton over aquatic macrophytes. For visual feeding fish species, excessive turbidity would affect their ability to feed.			
Temperature	These fish require cool water and cannot survive in the shallow waters of the Estuary or lagoons if temperatures increase (Oborne, 2003). In addition, some estuarine species (e.g. Bream) are cued by temperature changes for spawning.			
Water level	These fish require sufficient water level to maintain optimum temperature requirements and inundate preferred habitat. For example, juvenile species of Bream inhabit seagrass and submerged vegetation beds that provide protection from predators and food sources.			

Key ecosystem components and processes (continued)				
Ecosystem components and processes	Description			
Moon phase	Knowledge gap.			
Sedimentation and erosional processes	Excessive sedimentation and deposition in the Murray Estuary and associated channels has significantly reduced the estuarine habitat for these fish species.			
Habitat connectivity	Allowing passage through the Murray Mouth is important for these estuarine fish, many of which (e.g. Mullaway) have life history stages in marine and estuarine environments. In addition, these fish will move between the lagoons, Estuary and Lakes for optimum salinity conditions.			
Substrates and habitats	Estuarine mud and silt are probably more productive than straight sand habitats.			
Biological				
Competition	Knowledge gap.			
Reproduction	See above re movement of water, habitat connectivity and substrates.			
Primary production	Knowledge gap.			
Food sources	Small and larval fish feed on zooplankton. Conditions that limit zooplankton production/ abundance will limit larval and juvenile fish survival. Abrupt changes in salinity may cause mortality in freshwater and estuarine zooplankton (M.Geddes, pers. comm.).			

Population trends

Anecdotal advice (see below) from fishing families and the Ngarrindjeri community (see Section 7 for the full oral history accounts) suggest that the populations of a number of these species have declined markedly over the past few decades. Commercial catch data and scientific studies also suggest the same trends (see below).

Oral history accounts—Fishermen and families

Frank Gibbs—Coorong fisher and hunter from the 1930s to present

The white bait (hardyheads) have gone from the Coorong too, we don't see them anymore. We always had Bony Bream too.

We would get up on the crow's nest of the boat and spot black patches of Mulloway. There were 20-30lb fish right up to Salt Creek and behind Salt Creek Island which was very deep back then. Those deep holes were breeding areas for fish and always held Mulloway.

Bob Hera-Singh—Coorong fisher and hunter, 1940s to the present

Clearly in the 1940-1970 era, fishing was thriving, plenty of Mullet. Fish that like good quality water (e.g. Flounder, Bream, Mulloway, Congolli) were caught in very large numbers and were trucked to Melbourne Markets. No Flounder, Bream or Mulloway have been caught in recent years. Mullet numbers have tapered off catching less and less. The last three years, none whatsoever due to poor water quality and lack of oxygen in water**. Even the weed has stopped growing.

**Data to back up these historical records is available in terms of fish catch data (later provided by Bob for 1976 to 1984).

We used to get 10 boxes per day of Congolli, with about 30 kg per box, and the salmon were really thick. In midsummer, we always had fish, but in the last 20 years we don't catch fish in summer anymore.

Neil and Nancy Ferguson—long-term residents of South East, Coorong fishing 30 years

About 10 years ago, Mullet were caught in August for about three weeks down at Salt Creek, not anymore.

Ngarrindjeri community

Hardyhead fish are an important part of the ecosystem, providing food for larger fish and birds. Hardyheads were found throughout the Coorong system all the way down to Salt Creek in the late 1970s but now they are almost gone, with only small populations around Pelican Point (no further south than Long Point).

Commercial fishing data

EconSearch (2004) note also there have been declines in the quantity of Black bream and other commercial fish species caught in the Coorong and Lakes over the past 20 years. Figure 21 below, reproduced from the EconSearch report reflects this downturn. As was also noted in Section 5.6.1, the authors of this description of ecological character acknowledge that a more detailed analysis of commercial fishing data would enhance the understanding of population trends for some of these species. However, such an analysis was beyond the scope of this study. The authors wish to note that no inference should be drawn about the management of commercial fishing in the Ramsar site because of the apparent declines in some species. Further, it is noted that sustainable commercial fishing is fully consistent with Ramsar's wise use principle and practised in many Ramsar sites around the world.



Mullet numbers are 'tapering off

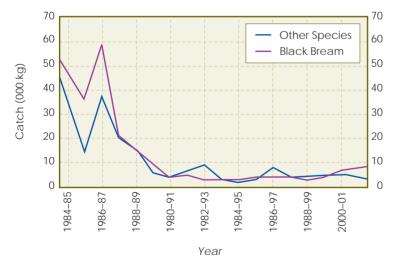


Figure 21 - Total catch of Black Bream and other species from 1984-1985 and 2001-2002 in the Lakes and Coorong (reproduced from the EconSearch report) (SARDI, 2003)

Scientific studies

Paton (2005) observes that along with chironomid larvae and the seeds and turions of Ruppia tuberosa, (see Section 6.3) Small-mouthed Hardyheads (Atherinosoma microstoma) are important food items for aquatic birds in the South Lagoon of the Coorong (see Section 5.4). Based on annual sampling for the years 2001–2005, Paton (2005) records that the abundance of both Ruppia tuberosa (seeds and turions) and hardyhead fish has declined considerably in the South Lagoon, and in particular in the most southerly sections. He also provides detailed data on the distribution and abundance of aquatic birds in the Coorong for the period 2000–2005 and concludes that several of the fish-eating bird species had reduced numbers and breeding activities in the South Lagoon, due, it is assumed, to the reduced availability of food items, hardyhead in particular. This includes species such as Australian Pelican, some waterfowl species, Fairy Tern and Hoary-headed Grebe.

Geddes (2005) also reinforced this view, saying that in his surveys in July 2004 'fish numbers were low and distributions restricted in the North Lagoon. In the South Lagoon, only Atherinosoma microstoma, were collected, and these were in low numbers."

Limits of acceptable change and traffic light assessment

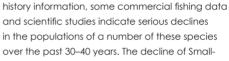
It is not possible to establish the population sizes for these species either around the time the site was Ramsar-listed or today. Further survey work is needed to provide robust estimates of population sizes and the extent of the habitats each rely upon. From the perspective of setting limits of acceptable change, there are three primary considerations as follows:

1. Population size—these cannot be determined at present although, as noted above, several of these species appear to have undergone considerable declines over the past 30–40 years and some, such as the Small-mouthed Hardyhead, more recently. Given this, the precautionary approach suggests a 0% limit of acceptable change for these species, meaning they warrant priority consideration in the management of this site and actions are needed to address apparent population reductions. The decline of Small-mouthed Hardyhead is of special note given its key role as a food item for waterbirds. This decline, associated with the loss of the keystone Ruppia aquatic plant species is considered further in Sections 5.4 and 6.3.

- 2. Areal extent of primary habitats—too little is known of the habitat needs of these species at present to allow a LAC to be recommended. However, as noted above, the decline of keystone Ruppia aquatic plant species is likely to be a primary factor in the declines of these species, and so warrants immediate management intervention. LAC in relation to Ruppia have been provided in Section 6.3.
- 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively.

Traffic light assessment







over the past 30–40 years. The decline of Smallmouthed Hardyhead is of special note given its key role as a food item for waterbirds. This decline is considered to be associated with the loss of the keystone Ruppia aquatic plant species (see Sections 5.4 and 6.3).

While population numbers are not known, oral

5.6.4 Marine stragglers

Qualitative description

This review has identified eight so-called 'marine stragglers', being marine species of fish that randomly enter and leave inlets and estuaries. Their inclusion as significant species in this context results from being listed as vulnerable by the IUCN 'red list' (for the Big-bellied Seahorse), because they rely on parts of the system for certain key parts of their life cycle or they represent a unique part of the diverse fish community supported by the Coorong and Lakes Ramsar site (see decision rules associated with the selection of these species, Appendix C, Attachment 6).

Not surprisingly, as marine stragglers these species are mostly found in the Murray Mouth and Estuary, or North Lagoon units of the Ramsar site. No data is available to indicate how frequently, at what times of the year or in what numbers these species are found in the system and these fundamental knowledge gaps mean it is not possible to specify their habitat needs.



Many marine stragglers are thought to inhabit the Murray Mouth and Estuary

Table 20 - 'Marine straggler' fish species					
Common name	Scientific name	Ramsar criteria	National/ IUCN Status	SA Status	System units
Blue Sprat	Spratelloides robustus	4,7,8			1,2,4,5
Sand Fish	Crapatalus arenarius lasti	7			1
Goblin Shark	Mitsukurina owstoni	7			1
Big-bellied Seahorse	Hippocampus abdominalis	2,3,7	-/V		1,2
Striped Perch	Helotes sexlineatus	4,7,8			1,2
Prickly Toadfish	Contusus brevicaudus	7			1
Smooth Toadfish	Tetractenos glaber	4,7,8			1
Richardson's Toadfish	Tetractenos hamiltoni	7			1

SYSTEM UNITS

1 - Murray Mouth and Estuary; 2 - North Lagoon; 3 - South Lagoon; 4 - Lake Albert; 5 - Lake Alexandrina; 6 - Tributary wetlands Note: Unit 1 (Murray Mouth and Estuary, includes the freshwater flood channel on Hindmarsh Island).

Key drivers, levers, components and processes

As indicated above, little has been documented about these species in terms of how they occupy and use the Coorong portion of this Ramsar site and so it is not possible to consider them in the same detail as the other fish species groups. Needless to say, as species that are predominantly marine dwellers, providing them with opportunities for passage into and out of the system is a critical ecological process. Closure of the mouth of the Murray will clearly prevent them forming part of the diverse fish community of this system. Perhaps paradoxically, their increased presence in the system may in fact indicate change in ecological character, as the system becomes more marine (and less estuarine) with reduced freshwater in-flows over the barrages.

Limits of acceptable change

No limits of acceptable change are recommended due to knowledge gaps. As noted, the increased presence of these species in the system probably indicates a change in ecological character within the Coorong. As the system becomes more saline with Murray Mouth restrictions and reduced freshwater in-flows over the barrages, it may become more conducive to marine species visitation. There is anecdotal evidence that this is the case (see Section 7.2).



Aerial view of the Murray Mouth

Primary determinants of ecological character



This section examines in detail the primary determinants of ecological character: salinity, turbidity and sedimentation, keystone aquatic plants, water level and flow patterns and habitat connectivity.

Primary determinants of ecological character

Section 3 of this report provided an overview of the ecosystem drivers, levers, components and processes of the Coorong and Lakes Ramsar site and this was followed by consideration of how these work together within the system units (Section 4) and also in relation to the Ramsar Significant Biological Components (ecological communities and species) (Section 5).

The drivers, levers, components and processes operating within this large and diverse wetland ecosystem can be broken down as shown in Figure 7 (reproduced from Section 3). While all ecosystem components and processes are important to the overall healthy functioning of the system, some stand out as being central to maintaining ecological character or could be considered primary determinants. If these primary determinants are maintained within certain limits then the expectation, based on scientific and local knowledge, is that the system as a whole, and its individual components and processes, will also operate or function as expected.

Primary determinants of ecological character

For the Coorong and Lakes Ramsar wetland, the following have been identified as the primary determinants of ecological character, and each is examined in detail in the sections that follow:

- salinity
- turbidity and sedimentation patterns
- keystone aquatic plant species and assemblages
- · water levels
- · habitat availability, particularly temporal and spatial connectivity
- water regime, particularly flow patterns.



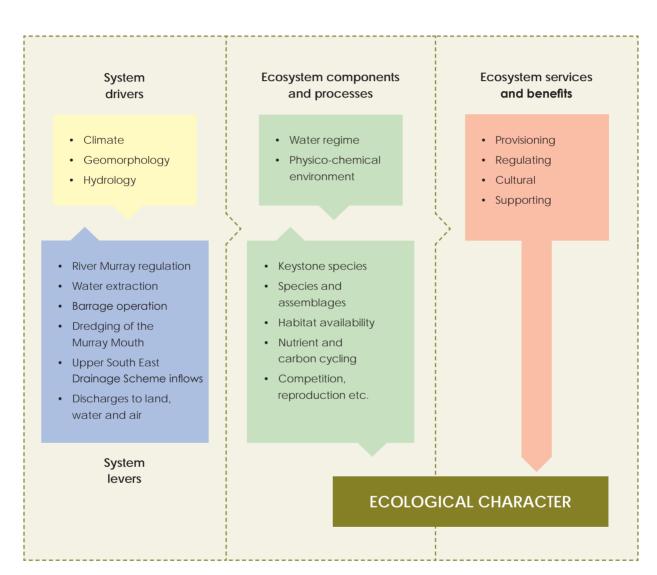


Figure 7 - Ecosystem drivers, levers, components, processes and services that determine ecological character (reproduced here from Section 3)

6.1 Salinity

6.1.1 Salinity in the freshwater units of the system

Salinity status

- salinity levels in Lake Alexandrina range from 400 EC to 1,500 EC (see below) and in Lake Albert from about 1,300 EC to 2,300 EC. In both cases much higher recordings have been observed at low flow times
- salinity levels in the Tributaries are estimated to range from around 400 EC to 5,000 EC (and higher at some times—see below)
- salinity levels in the Lakes are primarily governed by the balance between freshwater inflows, occasional seawater ingressions over the barrages, groundwater influxes, water extraction rates, rainfall on the lake surfaces and evaporation
- the Coorong and Lakes Ramsar site is the only point of discharge for River Murray flows from the Murray-Darling Basin and thus acts as a salt sink for the basin
- reduced River Murray inflows do not necessarily translate to reduced salinity inputs over the long-term because salt stored during dry years is flushed in to the river during higher flow periods. However, reduced River Murray flows do mean that the Murray Mouth is not being kept open with river flows and thus salt accumulation increases due to reduced discharge and evaporation from an effectively closed water body
- · Lake Albert has no direct flow through to the Coorong and thus acts as a local sink for salt and sediment from River Murray inflows, overland run-off and lakeshore erosion. See Section 6.2 in relation to sedimentation (See Figure 6 on page 17)
- · Lake Albert has only a narrow connection to Lake Alexandrina and no other significant inflows. Therefore, its salinity (see above) is related to River Murray flows via transfer of fresh water from Lake Alexandrina
- the water table under Lake Albert, and much of its floodplain, is shallow and saline and groundwater discharge creates seasonal and permanent saltwater marshes in depressions or swales around the lake edge. Similarly, Lake Alexandrina has high level salt marshes around its edge, partially supported by saline groundwater discharges
- salinity in the tributaries of Lake Alexandrina is dependent on catchment land and water use, geomorphology, rainfall: evaporation and recharge: discharge ratios and the degree of ingression of more saline Lake Alexandrina water (see data above and in Appendix H)

- most obligate freshwater fish residing in the freshwater system units require salinities in the range from fresh to <10 ppt (=approx 16,500 EC) and are thus threatened by increasing salinity (see Section 5.6.1)
- at current rates of salinisation of the Tributaries (30-47mg/l/yr), the salinity tolerances of species such as Southern Pygmy Perch will be exceeded within the next 50 years (based on baseline of 1500 mg/l and salinity tolerances in Section 5.6.1)
- keystone submerged aquatic plants are adversely affected by salinities over c.1,500EC although emergent species such as Phragmites australis can tolerate estuarine conditions.

Comparing the historical and current situations

The waters of Lakes Alexandrina and Albert have been steadily salinised by a combination of system levers (see Figure 7) and anthropogenic impacts. At the time of European settlement, the lakes were fresh and reliable water sources as is evidenced by the importance of townships such as Clayton, Milang and Meningie, and the original intention to locate Adelaide at Currency Creek, in the early years. By the late-1800s, alternative freshwater supplies to the lakes had to be sourced from underground supplies for town, stock, domestic and industrial supplies. Boilers in steam engines began to rust from using the increasingly brackish Lake Alexandrina water drawn at Milang in late 1890s (Sim and Muller, 2004). Major initiatives such as the installation of Salt Interception Schemes upstream of the Ramsar site have helped to stabilise lower River Murray salinities and a delivery target of 800 EC at Morgan in South Australia 95% of the time is being implemented; primarily to protect Adelaide's water supply (MDBC, 2004).

Salinity recordings from Milang, starting in 1971 (SA EPA data, see Appendix H) show great variability, which is presumed to be flow-related, with a marked increase since 2002. Over the past six years (2000 onwards), salinity levels in Lake Alexandrina have ranged between 400 EC to nearly 1,500 EC. It is notable that the recordings upstream of the Goolwa Barrage through this same period have ranged between 448-8,460 EC, the latter recorded in April, 2003.

In modern times, Lake Albert has been generally more saline than Lake Alexandrina due to its dependence on flow-through of River Murray water and it typically reaches conductivities of up to 3,000 EC at the end of periods of low river flow. Prior to closure of the Murray Mouth in 1981, the Lakes were much fresher. For example, Lake Albert regularly had conductivities of around 600 EC at the end of winter and 900 EC at the end of summer (Raukkan farmer, pers. comm.). Increases in groundwater

salinity have recently been reported in the Black Swamp area. Salinity levels in observation bores in the aquifer that feeds Black Swamp have increased from around 1200 to 1550 mg/l (approx. 2,000 to 2,500 EC) since 1999, representing an increase of 30 to 47 mg/l/yr (approx. 50-80 EC/yr) (Barnett, 2005).

In Lake Albert, there is less historical data (see Appendix H). However, salinities are typically higher than in Lake Alexandrina, which is no doubt a legacy of it being a closed system and one where salt and silt accumulate. Since 2000, the salinity levels in Lake Albert have ranged from about 1,300 EC to nearly 2,300 EC (See Appendix H). As indicated above, in periods of low flow this can reach 3,000 EC (DWLBC, 2005).

Salinity levels in the Tributaries vary considerably, although a preliminary analysis of the SA EPA data shows only a gradual increase over time (See Appendix H). On the Finniss River (4km east of Yundi), average salinity from April 1970 to January 1976 was 1,183EC (range 381-2,551 EC) and from January 2000 to October 2005, it was slightly higher at 1,351EC (range 575-3,301EC). On the Bremer River, a similar pattern to the Finniss was seen in that the average for March 2000 to October 2005 was 3,164EC, slightly higher than the figure for May 1973 to December 1976, of 2,552EC. Another site on the Bremer River. Wanstead Road recorded salinities of between 981 and 11,410 in the period May 2003 to October 2005. On Currency Creek (near Higgins), average salinity from January 1972 until January 1976 was 2,539 EC, across a range of 482–7,600 EC. At the same location from February 1985 until August 1993, the average was slightly lower at 2,407 EC with a range from 423-7,320 EC. Hammer (2004) also provides salinity information for Tookayerta Creek, which he notes is the only stream with year round flows, and which has possibly the highest quality water with autumn readings across most of the catchment being less than 500 EC.

Implications for other primary determinants of ecological character

Turbidity and sedimentation patterns (see Section 6.2): Increasing salinity leads to increasing rates of flocculation of fine sediments and increased deposition of calciferous materials.

Keystone species (see Section 6.3):

All species have a salinity tolerance threshold beyond which they cannot survive in a given system; therefore salinity is a fundamental determinant of species composition and health as well as ecosystem processes.



Habitat availability (see Section 6.5):

Salinity regimes will in part determine what patterns of plants, animals and microbes occur that in turn infer habitat availability, particularly type and condition.

Asset Plan 2005 targets

In relation to maintaining and enhancing habitat for fish in Lakes Alexandrina and Albert:

Salinity: <2,000 µS/cm (= EC).

Limits of acceptable change

Lakes Alexandrina:

Salinity maintained below 700 EC, based on a five-year average. This allows for periods of higher salinity during low flows as would have been experienced naturally. Based on the data for Milang (see Appendix H), the 10 year average EC's since 1971 have been as follows:

1971-1980: 672EC; 1981-1990: 769EC, 1991-2000: 693EC, and the 2001-2005: 1062 EC.

Lake Albert:

Salinity maintained below 1,400 EC, based on a five-year average. This allows for periods of higher salinity during low flows and for the fact that Lake Albert is always more saline than Lake Alexandrina since it has no flow-through. This LAC is based on the data for three sites in Lake Albert recorded in 1995-1997 (see Appendix H).

Tributary wetlands

Limits of acceptable changes should be set for each tributary based on historical and other data. For the four tributaries where such data has been examined here (see above and Appendix H) it is apparent that each should be treated separately. For these, the following are recommended based on preliminary analysis only at this time. Monitoring salinities at point of discharge into the lake is recommended to confirm these limits:

- Tookayerta Creek: Salinity maintained below 500 EC at summer or drought peak, based on a five-year average
- Finniss River: Salinity maintained below 1200EC at summer or drought peak, based on a five-year average
- Currency Creek: Salinity maintained below 2400EC at summer or drought peak, based on a five-year average
- Bremer River: Salinity maintained below 2500 EC at summer or drought peak, based on a five-year average.

Traffic light assessment





Both lakes are at present routinely (and greatly) exceeding recommended salinity levels and this is contributing to the loss of key stone species and other freshwater species as well as threatening ecosystem services (irrigation, stock and human drinking water supplies etc.). Increasing salinity levels in the tributaries threatens under-represented habitats and biota and must be arrested as soon as possible to ensure the full complement of ecosystem components and processes remains.

Groundwater salinities feeding the tributary wetlands not to exceed 1,500 mg/l (= approx 3,000 EC) to maintain the full complement of freshwater obligate fishes and plants (see Sections 5.6.1).



Melaleuca halmatuorum, Coorong National Park

6.1.2 Salinity in the saline-estuarine units

Salinity status

- the Coorong lagoons are more saline than ever before in their 6,000 year history
- the Murray Mouth and Estuary is the only Estuary in the Murray-Darling Basin and the only natural exit for mobilised sediments and salts
- salinity levels in the Murray Mouth and Estuary unit are primarily governed by the balance between the inputs from Lake Alexandrina (barrage releases), seawater inflows through the Murray Mouth and evaporation (see Figure 6 on page 13)
- the North Lagoon is classified as estuarine-saline, with salinity controlled by freshwater inflows (primarily from the Tauwitcherie Barrage), tidal exchange through the Murray Mouth, rainfall, evaporation and inflows of hypersaline water from the South Lagoon (Lamontagne, et al., 2004)
- the North Lagoon has a salinity gradient with lower salinity in the north-west and higher salinity towards the south-east at the connection to the South Lagoon. The actual levels vary, being lower when river flows are high and higher when river flows are low. Closure or restriction of the Murray Mouth increases salinity in the North Lagoon through evaporation of already saline water and exchange with the hypersaline waters of the South Lagoon
- the South Lagoon is classified as saline-hypersaline in its current condition, up to 140 ppt (230,000 EC). Like the North Lagoon, it has a salinity gradient with lower salinity in the north-west and higher salinity towards the south-eastern end
- salinity in the South Lagoon is not directly controlled by River Murray inflows but rather by water exchange with the North Lagoon, openness of the Murray Mouth, rainfall, evaporation, groundwater inputs and inflows from the South East of South Australia. Closure or restriction of the Murray Mouth increases salinity in the South Lagoon through evaporation from an essentially closed and already saline system
- · reductions in groundwater inflows and flows from the natural watercourses of the South East of the state are major contributors to the high salinity of the South Lagoon. Inputs from the South East Drainage Scheme (USEDS) at Salt Creek may locally reduce salinities and benefit ecosystem components and processes
- horizontal salinity gradients can form in the water columns suggesting stratification under certain conditions (Geddes, 2003). Low flows or tidal pulses are needed to encourage mixing
- · longitudinal salinity gradients were a feature of the

- Coorong lagoons although in the past it seems the system was more variable (see below, including the observations for the Ngarrindjeri community). Although a salinity gradient still remains from the Murray Mouth to the South Lagoon, the longitudinal gradient has been lost from the South Lagoon itself, such that the whole water body has been 100 ppt (approx. 165,000 EC) or greater since mid-1980s. Localised salinity gradients may be re-established through Upper South East Drainage Scheme inflows
- Ruppia spp. are the keystone species for the Coorong lagoons (see Section 6.3). Ruppia megacarpa has a salinity range of 5–46 ppt (approx. 8,000 to 76,000 EC) thus it has been effectively lost from the North Lagoon (Nicol, 2004). R. tuberosa has a higher tolerance, up to 200 ppt (>330,000 EC)
- key food items for birds in the Coorong are submerged aquatic Ruppia species (keystone species—see Section 6.3), Small-mouthed Hardyhead fish and macro-invertebrates. These can tolerate differing ranges of salinity, as shown below in Figure 22. Note that the tolerances for high food value macroinvertebrates: crustaceans, polychaetes and molluscs are less than 60 ppt (approx. 100,000 EC) whilst insect larvae and hardyheads can tolerate up to 100 ppt (approx. 165,000).

Comparing the historical and current situations

Before European settlement, tidal input of marine waters dominated the North Lagoon and exerted a strong influence on the South Lagoon. The northern end of the South Lagoon occasionally experienced hypersaline conditions in the 300 years before European settlement but the rest of the Coorong typically had salinities at or below 35 PPE (sea water, 58,333 EC)) with evidence of regular freshwater inputs to the southern end of the South Lagoon (see Ngarrindjeri community and other comments below). Possibly early in European settlement, but definitely by the 1940s (the barrage construction period), the salinity of the middle section of the Coorong had increased significantly and salinities in the South Lagoon increased again after 1980 (Gell and Haynes, 2005), presumably because of the preceding long periods of no flow and Murray Mouth closure. The Coorong is a much more closed system than it was in the past which coupled with its location at the terminus of the Murray Darling Basin, means that it acts as a sink for mobilised salt.

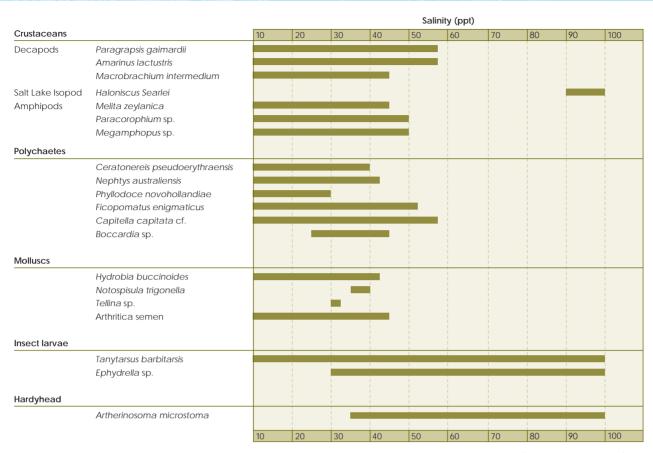


Figure 22 - Salinity tolerance ranges of a number of crustaceans, polychaetes etc. in the Coorong (from Geddes, 2005)

Ngarrindjeri community

Under natural conditions, the ecology of the Coorong would switch from freshwater species (e.g. cod, callop, ducks) during periods of high inflows from the River Murray and the South East to more marine species (e.g. seals, eels, flying fish) during periods of low inflows and/or high seas. This switch happened almost every year.

The Coorong is being lost from both ends. The lack of flows in the River Murray has closed the Murray Mouth and prevented the Coorong from naturally draining to the sea. The lack of flows from the South East has reduced freshwater inputs to the southern end of the Coorong and has thus reduced the flow-through and hence water quality in both the North and South Lagoons.

Flows from the South East used to flow along a clear channel of faster moving water in the centre of the lagoons all the way from Salt Creek to the Murray Mouth and would provide flushing flows for the Coorong Lagoons.

See also comments from local fishermen and families Section 7, and page 78.

The highest readings in the North Lagoon were in March 1982 (up to 65ppt, approx. 110,000EC) and January 2003 (up to 90 ppt, approx. 150,000 EC), both periods were preceded by Murray Mouth closure (1981) or severe constriction (2000) and long periods of barrage closure (Geddes, 2003). Similarly, the highest readings in the South Lagoon were recorded in March 1983, 1984 and 1985 (up to 140 ppt, approx. 230,000 EC) and January 2003 (up to 110 ppt, approx. 180,000 EC). Once such extremely high salinity levels are reached, large volumes of freshwater are required to lower the salinity gradients significantly and flush out the accumulated

salts. Meanwhile, irreversible changes can occur to the ecological character of the salinised wetland because salinity levels exceed the thresholds for many ecosystem components and processes.

Figure 23, reproduced below from Geddes (2005), reveals how salinity patterns have altered along the Coorong since 1975. Geddes summarises it as follow:

'The March (end of summer) salinities in the North Lagoon in 1983, 1984 and 1985 were up to 70 ppt, compared to salinities above 90 ppt in January

(mid summer) 2003 and 2004. In the South Lagoon in March 1983, 1984 and 1985 there was a gradient along the lagoon from 70 to up to 140 ppt. In January 2003 and 2004, salinities were not so high, up to 110 and 115 ppt, but were above 100 ppt throughout the whole lagoon. Presumably this lack of salinity gradient reflects outflows from Morella/Salt Creek in 2003 and 2004. In November 1975 and 1981 and October 1983 (late spring), salinities were from estuarine to 60 ppt in the North Lagoon and up to 80 ppt in the South Lagoon. Differences between the years reflected the extent of barrage outflow. By comparison, salinities in July (Winter) 2003 and 2004 were up to 70 ppt in the North Lagoon and to 100 ppt in the South Lagoon. Thus since the 1980s there has been an overall increase in salinity and in particular a substantial increase in summer salinities in the North Lagoon such that much of the lagoon has salinities above 60 ppt, and a change in summer salinity patterns in the South Lagoon so that extreme salinities at the southern end of the lagoon have been reduced but salinities throughout the lagoon are above 100 ppt."

Note: to convert ppt units to approximate EC values, multiply ppts by 1,667.

A recent study done by Everingham et al., (2005) for the Department Water, Land and Biodiversity Conservation, examined (among a range of issues—see Section 6 also) the salinity trends for the Southern Coorong since 1981. This is based on monthly grab samples and found that through the period 1981–2000, there has been an upward trend of 150 µS/cm (= EC) per year near Parnka Point and 480 µS/cm per year near Salt Creek (see Figure 23 below for these landmarks. Parnka Point is the northern end of the South Lagoon and Salt creek about the mid-point and where water from the south east region discharged into the Coorong historical, and does so now under the regulated releases of the Upper South East Drainage Scheme). Since 2000, this upward trend has accelerated to greater than 7000 µS/cm/ year at both these locations

The report by Everingham et al., (2005) also includes Table 21 (see following page) providing monthly EC averages for the periods May 1981 to April 2000, and May 2000 to January 2005 for sites along the Coorong starting at Tauwitchere Channel and moving south. This shows both the current longitudinal salinity gradient as well as the changes in the salinity across these two periods.

These data are supported by the report by Geddes (2005, citing data from D.C.Paton). He reports salinities at key locations in July 2004 as follows: Noonameena: 35ppt (58,000EC); Villa de Yumpa: 80ppt (133,000EC); Policeman's Point: 94ppt (157,000 EC); Salt Creek: 101ppt (168,000EC) and Tea Tree Crossing: 105ppt (175,000EC). The approximate ECs are shown in brackets.



Melaleuca woodland

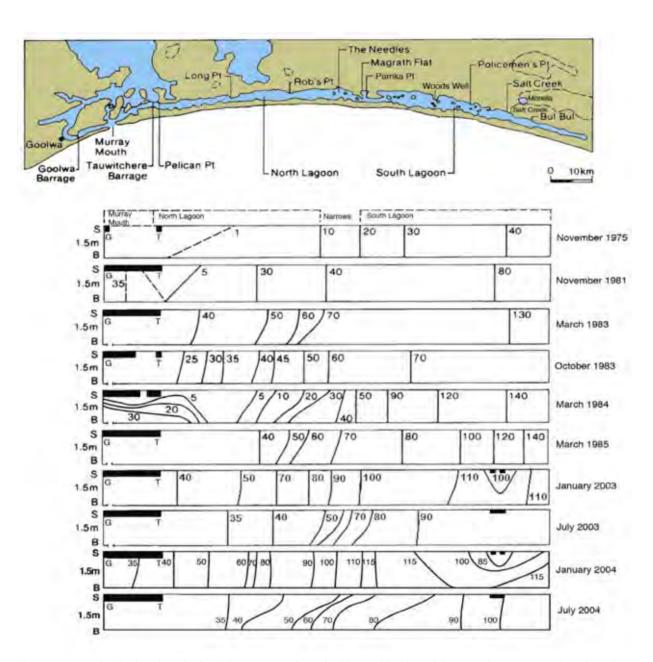


Figure 23 - Longitudinal and vertical salinity patterns along the Murray Mouth and Coorong in 1975, at various times in the 1980s and in January and July 2003 and 2004. The salinity isoclines are estimated from limited point measurements of salinity. The black bars indicate closure or the extent of opening of the Barrages at Goolwa (G) and Tauwitchere (T) and the Morella/Salt Creek outlet. (From Geddes, 2005)

Table 21 - Average electrical conductivity (μS/cm=EC) by month for the period 1981–2000 and 2000–2005														
_	(From Everingham et al., 2005)													
EC Monthly Average May 1981 to April 2000														
			Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
DWLBC	GRAB	TC	34227	31140	37658	34957	28265	19820	22087	17211	20565	17067	10390	25888
DWLBC	GRAB	MPa	39887	36599	46364	39293	33803	29430	28910	27069	29034	25311	24695	29685
DWLBC	GRAB	LPa	50170	48979	55582	45085	41274	37331	32417	31826	39155	35795	37036	40632
DWLBC	GRAB	RPa	70300	77183	79300	67538	53786	47045	51798	51000	54992	56080	55691	63183
DWLBC	GRAB	MFa	92819	97279	100600	78913	71663	71250	63673	66959	68266	70489	75086	84796
DWLBC	GRAB	Vya	98615	111650	116633	100764	91285	87255	83792	79336	75840	75707	84638	89654
DWLBC	GRAB	PRa	98575	110755	115317	119607	112329	98109	90431	86686	82660	83479	87562	94069
DWLBC	GRAB	SCa	100129	99013	104113	116392	116391	100333	94416	87892	85299	83979	90515	94750
DWLBC	GRAB	SGa	108989	128000	130138	125589	119000	100000	93900	86733	86800	87544	93688	102538
EC Monthly Average May 1981 to April 2000														
			Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
DWLBC	GRAB	TC	38497	50250	41188	40475	29862	21421	35340	31166	33968	20306	27640	34745
DWLBC	GRAB	MPa	50375	61400	52850	49025	43280	35774	46686	40228	31330	36713	46654	57980
DWLBC	GRAB	LPa	63875	74067	67450	82600	57560	41240	48635	46640	42829	48538	74033	80480
DWLBC	GRAB	RPa	94525	103825	108675	89200	78900	55020	78639	61300	60037	74500	94400	106200
DWLBC	GRAB	MFa	117800	133050	128850	102825	90220	65060	93283	76400	76533	93456	114408	123520
DWLBC	GRAB	Vya	133825	142100	153625	130850	129260	113260	102380	94720	95154	101240	112792	124380
DWLBC	GRAB	PRa	124750	127975	144650	141325	139620	117640	110625	98400	101843	105909	114569	120650
DWLBC	GRAB	SCa	136160	151800	143950	141700	140360	116140	111963	100860	104274	104456	107800	119533
DWLBC	GRAB	SGa	123040	139100	137775	141250	138700	119800	114560	100280	107389	107867	113469	117600

Site key

TC......Tauwitchere Channel

MPa.... Mark Point

LPa..... Long Point

RPa Robs Point

MFa..... Magrath Flat

VYa Villa Dei Yumpa

PRa Pelican Reef

SCa..... Salt Creek

SGS..... Sandspit Pt

Implications for other primary determinants of ecological character

Turbidity and sedimentation patterns (Section 6.2): Increasing salinity leads to increasing rates of flocculation of fine sediments and increased deposition of calciferous materials.

Keystone species (Section 6.3):

All species have a salinity tolerance threshold beyond which they cannot survive in a given system; therefore salinity is a fundamental determinant of species composition and health. In the case of the Coorong lagoons, this case contributed to the loss of keystone species such as Ruppia spp. (see Section 6.3) which in turn has led to a reduction of small-mouthed hardyhead fish and the wading and other birds that relied on these food sources.

Habitat availability (Section 6.4):

The very high salinity levels seen in the Coorong lagoons will impact on all aquatic habitats reducing availability

and condition of habitats requiring salinities less than sea water. Effectively the estuarine habitats that once dominated these units are now confined to the Murray Mouth and Estuary and the northern end of North Lagoon (estimated at <25% of former area).

Asset Plan 2005 targets

In relation to Ruppia spp., interim targets are: North Lagoon: remain estuarine, not exceed 80,000 EC and to remain below 55,000 EC between September and February each year to promote R. megacarpa.

South Lagoon: not to exceed 80–100,000 EC at any time to promote R. tuberosa.

In relation to invertebrates, interim targets are: North Lagoon: remain estuarine, not exceed 80,000 EC.

South Lagoon: to vary between 50-100,000 EC.

In relation to migratory and other waders, interim targets as follows: North Lagoon: to remain estuarine and not to exceed 80,000 EC.

South Lagoon: 50,000-100,000 EC.

In relation to more frequent estuarine fish spawning and recruitment, interim targets are: Murray Mouth and Estuary: parts below 39,000 EC and not to vary by more than 8,000 EC over any 7 day period.

North Lagoon: parts below 39,000 EC and not to vary by more than 8,000 EC over any 7 day period, maintain salinity gradient.

South Lagoon: <60,000 EC for Small-mouthed Hardyheads.

Limits of acceptable change

Murray Mouth and Estuary: Salinity not to exceed 58,000 EC (sea water) with parts below 39,000 EC.

These are based on Table 21 above, for the period 1981-2000.

North Lagoon:

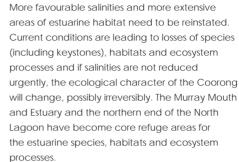
Salinity ranging from 8,000–60,000 EC for most of the time, with the following limits: Northern end: Salinity not exceeding 50,000 EC (at Long Point) in the summer peak.

Southern end: Salinity not exceeding 100,000 EC (at McGrath Flat) in the summer peak.



Traffic light assessment







Seasonal and spatial variability: Salinities around 30,000 EC in some parts in winter/spring with the following limits.

Northern end: Salinity not exceeding 100,000 EC (at Yilla de Yumpa) in the summer peak.

Southern end: Salinity not exceeding 130,000 EC (at Sandspit Point) in the summer peak.

6.2 Turbidity and sedimentation patterns

Turbidity and sedimentation are related in that suspended solids contribute to water column turbidity and then may drop out of the water column or be resuspended back into the water column depending on physical drivers such as wind speed and direction, wave action or flow rates.

6.2.1 Turbidity and sedimentation in the freshwater units of the system

Turbidity and sedimentation status:

- Lake Alexandrina acts as both a sink for sediment brought in by the River Murray and a source of sediments (via lakeshore erosion and transfer of River Murray water) to the Southern Ocean, Murray Mouth Estuary and Coorong lagoons
- · Lake Albert acts primarily as a sediment sink for the basin given its lack of through-flow and thus long water residence time. Erosion of the Lake Albert lakeshore is likely to act as a sediment source
- · turbidity in the tributaries is generally low (see below), although erosion of poorly consolidated stream beds further upstream (i.e. outside the Ramsar site) and erosion heads in the upper catchment can be significant, episodic sources of sediments
- average water residence time has generally increased throughout the freshwater units due to reduced inflows and outflows, leading to increased rates of sedimentation (settling of sediments). However, wind-induced mixing and wave action lead to resuspension of these settled particles in the exposed lake environments
- the highly turbid conditions found in the lakes are a more favourable physico-chemical environment (light penetration and nutrient levels) for algal growth than plant growth and can limit the hunting success of sight-feeding fish and birds.

Comparing the historical and current situations

Turbidity levels in Lakes Alexandrina and Albert have steadily increased since European settlement due to wind and water erosion in the catchment, river regulation and lakeshore erosion.

Historically, most of the water that has entered South Australia comes from the River Murray headwaters in Victoria and New South Wales. However, Darling River water has become the main source of water entering South Australia (up from 35% to 58%) in recent years due to river regulation, channel delivery restrictions and differential rates of water use in different parts of the basin. Darling River water tends to be more turbid than

River Murray water and this has increased lower River Murray turbidities. In the South Australian Lower Murray, 'it is not unusual for the turbidity to exceed 100 NTU (Nephelometric Turbidity Units) for periods of several months, hence the need for treatment. The World Health Organisation recommends a desirable maximum of 5 NTU for drinking water' (MDBMC, 1987). River regulation also directly impacts on turbidity levels through static weir pools accelerating back slumping and thus increasing sediment loads into the river. Bank slumping occurs along the whole length of the River Murray from Wellington back to the Hume Dam.

Erosion of the lakeshores themselves is the other major source of turbidity in the form of suspended sediments. An erosion—susceptible clay horizon is typically found above 0.55 m AHD (Australian Height Datum) around the lake margin. These clays are more rapidly eroding than the soils covering them so as the clay erodes, it undermines the banks of the lakes causing slumping and collapse of the top soil into the lakes. Static lake levels and uncontrolled grazing promote this erosion which will continue at rates of up to 3 m/year (GWLAP, pers. comm.) until the eroding shoreline reaches a harder material (Bourman, 2000).

Data provided by the EPA of South Australia (Peter Christy, pers. comm., 2006—see Appendix H) provides insights into the past and present turbidity for the freshwater system units. At this point in time only preliminary analysis of this data has been possible. It is evident that great care needs to be exercised as high flows and rainfall events can greatly increase turbidity readings, and skew average calculations.

Lake Alexandrina:

The dataset for Milang runs continuously from 1983 to the present (October 2005). It shows that annual averages (noting the comment above about caution) range from around 30 up 200 NTU with most years having average around 50-60 NTU. The range of actual recordings spans from <1 to 390, the latter being recorded in November 1983. Recordings at Poltalloch Plains since 1999 have ranged from 15.5–185 NTU and upstream from the Goolwa Barrage, from 2.5–91.5 over the same period.

Lake Albert:

In Lake Albert there is some data for a site described as 8 kms south west of Meningie from 1986–1994 (see Appendix H). It is based on few recordings but these cover the range 5.2-130 NTU. For three other sites where records were taken from 1996–1998, NTUs (excluding some very high readings) averaged around 50 NTU.

Tributaries:

There is also turbidity data collected by the SA EPA for three of the tributaries (see Appendix H). On the Finniss River (4km east of Yundi), average turbidity from April 1970 to January 1976 was 15.6 NTU (range 5-47 NTU) and from January 2000 to October 2005, it was lower about half this 7.9 NTU (range 2.2-34.1 NTU). On the Bremer River (near Hartley) the average for July 1979-November 1987 was 8.9 NTU (range 0.6–46 NTU) whereas for March 2000 -October 2005 it was 10.4 NTU (range 2.2-44.8 with one reading 110NTU excluded). Another site on the Bremer River, Wanstead Road, recorded average turbidity of 10.4 NTU for the period May 2003 to October 2005 (range 0.8-65.4 with one reading of 115 excluded). On Currency Creek (near Higgins), average turbidity from January 1972 until January 1976 was 12.1 NTU, across a range of 2-31 NTU. At the same location from February 1985 until August 1993, the average was higher at 17.4NTU with a range from 1.2-47 NTU.

Note: there is substantial investment occurring from 2006 to develop a 3-D hydrodynamic model for the lakes under the CSIRO CLLAMM ecology program which will map resuspension and turbidity trends.

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

Erosion and sedimentation may alter habitat salinities depending on geology of eroding soils and physicochemial properties of the suspended sediments.

Keystone species (Section 6.3):

Increased turbidity reduces light penetration and thus limits the depth to which keystone plant species can grow.

Water levels (Section 6.4):

Increased rates of sedimentation can reduce variability in lakeshore bathymetry and thus alter water levels at a habitat scale.

Habitats (Section 6.5):

A switch in primary production from plants growing in sediments to algae growing in the water column is promoted by high levels of turbidity and thus low light penetration which has implications for food webs, nutrient cycling and wetland community structure. Reduced water transparency also limits the success of sight-feeding birds and fish.

Asset Plan 2005 targets

No specific targets relating to turbidity or sedimentation in the Lakes.

Limits of acceptable change Turbidity

Lakes Alexandrina:

Turbidity maintained below 70 NTU based on a five-year average. This allows for periods of higher turbidities during high flows. Based on the data for Milang (see Appendix H), the average annual NTU level for the 18 years from 1983-2000 has been 76.2 NTU, with a range of <1 to 390 NTU.

Lake Albert:

Turbidity maintained below 50 NTU based on a five-year average. This allows for periods of higher turbidities during high flows. This is based on the historical and more recent data provided in Appendix H.

Tributary wetlands:

Unlike salinities (see Section 6.1) which seem to vary between tributaries, for the three tributaries able to be considered here (see above and Appendix H) the turbidities were quite consistent, and low by comparison with the lakes

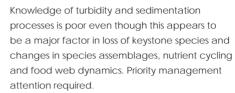
The LAC is therefore to maintain turbidity in the tributaries at less than 12NTU based on a five-year average to allow for periods of higher turbidities during high flows.

6.2.1 Turbidity and sedimentation in the estuarine-saline units of the system

Turbidity and sedimentation status

- the sediments transported by the River Murray are ultimately discharged to the Murray Mouth Ocean (via the Murray Mouth) and the Coorong. These sediments have increased in load and changed in character since European settlement
- the proportion of sediments delivered to the Coorong as opposed to the ocean will be related to the relative forces of out-flowing River Murray water compared to incoming sea water
- sediment suspended in River Murray water is the major source of sediment and thus organic carbon and nutrients to the Coorong and Murray Mouth Estuary. When there is no flow over the barrages, turbidity decreases in the Coorong and Estuary due to flocculation and lack of new inputs. Turbidity is thus likely to vary in response to timing and amounts of flows from the lakes
- the nutrient cycles and food webs of the Coorong are powered by the inputs of nutrients, biota and carbon from River Murray water but if rates of sedimentation exceed the rate of decomposition of deposited material then the mudflats and sand flats become smothered with sediment which impacts heavily on macroinvertebrate assemblages and thus food sources for birds and fish
- the highly turbid conditions that are generated during low or no flow periods adversely impact on Ruppia spp. germination and growth and promotes the growth of algae. It also reduces hunting success for sight-feeding fish and birds.

Traffic light assessment



Comparing the historical and current situations

The turbidity in the Coorong lagoons has increased markedly since European settlement, as indicated by shifts in diatom species assemblages over time. These diatoms show that possibly very early in European settlement, but definitely by the 1940s when the barrages were constructed, the Coorong lagoons became more turbid. Most notably there was a shift from species preferring saline conditions (sea water concentrations) to a group that are considered to prefer more turbid conditions (Haynes and Gell, 2005). This shift was caused by increases in the sedimentation rate and lithological changes towards fine clay deposits, marked clearly by recent deposits of black, fine silty clays over the more ancient marl/shell sediments that deposited on the old sea floor.

Gell and Haynes (2005) report that the inferred pre-European sedimentation rates in the Coorong were within the range 0.19-0.31 mm/year, based on core samples. For the past 20-years the rate in parts of the Coorong has been greater than 15 mm/year, an increase of two orders of magnitude. They note that 'As much as 55 cm of sediment has accumulated since 1850 AD.' Further work is under way to try to ascertain the origin of these more recent sediments and their impacts on ecosystem components and processes.

The project team was unable to locate any comprehensive long-term datasets of turbidity in the Coorong.

In the Murray Mouth and North Iagoon, Geddes (2005) provides some turbidity observations from surveys done in July 2004 as follows:

'Transparency, measured as Secchi disc transparency depth, was higher in the Murray Mouth region with transparency depths of 2 metres. Further into the North Lagoon, the transparency fell to 100 cm at NL5 [North of Dodd Point], 90cm at NL7 [North of Robs Point] and 60cm at NL9 [North of Needle Island]. A set of turbidity measurements made at the AWQC (Australian Water Quality Centre) show a similar pattern of increasing turbidity from Ewe Island (3.6 NTU) to Salt Creek Lagoon (6.6 NTU).' Geddes (2005) also reported a turbidity of 11 NTU at Parnka Point which he attributed to turbulent conditions caused by high flow from the North to the South Lagoon at the time of recording. The Secchi depth then was 50 cms.

Paton, through his long-term studies of the Coorong has provided turbidity data in several of his publications (Paton, 1999, 2000, 2002, 2003 and beyond; Paton and Bolton, 2001). In Paton (2002) he provides turbidity data for sites along the Coorong in July 1998 (sourced from Freebairn, 1998), 1999, 2000 and 2001. These data are reproduced below at Table 22.

In Paton (2003) a figure (Figure 4 in Conserving the Coorong) is provided showing a transect of turbidities along the Coorong for January 2001, 2002 and 2003. While the raw data are not included, the figure shows that for most of the transect length (41 kms south of Hell's Gate—The Narrows—to about 25 kms north of it), turbidities measured using Secchi disc depths, ranged between 20 and 40 centimetres. From around 25-30 kms north of The Narrows, the Secchi depths increased up to around 120-150 centimetres at 50 + kms north.

In the South Lagoon, Everingham et al., (2005) note in the context of trying to detect changes to water quality from discharges into the South Lagoon from the Upper South East Drainage Scheme (between 2000 and 2004) that '... the turbidity of the release water is lower than the receiving waters of the Coorong (≈5NTU as compared to 10-25 NTU).'

Table 22 - Turbidity data for various locations along the Coorong in 1998, 1999 and 2000 (From Paton, 2001) Data measured using Secchi disc depths from the surface. Values are means +/- standard error for five replicates in 1999 and 2000

Date	Sites									
	Noonameena	Villa die Yumpa	Policeman's Point	Salt Creek	Tea-Tree Crossing					
July 1998	87	31	34	36	28					
July 1999	43 +/- 1	42 +/- 2	42 +/- 3	41 +/- 3	41 +/- 1					
July 2000	64 +/- 2	42 +/- 3	38 +/- 0.2	41 +/- 2	43 +/- 1					
July 2001	60 +/- 3	31 +/- 1	30 +/- 1	30 +/- 1	30 +/- 1					

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

Turbidity, sedimentation and salinity interact in terms of changing rates and types of sedimentation processes across salinity gradients but this is poorly understood at this site.

Keystone species (Section 6.3):

Turbidity controls light penetration into the water column and thus is a key regulator for aquatic plant and algal growth, in this case the two Ruppia species. Ruppia megacarpa beds once formed a band between 0 and -1m AHD, which relates to an average growing season depth of about 60 cm (Seaman, pers. comm.). R. tuberosa is an annual that grows at depths of 0.3 to 0.9 metres. Turbidity changes can vary these growing patterns. The patches it occupies therefore shift with seasonal variations in water levels. High rates of sedimentation can also smother germinating plants and emerging animals thus preventing successful recruitment.

Water levels (Section 6.4):

Sedimentation can alter water levels by altering the bathymetry of the lagoons. For example, alterations to the shoreline or in-filling of deep holes important for fish spawning (see Section 7.1).

Habitats (Section 6.5):

Because turbidity is a key determinant of primary production (high levels favouring algae over plants) it has the potential to impact on all ecosystem components and processes. Sedimentation and turbidity directly impact on animals by reducing success of sight-feeders and by smothering the soft shelled eggs of fish thereby inhibiting recruitment. Smothering of macroinvertebrate communities also occurs with high sedimentation rates in Coorong. Resources delivered with the sediments such as nutrients can also alter food webs by channelling energy through different trophic pathways.

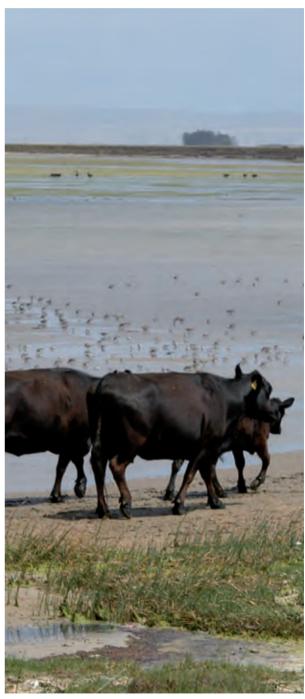
Asset Plan 2005 targets

Organic content of mudflats in the North and South Lagoons (Interim targets—Asset Plan 2005):

Depth: 0.40-0.90 m, during October to December of every year and, for a minimum of 90 days. Salinities during these periods: North lagoon to remain estuarine and not exceed 80000 EC, South Lagoon to remain within the range 50,000-100,000 EC.

Migratory and other waders—sediment size in the North Lagoon (Interim targets—DWBLC, 2005): Maintain sediment size between 250 um and <63 um (medium sand to mud). Organic content of mudflats in North and South Lagoons: establish and maintain total organic contents of:

- 3.0 to 9.0 in mud (<63 µm)
- 2.0 to 4.0 in fine sand (125 µm)
- 0.59 to 4.0 in medium sand (250 µm).



Livestock grazing the lake shores add sediments to the water column, increasing turbidity and impacting on the growth of keystone aquatic plant species

Limits of acceptable change and traffic light assessment for the Coorong lagoons

There is relatively little long-term data available at present upon which to base LAC for turbidity, apart from that indicated above, and also what is known about the light transmission requirements for the reproduction and growth of the Ruppia keystone species (see above and the following section). These have been used to recommend the following limits.

Murray Mouth and Estuary: Secchi disc transparency depths of no less than 2 metres.

North Lagoon: Secchi disc transparency depths of no less than 90 centimetres. To encourage R. megacarpa return and expansion back to former distribution (see above and Section 6.3).

South Lagoon: Secchi disc transparency depths of no less than 90 centimetres. To encourage R. tuberosa return and expansion back to former distribution (see above and Section 6.3).



North Lagoon from Parkna Point

Traffic light assessment



Knowledge of turbidity and sedimentation processes is poor even though this appears to be a major factor in loss of keystone species and changes in species assemblages, nutrient cycling and food web dynamics. Urgent management attention required.



The University of Adelaide is commencing a study in 2006 to determine the origin of sediments deposited in the Coorong lagoons and this will greatly assist with describing LAC for sedimentation in the future.

6.3 Keystone aquatic plant species

Keystone species are those whose loss from an ecosystem would precipitate the loss of many others because of their direct or indirect dependence on them. Often keystone species exist in assemblages. The loss of a keystone species, or an assemblage, is indicative of a fundamental shift in ecological state because of the resultant alterations to ecosystem components and processes. Therefore the loss of a keystone species or assemblage from a Ramsar-listed wetland is a major indicator of an adverse shift in ecological character.

6.3.1 Submerged aquatic plant species in the freshwater units of the system

Keystone species status

- the keystone species for Lakes Alexandrina and Albert and the Tributaries are the submerged and emergent aquatic plants that provide for physicochemical components and processes, create habitat architecture and the starting blocks for the food web
- in general terms, submerged aquatic plants are restricted to the littoral zone and assemblages of emergent plants dominated by Phragmites australis and Typha domingensis fringe the lake margins, the Tributary wetlands and the channels and depressions on the islands
- the diversity and abundance of submerged aquatic plants is greatest in the tributaries and near confluences where the water regime is more variable and turbidity levels are lower (see page 58)
- other species such as Melaleuca halmatuorum perform keystone species functions at a habitat scale (See Section 4.1.4, Xf wetlands).

Comparing the historical and current situations

Freshwater submerged aquatic plant communities were extensive in the freshwater units of the Coorong and Lakes Ramsar site prior to European settlement, spreading for several kilometres out into the lakes (Sim and Muller, 2004). The zone in which submerged aquatic plants could live was much wider than it is today because natural river flows provided a more variable water regime and thus bands of vegetation could form at different elevations in different years depending on where water regime conditions were optimal for growth.

Ganf (2000) identified four issues influencing the productivity, distribution and community composition of macrophytes: salinity, turbidity, water regime and wind and wave action. These factors combined mean that submerged aquatic plant growth is restricted to the littoral zone of the modern lake environment. In the case of Lakes Alexandrina and Albert, there has been a general simplification of the aquatic plant assemblages, both submerged and emergent, primarily because of the regulated, static water regime in the lakes; this resulting from the traditional 'fill and spill' operation of the barrages (see Section 6.6). Such a static water regime favours plants like Phragmites australis, that uses vegetative reproductive strategies, over plants that depend on sexual reproduction strategies and therefore require variable water regimes, such as Baumea spp. and Schoenoplectus spp. (see Section 4.1.4).

Increasing turbidity (see Section 6.2) has been a primary factor in restricting submerged and emergent aquatic plant growth to the lake margins; reduced light penetration preventing plants from establishing and growing in deeper water. For example, Lake Alexandrina turbidity levels typically range from 30-200 NTU (and as high as nearly 400 NTU on occasions—see Section 6.2) which limits growth of Vallisineria americana (water ribbons; keystone species) to depths of less than about 30 to 90 cm (based on Ganf, 2000). High turbidity levels also favour algal and biofilm growth over submerged aquatic plant growth, adding to the factors adversely affecting submerged plant growth in the lakes.

The confluence areas around the lakes, the tributaries, irrigation channels and the lake islands now represent remnant habitats of what the dominant wetland type in the freshwater system units was prior to European settlement, that is; clear, cool, sometimes tannic water with a variable water regime.

Freshwater keystone species are now essentially restricted to these remnants which provide habitat for locally and nationally endangered small native fish including the Yarra Pygmy Perch (Nannoperca obscura), Southern Pygmy Perch (Nannoperca australis) and Murray Hardyhead (Craterocephalus fluviatilis) (Wedderburn and Hammer, 2003 cited in DWLBC, 2005) (See Sections 5.61-3). These areas probably represent the most productive habitats in the freshwater part of the system and are considered core habitats in terms of providing propagules and juveniles to extend this habitat under a restoration regime.

Implications for other primary determinants of ecological character

Turbidity (Section 6.2):

Dense and continuous stands of submerged and emergent vegetation would protect the lakeshore from erosion and re-suspension by dampening turbulence, thereby reducing lake turbidity levels. Plants also act as physical filters of suspended sediments, increasing sedimentation rates and decreasing sediment transportation.

Water levels (Section 6.4):

Keystone species status may alter water levels indirectly by changing erosion and sediment deposition patterns and thus bathymetry and topography.

Habitats (Section 6.5):

By definition, keystone species status has the capacity to influence all other ecosystem components and processes and thereby determine nutrient cycling, food web structure and the various aspects of habitat availability (see Section 3).

Flows (Section 6.6):

Flow rates and turbulence are likely to be dampened by emergent vegetation until flow rates increase to the point where the plants are laid flat and overtopped by flows

Asset Plan 2005 targets

Interim target is to provide suitable lake levels to maintain and stimulate vegetation and vigour for:

- 1. Melaleuca halmatuorum.
- 2. Myriophyllum spp. and other submerged aquatic plants.
- 3. Samphire at lake edge.
- 4. Semi-aquatics: Schoenoplectus spp. Typha domingensis and Phragmites australis.

Limits of acceptable change

Areal extent:

Given their critical role in the functioning of the freshwater units, any further loss of these keystone species would be a matter for great concern. As such, the limit of acceptable of change is 0% of areal extent, even though it is acknowledged that at present we do not know that extent. Surveys and mapping to set that baseline should be a high priority. Ideally, the management target should be to reinstate these keystone species to areas they have been lost from during the past 20-years, at least. Consultations with long-term stakeholders should assist with gaining this understanding, and for target setting within the Ramsar plan for the site, similar to that done for the keystone species in the estuarine-saline units (see below).

Connectivity:

As noted above these keystone species are critical habitat for biota, and as such it is vital that efforts be made to reinstate connectivity between these areas so that the problem of habitat fragmentation can be addressed. The LAC is recommended as 0%, although, as with areal extent above, it is acknowledged that surveys and gaining an historical perspective are high priority so that this LAC can be meaningful, and used to set management targets.

Traffic light assessment



There is an urgent need to secure the core keystone species populations (whether they be in natural or human-made wetland types) and extend their range to ensure on-going provision of the environments needed to support freshwater ecosystem components and processes. The loss of, or severe decline in, keystone species population is considered a fundamental change in ecological character.

6.3.2 Submerged aquatic plant species in the estuarine-saline units of the system

Keystone species status

- the keystone species for the estuarine-saline units are the submerged Ruppia spp. Along with plants from the Lepilaena genus, these are the only submerged aquatic plants found in Australian inland waters with salinities greater than 4 ppt (6,200 EC)
- two main species of Ruppia occur: being Ruppia megacarpa which was once the dominant plant in the North Lagoon and R. tuberosa which dominated the South Lagoon
- other submerged species included Lamprothamnium and Lepilaena (Boon, 2000) but these species have been lost in recent years from both the North and South Lagoon (Geddes, 2003)
- R. megacarpa is a long-lived perennial species that generally favours permanent water and persists through unfavourable conditions as seeds. The beds formed a band between 0 and-1mAHD, which relates to an average growing season depth of about 60 cm (Seaman, pers. comm.)
- R. tuberosa is an annual that grows at depths of 0.3 to 0.9 metres. The patches it occupies therefore shift with seasonal variations in water levels. During winter and spring R. tuberosa grows, setting seed and retreating to underground turions during summer. It will grow as

- a perennial if conditions are favourable but will act as an annual if conditions are not favourable, persisting as seeds and turions until conditions improve
- R. tuberosa has a higher salinity tolerance than R. megacarpa which coupled with its annual-type reproductive strategy allows it to be opportunistic in terms of habitat occupation (e.g. recent appearance in Lake Albert)
- R tuberosa seeds and turions occur in a wide hand. which allows those propagules that receive the optimal water regime in any given season to flourish and provided they complete their life cycles, replace spent seeds and turions in the summer
- waterfowl consume the leaves, seeds and turions of Ruppia spp. and beds of the plants provide food and shelter for macroinvertebrates and fish. In addition, these plants provide detritus to fuel decomposition and thus nutrient and carbon cycling.

Comparing the historical and current situations

Historically R. megacarpa dominated the North Lagoon and R. tuberosa the South Lagoon. To put this in perspective, the accounts of the way the Coorong used to be from the Ngarrindjeri community and long-term local fishermen and their families are very instructive. Extracts from their oral histories on the subject are provided below, with the full descriptions in Section 7.

Oral history information Ngarrindjeri community

Swan weeds (Ruppia spp., Lamprothamnium sp.) once formed dense beds across the whole of the Coorong lagoons all the way to Salt Creek. They were the key to the whole system. They are now almost entirely gone with some small patches left at Kungair and Noonameena. The loss of the beds of swan weed from the Coorong lagoons has lead to the loss of fish and birds because they relied on the swan weed for food and as nursery areas. The red berried swan weed (Lamprothamnium sp.) has been gone from the Coorong since the late 1970s. It used to feed Coorong mullet and would act as an indicator to Ngarrindjeri fishermen looking to catch the mullet that schools of fish would soon be moving through to eat the berries.

The main swan weeds (Ruppia spp.) were still abundant in the late 1970s and have only been lost in the last 20-years. Bundles of Ruppia sp. would wash up along the shores of the Coorong lagoons after storms, forming small pools behind them. Congolli would become trapped in the bundles of swan weed and in the pools, making them easy to collect. The fish would stay alive and fresh in the bundles of swan weed for days.

Frank Gibbs—Coorong fisher and hunter from the 1930s to the present

Wire weed was everywhere, thick. It had red berries on it and the ducks loved it, fed on it. It was very thick all the way from Pelican Point to Salt Creek.

Swans used to feed in groups of 80-90 and you could see the schools of whitebait. We cursed wire weed because we would get balls of it stuck in the nets, it would clog them.

Bob Hera-Singh—Coorong fisher and hunter, 1940s to present

The water weeds were so thick. Blanket weed would come to the top and was green. It's still around here and there. Wire weed was what the birds thrived on, haven't seen that for a long time. Sometimes bits of plant get washed up that look like young wire weed but don't see it growing anywhere anymore.

Since the 1980s, it seems R. megacarpa has been lost from the Coorong altogether and R. tuberosa has shifted from the South Lagoon into patches within the Murray Mouth Estuary, North Lagoon and the southern end of Lake Albert. The South Lagoon and most of the North Lagoon no longer support these or any submerged aguatic plants, so that 100km of the 140km long stretch from the Goolwa barrages to Salt Creek is now effectively unvegetated. This area now supports algae, brine shrimp and a 'detritivore' faunal assemblage including crabs, barnacles and stingrays.

In order to try to gain a better appreciation of the likely former distribution of R. megacarpa in the North Lagoon and Estuary, Seaman (SA DEH, pers. comm., 2006) produced the predictive distribution map provided below. This is based on bathymetry and on observations that the species was only found at depths between 0 and-1m AHD. While it is acknowledged that this is a 'prediction', it is a well informed one, and contrasts starkly with a distribution map for R. megacarpa that would be drawn today showing none of this species at all in the North Lagoon. There is also good evidence to suggest that this predictive map by Seaman may be close to the former reality. Apart from the accounts from the Ngarrindjeri community and local fishermen (see above and Section 7), Dr Mike Geddes, has been studying the health of the Coorong since the early 1980s and he recalls as follows:

In 1985 it [R. megacarpa] was along the inland side of the North Lagoon from north of Mark Point to south of Dodd Point, almost to Noonameena [see Figure 6 on page 13 for these landmarks]. There were dense stands to 60 cm tall along the littoral zone to a water depth of about 1 metre. This represented a band of Ruppia 100 to 200 metres wide. In my sampling since 2003, I have not seen any R. megacarpa growing in the North Lagoon' (M. Geddes, pers. comm.).



Emergent Typha, floating Azolla and submerged Myriaphyllum



Figure 24 - Predicted former distribution of Ruppia megacarpa in the North Lagoon and Estuary

As noted in Section 5.4, the studies of Paton (2005b) reinforce the decline of R. tuberosa in the South Lagoon. Table 14 (see page 130) compares the abundances of R. tuberosa seeds and turions in 1985 with 2005. In most cases the reductions in abundance recorded are 10-15 fold

The loss of Ruppia spp. from the Coorong can be attributed to three main factors: salinity, turbidity and water levels. The salinities of the Coorong have exceeded that tolerated by R. megacarpa. However, areas are still available that have not exceeded the salinity tolerance of R. tuberosa, yet these areas still do not support its growth, suggesting other factors at work. Increased turbidity and sedimentation rates (see Section 6.2) have also limited Ruppia spp. growth and recruitment by limiting light penetration into the water column or by physically smothering or burying the seeds and/or turions to a depth where germination will not be successful. The loss of swans and ducks from the Coorong lagoons was seen by the Ngarrindjeri elders as a critical loss of ecological function because by feeding on the turions and seeds, the swans and ducks would turn over the sediment and thus bring propagules into more favourable positions for germination and growth. (George Trevorrow, pers. comm.).

Further limitations to Ruppia spp. growth and recruitment are caused by unfavourable changes or lack of changes in water levels at critical times (see Section 6.4). Examples include:

- 1. If water levels drop too early in the growing season, the plants will not complete their life cycles and thus new seeds and turions will not be added to the propagule pool, thus diminishing its reproductive capacity over time.
- 2. If the water levels rise too rapidly the plant growth may not match the water level rise and with current high levels of turbidity causing reduced light penetration, it may not be able to access enough light to grow.
- 3. If water level changes either up or down in winter or spring when the propogules are establishing, then the young plants may face either 'drowning' or desiccation.

As a consequence of losing these keystone species, all other ecosystem components and processes in the Coorong will be adversely affected. One major change expected is a shift in the nutrient cycling processes away from denitrification at high salinities and with poor plant cover, leading to phosphorus limitations. This may direct energy flow towards algae and thus brine shrimp rather than towards Ruppia, hardyhead fish and

their dependent biota. Another is a loss of key plant food sources for higher trophic levels, either directly through lack of seeds and turions for herbivorous birds, or indirectly through the subsequent loss of hardyhead fish that feed piscivorous birds and large fish. Therefore, keystone species loss promotes the establishment of an alternate ecological state. In this case this alternate state has algae dominating over plants. Such a shift in ecological character may be irreversible once it becomes established.

In short, the loss of Ruppia spp. from around 75% of its former habitat range in the Coorong is leading to a major, and possibly irreversible, change in the ecological character of the Murray Mouth Estuary and Coorong lagoons. Ruppia spp. are the most saline tolerant aquatic plants, so if salinities exceed their tolerances, the only primary producers that can colonise the area are algae. Algae do not support the ecosystem components and processes that aquatic plants do, therefore ecological character changes at a whole site scale.

In the Coorong, the ecosystem has been so simplified since the loss of Ruppia spp. that algae and brine shrimp have been the dominant biota in the South Lagoon and southern North Lagoon since spring 2005. The consequent loss of fish that depended on Ruppia spp. habitat has seen an increase in chironomid larvae and a shift in bird assemblages away from fish-eaters to those that will feed on brine shrimp (such as Banded Stilts). The loss of food for fish-eating birds in the Coorong lagoons has in turn seen a reduction in breeding effort by some species (see Section 5.3) and a congregation of these species at the Murray Mouth and Estuary which is placing disproportionably high pressure on the remnant wetlands and fish stocks in the estuarine areas. In essence, the estuarine Coorong ecosystem components and processes are now only supported in a 30km stretch from Goolwa barrages to Pelican Point, which represents less than 25% of the original estuarine ecosystem area, indicating that a comprehensive shift in ecological character is underway.

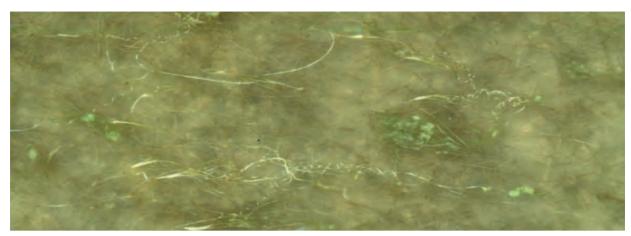
Implications for other primary determinants of ecological character

Salinity (Section 6.1):

High salinity levels impact on keystone plant species (R. megacarpa especially), and restrict the habitat options of other biota.

Turbidity (Section 6.2):

Dense stands of Ruppia spp. would protect the substrate from resuspension by dampening turbulence thereby reducing turbidity levels. Plants also act as physical filters of suspended sediments, trapping sediments and



Ruppia sp. keystone species of the Coorong. The loss of this signals a major change in the ecological character of the Coorong lagoons.

thereby decreasing sediment transportation and water column turbidity. Note: trapping suspended solids and reducing turbidity, ultimately threatens the plants capacity to photosynthesize.

Water levels (Section 6.4):

Keystone species status may alter water levels indirectly by changing erosion and sediment deposition patterns and thus bathymetry and topography.

Habitats (Section 6.5):

By definition keystone species status has the capacity to influence all other ecosystem components and processes and thereby determine nutrient cycling, food web structure and the various aspects of habitat availability (see Section 3).

Flows (Section 6.6):

Flow rates and turbulence are likely to be dampened by submerged vegetation to some extent.

Asset Plan 2005 targets

Interim targets:

Ruppia megacarpa—from the annual low tide level to one metre below the annual minimum low tide mark, R. megacarpa abundance will be 50% cover.

R. tuberosa—maintain water levels in South Lagoon for R.tuberosa. Aim for 50% cover.

Limits of acceptable change

Given their critical role as keystones of the ecological character of the estuarine-saline units, the apparent loss of Ruppia megacarpa from the North lagoon and the significant decline of R. tuberosa in the South Lagoon is a matter of grave concern for this Ramsar site.

The Asset Plan's interim targets provide a starting point for management action, and these will be verified or modified once further work is done on the predictive mapping for both Ruppia species (see Figure 24). As noted above, observations by local stakeholders and

Traffic light assessment

There is an urgent need to secure the core keystone species populations around the Murray Mouth Estuary and the northern end of North Lagoon and extend their range to ensure ongoing estuarine ecosystem functionality. The loss of, or severe decline in, keystone species populations is considered a fundamental change in ecological character. It is estimated that in these units keystone species coverage is less than 25% of original.

long-time researchers (see above) suggest that the predictive map produced for R. megacarpa may well reflect the former extent of the is species in the North Lagoon.

Irrespective of the estimates of the former areal extent and the targets set by the Asset Plan, the LAC for these keystone species has to be 0%. Any further loss cannot be tolerated if the ecological character of the estuarine and saline system units is to be recovered.

As was noted for the keystone species of the freshwater units (see Section 6.3.1), these species are critical habitat for biota, and a primary food source for many of the Ramsar significant birds and fish of this site. As such, it is vital that efforts be made to reinstate connectivity between these areas so that the problem of habitat fragmentation can be addressed. The LAC for connectivity is recommended as 0%, although, as with areal extent above, it is acknowledged that surveys and gaining an historical perspective are high priority so that this LAC can be meaningful, and used to set management targets.

6.4 Water levels

6.4.1 Water levels in the freshwater units of the system

Water level status

- the water levels of Lakes Alexandrina and Albert are regulated by inflows from the River Murray and outflows through opening of barrages gates (see Figure 6, page 13)
- Lake Alexandrina and Lake Albert combined hold 2098 GL at 0.85 mAHD, and 2015 GL at 0.75 mAHD (DWLBC, 2005)
- the low points of Lake Alexandrina (and thus the deepest points) occur at approximately -4.0 mAHD. This means that at 0.75 mAHD the deepest areas in the middle of the lake are 4.75 m deep. Whilst the 'average' depth is approximately 2.9 metres (Baker, 2000), wind action across the lake surface can vary lake levels considerably (average wind speed 28 km h-1. Bourman et al., 2000)
- barrage construction connecting the islands in the southern part of Lakes Alexandrina (and thus controlling River Murray outflows) commenced in 1935 and was completed in the early 1940s. The barrages were initially built to provide fresh water for the local community and passage for river craft. In more recent times the barrages, and therefore the lake levels, have been managed primarily to ensure irrigation supply through summer when River Murray and EMLR tributary inflows and rainfall are lowest, and evapo-transpiration is greatest
- the barrages have been operated on a 'fill and spill' rule meaning that water was released when lake levels reached 0.75 m AHD until lake levels dropped to 0.45 m AHD when they are closed to ensure enough storage for the coming irrigation season
- the 'fill and spill' rule has created a static water regime (see Section 6.3.1), with periodic and rapid draw downs, usually in late winter and/or early spring when ecological components and processes required higher levels and slow drawdown, if any (see ideal hydrographs from the Asset Plan, DWLBC, 2005, below)
- the static water regime has simplified the complexity of ecosystem processes and components that occur under a variable water regime. For example, the decline of emergent plants reliant on sexual reproduction (see preceding section)
- in the period between 1981 and 2003 there were seven periods when the barrages were closed continuously for more than 200 days with the longest period exceeding 643 days. The lowest level Lake Alexandrina dropped to during that time was 0.31 m AHD

- a new Barrage Operating Strategy (BOS) is being developed at present to better utilise water available during low flow conditions and mimic natural water regimes (see Asset Plan, DWLBC, 2005)
- water levels in the Tributaries are primarily controlled by catchment run-off and groundwater discharge. Groundwater levels surrounding the Tributary wetlands do not appear to be changing even though salinities are increasing (see Section 6.1). This suggests that more saline water will be drawn into the wetlands over time from the marginal parts of the discharging aguifer
- the mouth of Currency Creek can be periodically dried out by wind pushing water out of the wetland and into Lake Alexandrina. This may increase the draw on the discharging aquifer and contribute to declining inflows and thus lower water levels in the future.

Comparing the historical and current situations

Before European settlement, lake levels started to rise from groundwater inputs entering the lakes prior to the first rains in late autumn (presumably driven by decreasing atmospheric pressure). Levels would steadily rise through winter, driven by EMLR (Eastern Mount Lofty Ranges) tributary inflows, rainfall on the lakes and groundwater inputs, with levels peaking in late spring-early summer when River Murray flows came from the headwaters. Over summer, water levels would slowly drop when evaporation exceeded trickling inputs from draining groundwater and the tributaries of Lake Alexandrina.

Lake levels now vary with season; being high in winter and lower in summer. Levels vary considerably due to high variability in River Murray and tributary inflows and climatic factors such as rainfall, wind, tides and evaporation. However, the water levels of the lakes are now far less variable than in the past and remain static or may drop abruptly during late winter-early summer when key ecological components and processes require a gradual rise and fall in water level.

Figure 25 below shows that under the current regime the lake level sits between 0.75 to 0.8m AHD for approximately 70% of the time and is greater than 0.6 m AHD 90% of the time. Under a natural regime, water levels rose and fell such that higher levels were only seen relatively briefly each season (that is, 0.6 m AHD was only exceeded about 5% of the time compared to 90%). These changes have effectively seen a dampening of 90% of the temporal seasonal variation which has changed the fringing 500 metres or more of lake habitat from variable depth and ephemeral, to static depth and permanent.

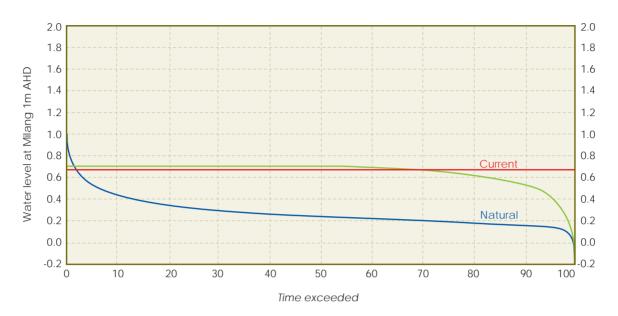


Figure 25 - Comparison of daily water levels at Milang (Lake Alexandrina) under natural and current conditions (Asset Plan, DWLBC, 2005)

The barrages that control lake levels were built in the 1930–1940s on limestone outcrops (or reefs) that formed part of the old sea bed prior to the formation of the Sir Richard and Younghusband Peninsulas. This reef or limestone outcrop connects Tauwitcherie, Mundoo, Ewe and Hindmarsh Islands at approximately 0.3 m AHD, whilst the spill height of the barrages is 0.81 m AHD, effectively raising lake levels by about 50cm at capacity. Although, as can be seen above in Figure 25, the lake is typically operated between 0.6 and 0.75 m AHD. This is to minimise stress on the barrage structures that were not designed to hold water for extended periods above this height, and also ensure irrigation supplies are met at least 95% of the time (MDBC River Murray Water staff, pers. comm.).

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

In general, when lake levels are lower, the water is saltier due to the combined impacts of evaporation exceeding inputs and a relatively high contribution of groundwater in localised discharge areas. Conversely, when lake levels are high, the water is generally fresher because of relatively high inputs versus evaporation, and thus, dilution of residential water. Localised highly saline patches can occur where sea water ingresses, for example Holmes Creek on Hindmarsh Island and the lake side of the barrages.

Turbidity (Section 6.2):

Erosion of the lakeshore is accelerated if water levels are maintained at 0.55 m AHD; a height where highly erodable soils are susceptible. Rates of sedimentation are accelerated when variations in water regime are dampened and residence time increases (see Section 4.1.4).

Keystone species (Section 6.3):

Water levels are a key determinant of the patterns and extent of submerged and emergent aquatic plants which are the keystone assemblages for the freshwater units (see Section 6.3).

Habitats (Section 6.5):

Water levels are a key determinant of all aspects of habitat availability and thus the patterns and extent of all ecosystem components and processes. Water level determines water regime at a habitat or 'biotic' scale (that is, at higher elevation, components and processes have a more spatially variable and ephemeral water regime than at lower elevation where water is more permanent, although still highly variable in depth, see Section 6.5). Static water regimes lead to simple communities. Water level changes connect habitats across time and space.

Flows (Section 6.6):

Water levels and flows are intimately connected. Changes in flows, into and out of a system, drive water level changes by changing the input to output ratios. Changes in water levels through a range of processes (e.g. wind driven 'tilt' of the lake surface) can drive flows by providing head differences (see Section 6.6).

Asset Plan 2005 targets

(Interim targets—DWBLC, 2005)

Water levels to stimulate vegetation growth (including submerged aquatics, samphire etc.):

Vary lake level between 0.6 and 0.7 m AHD, in late spring to summer or every second year for a minimum of 60 days. Water level fall does not exceed 2cm/day for 30 days.

Water levels to expose mudflats in summer for migratory waders: Lakes Alexandrina and Albert: manipulate lake level to 0.60 m AHD spring and summer, every second year and for a minimum of 60 days.

Maintain and enhance habitat for native fish: Maintain maximum lake levels over winter up to 0.81 m AHD for channel inundation and allow variation between 0.6 and 0.7 m AHD during spring and summer, every year.

More frequent estuarine fish spawning and recruitment: Elevated lake levels at Mundoo Barrage to 0.85m AHD between June and September, each year for small bodied fish.

Limits of acceptable change

Lake levels need to be drawn down in summer and raised in winter in order to mimic natural, seasonal variations, thereby reducing erosion and allowing for expansion of more complex ecological communities. The current proposal contained in the Asset Plan (DWLBC, 2005) is to have a rate of rise and fall of no more than 2cm per day in the pattern described below (see Figure 26). This is being tested at present and developed as on-going work of the Lakes and Coorong Environmental Flows Working Group (multi-agency working group convened by DWLBC).

Until this further work is done, no LAC is recommended for now.



Tauwitchere barrage. Operations of the barrages are critical in determining water levels both in the lakes and downstream

Traffic light assessment Lake levels are a key determinant of all ecosystem components and processes. The current regime is counter-seasonal to the natural one and too static to support the full complement of the lakes' biota. Species reliant on variable water levels are under-represented and at risk of local extinction. 0.90 Current

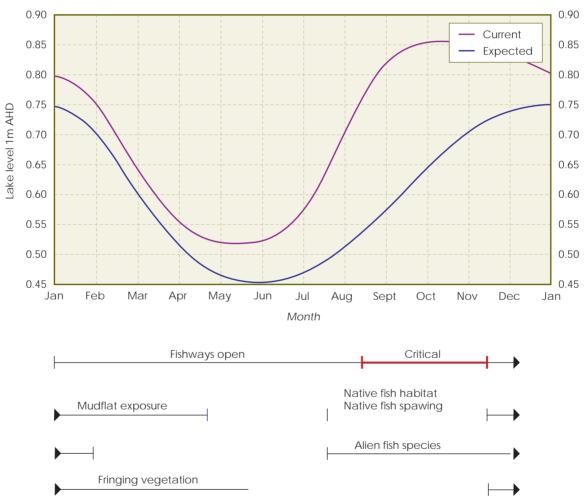


Figure 26 - Proposed revised hydrograph for the lakes (Asset plan, DWLBC, 2005)

6.4.2 Water levels in the estuarine-saline units of the system

Water level status

- water levels in the Murray Mouth Estuary naturally vary with tides, winds and Lake Alexandrina inflows. typically being higher in winter than summer. Under current conditions the tidal signal does not persist more than 30km north of Goolwa Barrage into the North Lagoon (at Pelican Point the signal is weak) and this is the area currently providing estuarine habitat
- water levels in the Coorong undergo a seasonal cycle of up to ~0.7 m in range, higher levels tending to occur in late winter to early spring and lower in late summer-early autumn. This seasonal variation is due to a combination of variation in sea level outside the Mouth and back-up due to discharge through the barrages. Shorter term water level variations of ~0.05 m typically are due to the 'tilting' of the waters' surface by the wind. Tidal level variation is important near the Murray Mouth (Webster, 2005)
- if the Murray Mouth is open, the volumes of sea water entering and exiting the Estuary on any given tide cycle is equal. If the Murray Mouth is restricted, the volume of water entering the Coorong exceeds that which leaves on any given tidal cycle and water levels in the lagoons increase on each tide cycle, being lowered again by evaporation of the 'sea' water
- the Murray Mouth has been kept open with dredges since October 2003. The dredged channel connecting the Coorong to the Murray Mouth is successfully allowing tidal exchange such that water levels in the Coorong are not being elevated by greater influx than efflux of sea water (see Section 6)
- although the North Lagoon is a permanent waterbody, the area of inundation varies both diurnally and seasonally with water level variations driven by variations in tide and inflows
- water levels in the South Lagoon vary seasonally by approximately 0.9 m (Lamontagne et al., 2004), being higher in winter and lower in summer, resulting in the seasonal exposure of extensive areas of mudflats
- at its southern end, the South Lagoon grades through an annually drying section into a series of shallow and ephemeral salt lakes where water levels vary from subsurface in late summer to about 30 cm depth in late winter to early spring.



Murray Mouth and Estuary

Comparing the historical and current situations

According to Noye (1975), changes in the water levels in the Coorong can be '... classified into three main types; wind-induced short period changes of a foot or so (sic), with a time scale of days, in which opposite ends of each lagoon move out of phase with each other; short period increases in levels in the North Lagoon which occur when the barrages at the north end of the Coorong are opened for several days at a time; and seasonal variations of up to four feet (sic). Water level changes in Encounter Bay including tides are also acknowledged as penetrating through the Mouth to influence levels within the Coorong."

'As long as the Mouth is open, the seasonal variation in sea level appears to penetrate the length of the Coorong and is not likely to be strongly influenced by the degree of Mouth opening. Conversely, the water level response of the Coorong to barrage discharges is likely to be affected by which barrage is discharging and by the degree of channel constriction in the Mouth region. Significant shorter period water level variations are caused by the wind which tilts the water along the lagoon basins one way or the other and by the tides which penetrate into the northern end of the North Lagoon.'

The major changes in water levels induced by euroanthropogenic factors are counter-seasonal peaks in level (levers—barrage releases and Murray Mouth dredging), persistent high water levels (lever-Murray Mouth dredging) and dampened intra-seasonal variation from reduced groundwater and surface inflows directly into the Coorong.

Implications for other primary determinants of ecological character

Salinity (Section6.1):

'The rise and fall of water level pumps water from one part of the Coorong to another. The balance between evaporation and water exchange caused by water level change results in a seasonal cycle of salinity variation in the South Lagoon and determines overall salinity levels there. Thus, manipulation of water levels in the system through dredging of the Mouth or varying barrage discharges has implications for the salinity regime and for the exchange of other materials such as nutrients.' (Webster, 2005).

Turbidity and sedimentation (Section 6.2): Sedimentation in the Murray Mouth area can reduce tidal exchange, which in turn can increase turbidity and nutrient concentrations.

Keystone species (Section 6.3):

Water levels are a key determinant of the patterns and extent of the submerged aquatic plants (Ruppia spp.) which are the keystone species for the Coorong system.

Habitats: (Section 6.5):

Water levels are a key determinant of all aspects of habitat availability and thus the patterns and extent of all ecosystem components and processes. Water level determines water regime at a habitat or 'biotic' scale (i.e. water level determines extent of mudflat exposure and thus whether waders can access macroinvertebrates and other food types living in and on them, see Section 6.5). Water level changes also connect habitats across time and space.

Flows (Section 6.6):

The degree of openness of the Mouth is of critical importance in the way the system exchanges water with the sea and with setting water levels within the Coorong Lagoons. River Murray inflows most strongly affect water levels in the Murray Mouth Estuary.

Asset Plan 2005 targets:

(Interim targets—DWBLC, 2005)

Water levels to enhance Ruppia megacarpa and R. turberosa:

Ruppia megacarpa—from the annual low tide level to one metre below the annual minimum low tide mark, R. megacarpa abundance will be 50% cover. Map of expected R. megacarpa distribution to be provided.

R. tuberosa—maintain water levels in the South Lagoon for R. tuberosa, Aim for 50% cover, Map of expected R. tuberosa distribution to be provided. Between 0.3 and 0.8 m AHD for minimum of 90 days, September to December.

Establish invertebrate populations in the South Lagoon. Maintain water level between 0.1m and 0.2m, minimum of 90 days, September to February.

Water levels to expose mudflats in summer: (Interim targets —DWBLC 2005):

North Lagoon: No greater than 0.3 to 0.5 m AHD in November to February, every year, and for a minimum of 90 days.

South Lagoon: Maintain between 0.1 to-0.2 m AHD from November to February, every year, and for a minimum of 90 days.

Maintain sediment size range and establish target organic carbon content in mudflats: North Lagoon: 0.4 to 0.9 m for minimum of 90 days, August to October.

Limits of acceptable change

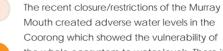
Coorong lagoon levels need to vary with a natural pattern of high water levels in winter and low in summer. Seasonal, short term and tidal patterns are lost if there is insufficient inflow or connectivity to the Southern Ocean via the Murray Mouth and thus an open Murray Mouth at all times is essential.

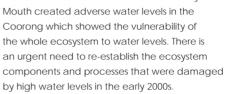
LAC-Murray Mouth Open 100% of the time, preferably via river flows than dredges

In terms of LAC for water levels, variation across time and space and absolute depths at critical times, are the key parameters. The Lakes and Coorong Environmental Flows Working Group have developed the proposed ideal hydrograph in Figure 27 below. This proposal integrates the Asset Plan targets into an ecological envelope of target water depths throughout the year and will be tested in terms of capacity to achieve the hydrograph and observed ecological outcomes from delivery.

Until this further work is done, no LAC is recommended for now.

Traffic light assessment







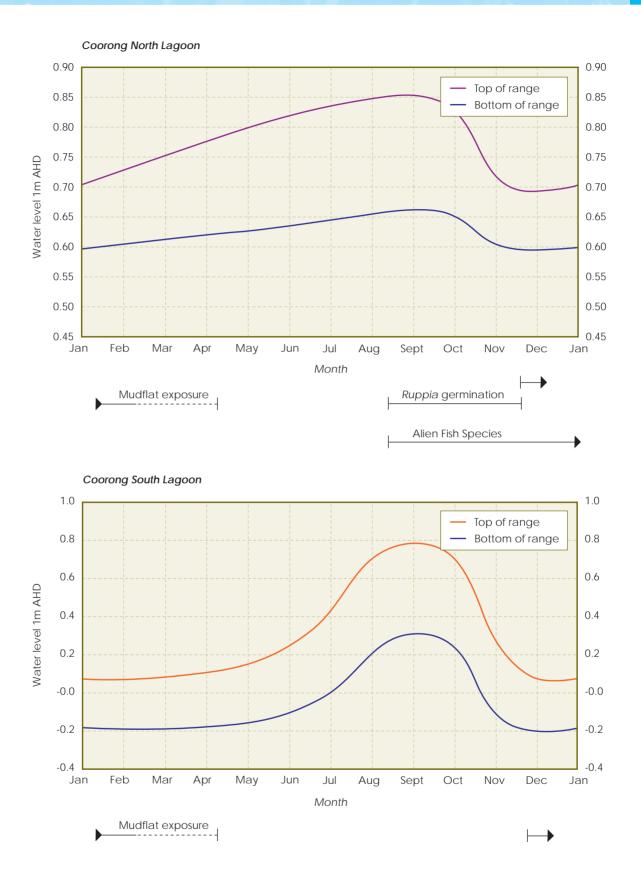


Figure 27 - Proposed 'ideal' hydrographs for the North and South Lagoon (Asset Plan, DWLBC, 2005)

■ 6.5 Habitat availability, particularly temporal and spatial connectivity

Habitat availability is an overarching term for all aspects of habitat use and requirements. Habitat availability varies naturally over time and space driven by geomorphology, climate and hydrology but in order for a site to support its dependent biota, the right habitat type(s) need to be available in the right condition at the right time(s). If habitats change, or are not available for extended periods, then the ecological character will change through resultant changes in ecosystem components and processes. Measures of habitat availability, and therefore the capacity of a site to support resident and transient species and assemblages and maintain its ecological character, include:

- the variety and specific type(s) of habitat(s) (e.g. number of different Ramsar wetland types present)
- how accessible they are to the relevant species (e.g. provision of seasonal water level variations required for waders to feed on mudflats)
- the extent of habitat compared to the competitive pressure for that habitat
- the condition of the habitat (e.g. status of keystone
- the degree of temporal and spatial connectivity between required habitats (e.g. integrity of habitats connections along migration paths).

The freshwater and estuarine-saline units are considered together in this section because of the high degree of connection required between the fresh, estuarine and saline environments at this site.

Habitat status

- twenty-three different Ramsar wetland types are interconnected across the Coorong and Lakes Ramsar site, ranging from freshwater soaks and wetlands with salinity at or below rainwater levels to hypersaline lagoons with salinity levels greater than sea water
- freshwater aquatic, plant-based habitats are restricted to near shore (littoral) locations around the Lakes, tributary wetlands, the Lake islands, natural and artificial channels and in patches around freshwater soaks
- remnant freshwater aquatic communities are dominated by plants that reproduce vegetatively. Those that rely on the alternative strategy of sexual reproduction are now under-represented
- transitional areas, such as the Lake islands and confluences that connect dominant wetland types are critical in terms of providing habitat availability in

- different seasons and locations and allowing species to move between habitats as required (for example, island channels allow movement of diadramous fish between fresh and saline habitats—see Section 5.6.3)
- estuarine aquatic plant species (e.g. Ruppia spp.) are restricted to remnant patches in the Murray Mouth Estuary and the North Lagoon and new patches are forming in the southern end of Lake Albert
- woodlands are under-represented except in the ephemeral wetlands south of the South Lagoon where significant areas of Melaleuca halmatuorum occur. River Red Gums only occur in the riparian areas of the Tributaries.

Comparing the historical and current situations

Extensive and permanent freshwater wetlands dominated by Phragmites australis once connected the River Murray to Lake Alexandrina prior to European settlement. This area is now referred to as the 'reclaimed swamps' irrigation area. The cleared land is lower in elevation than the River Murray and is dominated by dairy pastures that require an Environmental and Land Management Allocation of water to be applied under water license to ensure that the pastures are always draining downwards and saline groundwater is not allowed pushed up into the root zone of the pastures by head pressure from the River Murray (see RMCWMB, 2002). This area is not part of the Ramsar site but lies immediately upstream of Lake Alexandrina and has historically provided flows and habitat connectivity between Lake Alexandrina and the River Murray.

The lakes are now more turbid, more saline, deeper on average, and more static in water regime than they were naturally. This has lead to a simplification of the freshwater habitats and a reduction in diversity and abundance of keystone submerged and emergent aquatic plants. Habitats that require a variable water regime with cool, clear flowing water, at least during the winter and spring months, are now very rare within the Ramsar site and tend to support threatened species that depend on this variable water regime. In particular, habitats that can support short-lived Murray Hardyhead and both Yarra and Southern Pygmy Perch are now critically underrepresented, suggesting that loss of these fish species is imminent under the current management regime. These habitats now only occur in the tributaries, a few lake fringing wetlands, irrigation channels and the lake islands.

The reduction in River Murray flows and the construction of the barrages in the 1930–1940s has impacted on habitat connectivity at a whole site level. The almost complete loss of species such as the diadramous lampreys clearly indicates the adverse impacts of these structures. Before the barrages were built, prime angling species such as Mulloway were caught in backwaters of the freshwater units when they came in to feed in the productive wetland areas. Similarly, in the first few years after barrage construction, fishing was exceptionally easy near the barrages because thousands of fish would congregate on either side trying to pass either from fresh to estuarine environments or vice versa. A sequential shift in fish species assemblages was observed by anglers in the period after the barrages were constructed (Grundy, 2000) which reflected adverse changes in habitat connectivity rather than degradation of habitat condition per se.

The estuarine component of the Ramsar site has also declined in areal cover and habitat condition. Under natural hydrological conditions, estuarine habitats were provided from the Murray Mouth to the southern end of the South Lagoon with patches of hypersaline habitat at the northern end of South Lagoon where the influence of freshwater inputs from either the north (River Murray) or the south (South East surface and groundwater inflows) was minimal. Currently, estuarine conditions only occur between Goolwa channel and Pelican Point (approx. 30 km in length). This represents less than 25% of the original estuarine habitat and now supports all the estuarine ecosystem components and processes that once occurred throughout the Coorong Lagoons.

Simultaneously, there has been an increase in hypersaline habitats (salinity greater than sea water) (see Section 6.1) that are also highly turbid (see Section 6.2) and thus unable to support keystone species such as Ruppia spp. (see Section 6.3). The loss of Ruppia spp. has had an adverse cascading impact on all other estuarine components and processes. For example, the loss of Ruppia spp. lead to the loss of macroinvertebrates that fed hardyheads which in turn lead to the loss of hardyheads that fed larger fish and piscivorous birds which in turn has lead to their decline in the hypersaline habitats. It appears that these hypersaline habitats are undergoing a major shift away from plant basedsecondary consumer habitats towards algal-decomposer based systems which will lead to a change in ecological character and a loss of traditional ecosystem services from this site.



Myriophyllum sp. and Triglochin procerum

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

Reduction in habitat availability is unlikely to alter salinity processes other than to alter transport rates and the fate of mobilised salt.

Turbidity and sedimentation (Section 6.2): Reduction in plant cover, particularly along shore lines, will increase turbulence and therefore rates of resuspension and turbidity levels. Reduced bioturbation may also result from reduced habitat availability. Sedimentation patterns will also be altered by changes in physical habitat attributes.

Keystone species (Section 6.3):

Reduced habitat availability will adversely affect keystone species abundance, condition and capacity to support other ecosystem component and processes.

Water levels (Section 6.4):

Reduction in plant cover resulting from reduced habitat may impact on water levels at an individual component or process scale.

Flows (Section 6.6):

Widespread changes in physical habitat attributes can impact on head differences and impedance to flow transmission.

Asset Plan 2005 targets:

All of the interim targets in the Asset Plan (DWLBC, 2005) relate to habitat availability directly or indirectly by providing a platform to maintain and restore ecological character at a whole site scale.

Of particular note here are those relating to Ruppia spp. Interim targets:

Ruppia megacarpa—from the annual low tide level to one metre below the annual minimum low tide mark, R. megacarpa abundance will be 50% cover. Map of expected R. megacarpa distribution to be provided.

R. tuberosa—maintain water levels in South Lagoon for R. tuberosa. Aim for 50% cover. Map of expected R. tuberosa distribution to be provided.

Limits of acceptable change

Lake Alexandrina:

No further reduction in habitat availability. Reduced turbidity and maintenance or restoration of habitat connections are considered critical for listed species and under-represented habitats.

Traffic light assessment





Restoration of habitat availability is required as a priority action. In particular, the full suite and extent of habitat types, needs to be restored and connections between habitats (particularly through the barrages and the lakes islands) need to be improved as soon as possible. Re-establishment of estuarine conditions in the Coorong lagoons is critical for restoration of ecological character.

Lake Albert:

No further reduction in habitat availability. Reduced turbidity is essential for plant growth and improved hydrological connectivity between the Lakes via the Narrung Narrows is essential for the integrity of this otherwise closed part of the system.

Tributary wetlands and Hindmarsh Island: No further reduction in habitat availability. Maintaining or restoring habitat connectivity is required to maintain and enhance isolated remnant fish, plant and bird populations and allow for migration of species between habitats to escape adverse local conditions.

Murray Mouth and Estuary, North Lagoon and South Lagoon:

No further reduction in habitat availability.

Appropriate management targets for restoring ecological character are:

- · reinstatement of the former estuarine habitats of the Coorong, which it is estimated currently sit at 25% of the former coverage (see Sections 6.3.2 and 6.4.2). This is a matter of some urgency;
- interim target for Ruppia as contained as interim targets in the Asset Plan.

6.6 Water regime, particularly flow patterns

The preceding five parts of this Section have examined the key determinants of the ecological character of the Coorong and Lakes Ramsar site. Woven through each of these parts are issues that relate directly to water regime, that is, the timing, extent, duration and frequency of inundation, which is primarily determined by rates of flow into, out of and through the system. This is perhaps not surprising given that water regime, driven by climate, geomorphology and catchment-scale hydrology, is a fundamental determinant of wetland ecosystem types and condition and thus ecological character.

In Figure 6 of this report (page 13), an overview was provided of the flow pathways for this Ramsar site and in Figure 7 (page 15) the range of drivers, levers, components and processes was summarised. In this section several of the system levers regulating flows are examined more closely.

Summarised, these flows patterns are as follows:

- · Lake Alexandrina gains freshwater inputs from rainfall on the lakes' surface, local floodplain runoff and inflows from the River Murray, the tributaries and from discharging ground water
- some of these waters flow through the Narrung Narrows into the land-locked Lake Albert which also has the supplementary inputs of rainfall, local runoff and groundwater flows
- Lakes Alexandrina and Albert, the tributaries and the lake island channels all have water extracted for irrigation, stock, domestic and town supplies, as well as losing water to evaporation
- wind patterns (speed and direction) can greatly influence flow patterns and water depths by 'tilting' the lake surface or creating waves that generate head differences between the lakes themselves, and also between the lakes and other connected water bodies (the tributary wetlands and island channels)
- flow through the freshwater units to the estuarine-saline units is controlled by the five barrages that connect the lake islands. The barrages are constructed on an ancient limestone 'reef' that sits at about 0.35 m AHD; this providing a lower threshold lake level for barrage operation. The spill height of the barrages is about 0.81 m AHD giving an upper threshold. Therefore, through flow (managed releases) is controlled by lake level until about 0.85 m AHD, when the barrages are overtopped and flow downstream is then unimpeded

- freshwater flows through or over the barrages are either discharged through the Murray Mouth, distributed along the Coorong lagoons or evaporated from the estuarine-saline units. The partitioning of flows either out of the Mouth or along the Coorong is driven by hydrology and geomorphology and levered by barrage operation
- water chooses the path of least resistance, which is direct transfer from Goolwa Channel out of the Murray Mouth under natural hydrological conditions. However, different options for release through the different barrages will deliver water at different points along the Murray Mouth Estuary, thus changing flow dynamics within the system. The Murray Mouth is the preferential discharge point for water delivered through any of the barrages provided it is open and unrestricted
- the greater the flow rate, or the more impedance to discharge out of the Mouth, the more freshwater that will 'back-up' and enter the North Lagoon. Transfer from the South Lagoon will depend on relative head differences, noting that the South Lagoon is higher in elevation than the North Lagoon and thus water will not tend to flow from north to south
- sea water also enters the system via the Murray Mouth under tidal influence and wave dynamics, mixing with freshwater inputs from Lake Alexandrina, groundwater and rainfall to create the estuarine-saline environment of the Coorong. Sea water inputs are greatest when 'spring' tides (that is, during new and full moons), storm surges and southerly winds coincide
- as with the lakes, wind patterns have a major influence on flow patterns and water levels along the Coorong. For example, northerly winds which occur throughout winter, push water from the North Lagoon to the South Lagoon. When these winds ease water 'sloshes' back into the North Lagoon which is lower in elevation than the South Lagoon
- historically, the southern end of the Coorong received significant surface water inflows from the South East region of South Australia via watercourses that extended into western Victoria. Drainage activities in the 1960s and 1970s reduced inflows to the Coorong but works under the Upper South East Drainage Scheme since 2000 have allowed collected groundwater to be released into the South Lagoon via Morella Basin and Salt Creek.

From the perspective of describing ecological character it is therefore appropriate to examine the following:

- 1. Inflows from the Eastern Mount Lofty Ranges.
- 2. Inflows from the River Murray.
- 3. Barrage Operating Strategies.
- 4. Murray Mouth opening.
- 5. Inflows from the Upper South East Drainage Scheme.

Note: groundwater is not considered in detail below as an input to the system because of poor technical understanding of the regional groundwater dynamics and the paucity of quantitative data. See Section 7 for anecdotal evidence of the decline in groundwater quality and quantity.



The River Murray—primary freshwater source for the Coorong and Lakes Ramsar site—enters Lake Alexandrina just south of Wellington

6.6.1 Inflows from the Eastern Mount Lofty Ranges (EMLR) Tributaries of Lake Alexandrina

Tributary flow status

- the Eastern Mount Lofty Ranges (EMLR) contain 13 streams, five of which discharge into Lake Alexandrina; namely Currency Creek, Tookayerta Creek, Finniss River, Angas River and the Bremer River
- these streams gain water from catchments that vary in rainfall from 350 mm to 850 mm annually, and from aquifers in the hills and across the plains recharged by stream flow and rain infiltration
- the lower reaches of the Finniss River, Tookayerta Creek and Currency Creek lie within the Ramsar site, however all but the mouths of the Angas and Bremer Rivers are outside the boundary
- gauging stations on Currency Creek and the Finniss, Angas and Bremer Rivers show that median winter runoff equates to 53 GL (DWLBC, Hydsys data). However, typical inflows are likely to exceed 100 GL if extrapolated to include Tookayerta Creek, the whole annual cycle and parts of the catchments that are ungauged but contribute flow. Flooding flows in wet years may be up to four times this given variability in climatic drivers

- · Tookayerta Creek is notable for its exceptionally high water quality (namely, <500 EC, Hammer, 2004 —see Section 6.1) and is one of the only streams in the Ramsar site that has permanent flow. Water resource impacts are being felt near Nangkita, where stream flow stopped temporarily in summer 2003 from excessive localised pumping (Hammer, 2004; Muller, unpubl. data)
- the irrigation channels between the mouths of the Angas and Bremer Rivers are important habitats, providing cool, clear, flowing water along the channels when the pumps are operating during the spring-summer irrigation season. In winter, when the pumps are not operating, these channels receive runoff from the samphire-lignum floodplain and the lakeside road and thus are likely to be important nutrient and carbon cycling sites as well as providing for flowing habitat dependent biota
- the critically endangered swamps of the Fleurieu Peninsula and the endangered Mount Lofty Ranges Southern Emu-wren (see Sections 5.1.2 and 5.13, respectively) are found within the tributary wetlands and are dependent on the variable water regime provided by surface and ground-water flows. These flows are also critical for certain obligate freshwater fish (see Section 5.6.1)
- Black Swamp is a critically important Fleurieu Swamp for freshwater habitat availability in the Ramsar site given its location at the confluence of Tookayerta Creek, Finniss River and Lake Alexandrina and thus its variable water regime and relatively clear, flowing water (see Section 5.1.2 and 4.1.3).

Comparing the historical and current situations

Flow was essentially permanent in all five EMLR streams prior to European settlement with summer baseflows being provided by groundwater discharge and wetland drainage (ABWMC, 2001). Freshwater supplies were so reliable that this was one of the first areas in South Australia to be developed for agriculture. Adelaide, the State's capital, was originally planned to be located along Currency Creek close to the river port of Goolwa and located where year-round freshwater supplies from the lakes and streams was assured (Sim and Muller, 2004).

Water resource development thus began very quickly after European settlement to the point that the local papers began running articles on the need for policy to safeguard 'riparian rights' of landholders along the tributaries such as the Bremer River, which was drying up and becoming badly polluted (Sim and Muller, 2004). The Angas Bremer Land and Water Management Plan reports that floods in the Bremer River occurred between five

and 45 times per year in the late 1800s and early 1900s and that this rate has dropped to one flood per five-years on average since the 1970s (ABWMC, 2001).

In modern times, the Angas and Bremer Rivers are ephemeral and do not run every year, or generally for more than 6–9 months when they do flow. The lower Angas River is groundwater fed so it tends to provide trickle flows for much longer periods than the Bremer River and may trickle for more than 12 months at a time in wet years. The Finniss River, Currency Creek and Tookayerta Creek are still considered 'permanent' although flow may stop for several weeks in summer, depending on local climatic conditions and extraction rates (RMCWMB, unpubl. data). Tookayerta Creek is the most reliable of these streams and has only dried up for a short period in one reach in summer 2003. Currency Creek is the least reliable of these three streams now and it dries up in summer each year, except in very wet years.

Water resource development was capped at 30% of winter run-off by the River Murray Catchment Water Management Plan in 2003 and Notices of Prohibition and Intent to Prescribe were issued under the Water Resources Act 1997 in October 2003. Water Allocation Plans will need to be developed and implemented before water will be returned to these streams from the consumptive pool.

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

The salinity of the tributaries was naturally low but has increased most notably since 2000 such that tributary salinities often exceed 1500 EC which is a critical threshold for adverse impacts in freshwater wetlands (Hart et al., 1991). Tookayerta Creek still provides fresh habitat having salinities <500 EC (see Section 6.1).

Turbidity and sedimentation (Section 6.2): Turbidity in the tributaries is generally low, although erosion of poorly consolidated stream beds further upstream (that is, outside the Ramsar site) and erosion heads in the upper catchment can be significant, episodic sources of sediments. Dense aquatic plant cover in the tributaries would assist in reducing turbidity and resuspension, and thus in increasing sedimentation rates.

Keystone species (Section 6.3):

The tributaries are critical habitat within the freshwater units for keystone aquatic plants. The diversity and abundance of these plants is greater in the tributaries than anywhere else in the Ramsar site.

Water levels (Section 6.4):

The variable water regime dictates variations in water levels on a seasonal and annual basis which supports a range of ecosystem components and processes that are not supported by static lake levels. Releases through the barrages may reduce water levels in Lake Alexandrina and thus water levels of tributary wetlands.

Habitat availability (Section 6.5):

The tributaries provide substantial cool, clear flowing water habitats that are now under-represented in the Ramsar site. The natural patterns of flow that these streams provide to the site are at least as important as the flow quanta they provide because these variations promote flow related processes such as fish spawning, floodplain/core habitat connectivity or submerged plant growth and reproduction that are not supported in the static lake environment.

Flows (this Section):

In low flow years for the River Murray, the tributaries provide the bulk of the freshwater inputs to Lake Alexandrina and thus the bulk of the water available to release through the barrages.

Asset Plan 2005 targets

The Asset Plan does not contain any specific targets for EMLR tributaries but they are referred to as important water sources for delivery of water to the Asset and thus it is implied that these flows need to be managed in order to assist in achieving Asset targets.

Limits of acceptable change

No areater than 30% of winter run-off to be taken from each sub-catchment, as per the River Murray Catchment Water Management Plan (2003).

Patterns of inflows need to be protected. In particular, disconnection or untimely drying out of critical tributary habitats should be avoided, particularly given the high diversity and abundance of significant taxa utilising these habitats (see Section 6.6.3).

Groundwater pumping policies (such as zones of influence) that limit pumping on a spatial and seasonal basis and improved delivery of low to medium flows are needed to prevent truncation of flow events and adverse changes in water regime and water quality.

Closely related LAC

Salinity:

LAC should be set for each tributary based on historical and other data. For the four tributaries where such data has been examined here (see above and Appendix H) it is apparent that each should be treated separately. For these, the following are recommended based on preliminary analysis only at this time. Monitoring salinities at point of discharge into the lake is recommended to

- at summer or drought peak, based on a five-year
- Finniss River: Salinity maintained below 1200EC at summer or drought peak, based on a five-year
- Currency Creek: Salinity maintained below 2400 EC at summer or drought peak, based on a five-year
- Bremer River: Salinity maintained below 2500 EC at summer or drought peak, based on a five-year average.

Groundwater salinities feeding the tributary wetlands not to exceed 1,500 mg/l (= approx 3000 EC) to maintain the full complement of freshwater obligate fishes and plants (see Sections 5.6.1).

Turbidity:

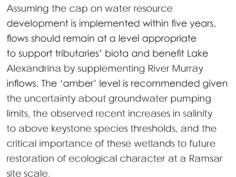
The LAC is to maintain turbidity in the tributaries at less than 12NTU based on a five-year average to allow for periods of higher turbidities during high flows.



Black Swamp and Tookayerta Creek

Traffic light assessment







6.6.2 Inflows from the River Murray

River Murray flow status

- the River Murray is a highly regulated system that is effectively a series of cascading pools, controlled by locks and weirs, from the Hume Dam in New South Wales to the barrages at Goolwa near the Murray Mouth
- in general, the weir pools along the river are held at a constant level with target variations in the order of 5 to 15 cm in height in order to provide water at known pool levels for irrigation and town supply off-takes. Thus, the inflows of River Murray water to the Ramsar site are highly regulated and truncated and the flow variation is strongly dampened by the need to operate weirs to maintain these precise pool levels
- · the locks and weirs were originally built to provide year-round passage for river traffic along the highly variable River Murray (as well as to ensure freshwater supplies in the lower catchment) but they are now operated primarily as water delivery structures for town, stock, domestic and irrigation supplies along the River Murray
- privately and publicly owned storages have increased since European settlement such that these storages can now hold 1.5 times the annual run-off of the catchment (T. McLeod, pers. comm.)
- the locks and weirs, plus these storages, allow river managers to mitigate flood peaks and thereby minimise or prevent infrastructure damage. They also allow for the delivery water to irrigators during summer with a high degree of certainty, except in the driest years or during extended drought periods
- the mitigation of floods and flows, and the impacts of river pollutants, are more apparent as river length increases. Accordingly, this Ramsar site, at the bottom of the catchment, is likely to experience the strongest impact from these anthropogenic factors of all River Murray sites
- · River Murray water quality entering the site is generally poor and is a major source of nutrients, salt, silt and algae to the Ramsar site.

Comparing the historical and current situations

River Murray flows, as variable as they were under natural conditions, kept the mouth of the river open at all times, even during drought periods. Geomorphological studies show that since it formed approximately 7,000 years ago, 1981 was the first time it had closed (Gell and Bourman, pers. comm.). This suggests that flows were at least 1,000 to 2,000 ML/day out of the mouth at all times (see Section 6.6.4), and modeling by the Murray-Darling Basin Commission (MDBC) indicates that natural discharge to the sea was in the order of 14,000 GL/year (which equates to about 58% of runoff) (T. McLeod. pers. comm.).

As stated above, high flows and floods have been reduced in frequency and length, as can be interpreted from the following diagram (Figure 28). It shows average monthly flows (in the units of ML/day) in the River Murray under three scenarios:

- 1. Natural conditions as modeled by assuming there were no volumes of water in storage or being
- 2. MDBC cap conditions of 1993/94.
- 3. Current conditions plus the 1500 GL the Expert Reference Panel (Jones et al., 2002) nominated as being required to have a moderate chance of achieving a healthy working river (see below).

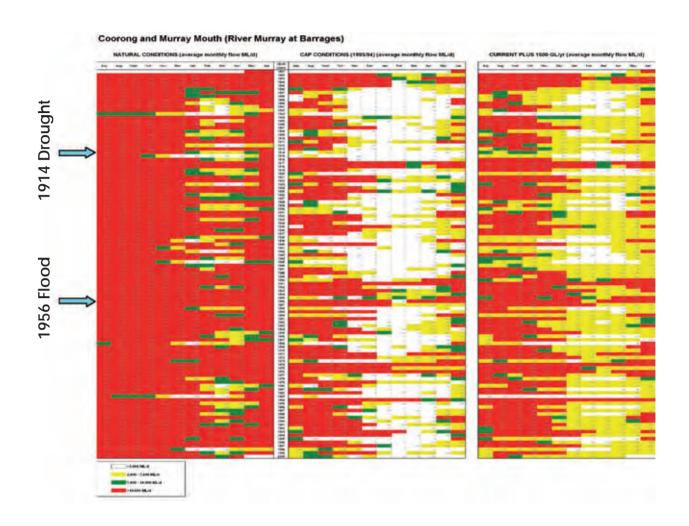


Figure 28 - Modelled average monthly flows (in ML/day) in the River Murray under three scenarios—natural conditions, MDBC cap conditions of 1993-1994 and current conditions plus the 1500 GL Expert Reference Panel scenario For a larger version of this figure, please see Appendix I.

Key trends depicted above include

Shift in dominant flow bands. Under natural conditions, flows greater than 10,000 ML/day were the dominant flow band as indicated in red in the table on the left-hand side. By contrast, under cap conditions (the centre), flows less than 2,000 ML/day dominate. Flows of 2,000 ML/day are the threshold for maintaining open Murray Mouth with river flows, further supporting the argument that lack of river flows has caused the closure-severe restriction of the Murray Mouth in modern times.

Significant reductions in high flows from natural to cap conditions. Under natural conditions, 44 out of the 109 years (or 40%) on record would have had flows exceeding 10,000 ML/day for the whole year and there were 12 periods where flows exceeded 7,000 ML/day for at least 36 months continuously (red and green bands). Whereas under cap conditions, only 3 years in the 109 years (or 2.75%) had flows exceeding 10,000 ML/day all year and there were no periods when flows exceeded 7,000 ML/day for at least 36 months continuously.

Significant increases in low flows from natural to cap conditions. Under natural conditions, flows that were less than 2,000 ML/day were rare events, only occurring in 32 out of the 1308 months (109 years) on record, or 2.5% of the time. This increases to over 500 months out of 1308 or more than 38% of the time under cap conditions.

Mitigating effects of returning 1500 GL/year. Returning 1500 GL/year (right hand panel in Figure 28) to the river would not increase the number of years with 10,000 ML/ day or more flow, but it would significantly extend the higher flow periods (particularly the yellow and red bands) in more than 75% of years. It would also partially mitigate the increase in very low flows by increasing the number of months with less than 2,000 ML/day from 38% under cap conditions to 13% (or 169 out of 1308 months). Moreover, these increases in flow rates would occur in winter-spring when consistent flows are required for seasonally-dependent ecosystem processes such as fish spawning and recruitment of Ruppia spp. (see Section 6.3). Thus, timing of the delivery of 'new' environmental water may be just as important as the quanta recovered.

It is important to note that in calculating the 'natural conditions' used in Figure 28, groundwater use and declines in effective rainfall that have already taken place under climate change, were not considered and therefore, in reality, the cap flows would have departed further from natural than is shown here.

Further interrogation of the data underlying this figure shows that years with annual flows less than 5000 GL occurred 7% of the time under natural conditions, but now occur 66% of the time under regulated conditions. Similarly, medium-sized flood events (20,000–80,000 ML/ day) have had a threefold reduction in frequency and their duration has also decreased.

Long-term median discharge to the sea was also modelled by MDBC in 2000 to be 27% of natural, or about 3,700 GL/year. Since 2001, River Murray discharges to the sea have dropped to between 0-4.8% of natural. Moreover, during the period 1981 to 2003, there were 7 periods where no water was discharged through the barrages for 200 days or more, with the longest period being 630 days ending on 6th September 2003. Under these conditions, it is likely that the Murray Mouth would have closed in 2001 and remained closed since, if the dredges were not operating.

Periods of no flow for more than 50 days, and the resultant reduction in oceanic exchange, are seriously detrimental in terms of seasonally dependent ecological processes, particularly if they occur in spring when major recruitment processes are underway. If extended no-flow periods occur in spring, entire cohorts may not complete their life cycles, and so the propagule pool may become seriously depleted. The River Murray has been running at 0-4.8% of natural flows since 2001, well below the 30% flow that some experts believe is the minimum needed to maintain the ecological functionality of systems similar to the Coorong and Lakes Ramsar site.

'The distribution of median natural flows under natural and current conditions over the barrages is shown in Figure 3.5 [Figure 29—reproduced below from the Asset Plan, DWLBC, 2005]. For eight months of the year (November-June), median monthly flows are less than the minimum median monthly flow in any month under natural conditions. The seasonality is similar, but currently quite truncated (MDBC 2004c).' (Asset Plan, DWLBC, 2005).

The impacts of these reduced flows, and the altered seasonality of the flows that do reach the site are now being manifested in a number of ways within the Coorong and Lakes Ramsar site as documented in this report. The most significant of these has been the accelerated conversion of the Coorong Lagoons away from predominantly estuarine environments toward predominantly hypersaline environments; increasingly devoid of keystone aquatic plant species, and with resultant declines of hardyhead and other fish, and the bird species that rely on these as food sources.

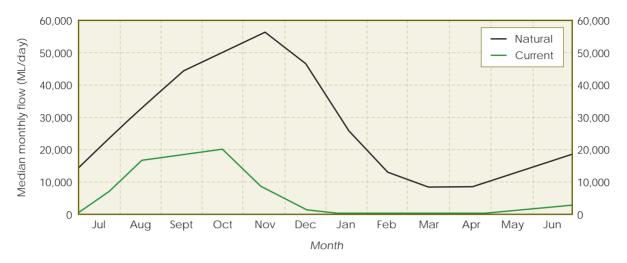


Figure 29 - Median monthly flows over the barrages under natural and current conditions, MDBC (reproduced here from the Asset Plan, DWLBC, 2005)

Political response to these changes in River Murray flow

In 2001, an Expert Reference Panel (Jones et al., 2002) was convened to provide scientific advice on environmental flows for the River Murray in response to community concerns about the declining health of the River Murray. They found evidence to indicate that there was an overall decline in ecological health of the River Murray, that the river could no longer be considered 'healthy' and that it could only be restored to a healthy state with 'major improvements to river management' (Jones et al., 2002 as cited in MDBC, 2005). Further , Jones et al., (2002) developed a conceptual model of the trend in the health of the River Murray system which is reproduced below as Figure 30. This shows that underlying the considerable natural variation in River Murray flows, that have been 'smoothed', in this diagram there is evidence that the health of the system has steadily declined since the early-1900s and that this decline can be circumstantially and directly linked to water resource development. River health can be increasingly restored by returning flows of increasing magnitudes to the river.

The Expert Reference Panel also showed that in order to have a high probability of achieving a 'healthy, working River Murray' system, 3350 GL/year of new environmental flows, plus a set of operational improvements would be needed. They observed that the same operational improvements, combined with 1630 GL/year of new environmental flow, would have a moderate chance of achieving a healthy working river system. This was the basis of modeling the 'current plus 1500 GL' scenario in Figure 28.

The response from the Murray-Darling Ministerial Council to declining river health was to announce the First Step Decision of The Living Murray Initiative agreed to at their 14th of November 2003 meeting, committing the governments to recovering water over a five-year period to reach an estimated average of 500 GL of 'new' environmental water per year and to a \$150 m Works and Measures program to improve water delivery and river operation. This marks the beginning of the Council's collective actions to return the River Murray to the status of a 'healthy working river', according to The Living Murray Foundation Report (MDBC, 2005). Therefore, there is an expectation that subsequent steps will seek to return at least an additional 1,000 GL of flows (in addition to the 500 GL First Step decision) to the River Murray, presumably over something like the following ten-years, in order to have a moderate chance of achieving Councils' stated objectives.

As part of The Living Murray Initiative, the Coorong and Lakes have been recognised (along with four other wetland sites and the river channel itself) as a Significant Ecological Asset, and the first Asset Environmental Management Plan was developed and released in July 2005 (DWLBC, 2005) (See Section 8).

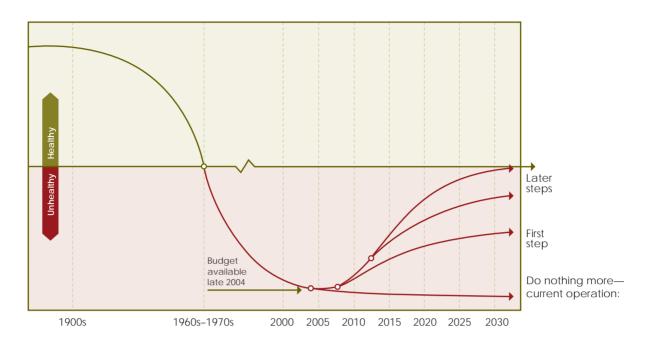


Figure 30 - Conceptual model of the trend of health in the River Murray System. Based on Jones, et al., (2002) and redesigned based on a figure from The Living Murray Foundation Report (2005)

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

River Murray flows are a source of salt to the Ramsar site but are also instrumental in moving the salt through the system and discharging it out the Murray Mouth. MDBC models suggest that 100,000 tonnes of salt are transported with every 100 GL of water that exits the barrages (see Section 6.1).

Turbidity and sedimentation (Section 6.2):

River Murray flows are a source of sediments and turbid water to the site. Lake Albert is a sink for these sediments. Outflows through the barrages can result in sediments being transported out to sea or deposited in either the Murray Mouth Estuary (Bird Island has been formed by sedimentation) or the Coorong lagoons where sedimentation rates are two orders of magnitude greater than pre-European settlement.

Keystone species (Section 6.3):

Submerged aquatic plants in the fresh, estuarine and saline units rely heavily on River Murray inflows to provide a suitable water regime and physico-chemical environment in the lakes (directly) and in the Coorong (indirectly).

Water levels (Section 6.4):

River Murray flows and barrage operations are the primary determinants of lake levels and these also indirectly impact on water levels in the Coorong lagoons via Murray Mouth openness (see also Section 6.6.4).

Habitat availability (Section 6.5):

River Murray inflows are critical in terms of determining the type, extent, connectivity and condition of habitats in the lakes, around the islands, in the Murray Mouth Estuary and in the northern part of the North Lagoon. They have indirect impacts on habitats in the South Lagoon (see Section 6.5).

Flows (This section):

River regulation and water extraction have reduced the total volume of water available to the site and has adversely affected flow regime so that flows above 2,000 ML/day are less frequent, less extensive, less variable and of altered duration and seasonality compared to the natural situation. At the barrages, the median annual outflow from the River Murray to the sea is now 27% of natural.

Asset Plan 2005 targets

No flow targets are set for River Murray inflows per se. Instead, the focus of the interim targets in the Plan is on managing inflows and outflows to achieve ideal hydrographs for a range of ecosystem components and processes. This recognizes that increased River Murray flows are likely to take considerable time to be delivered and will need to be shared among different assets. Therefore, River Murray inflows are considered only one option for improving delivery of water to the site.

Limits of acceptable change

It has been beyond the scope of this project to specify the minimum annual flow that is needed for retaining the ecological character of the Coorong and Lakes Ramsar site (refer to The Living Murray Foundation Report [MDBC, 2005] and work of the Expert Reference Panel [Jones et al., 2002]). The clear indications from the conclusions drawn and reflected throughout this report (see Section 8) is that the ecological character of this site has changed significantly since the time of Ramsar listing and that urgent remedial actions are needed. These changes are to a large extent flow related and thus the following acts as a guide to river managers to reverse the change in ecological character:

- 1. The Coorong and Lakes is a site that is strongly influenced by water levels; these being a product, in large part, of freshwater inflows and tides. Keeping the Murray Mouth open at all times with barrage releases rather than dredging should be the first target to recovering the ecological character (see Section 6.6.4 below) of this site. To this end, a secure allocation of at least 2,000 ML/day needs to be made for the Murray Mouth at least during surplus flow periods to allow for the dredges to be intermittently stopped whilst river flows are great enough to keep the mouth open. This allocation should then build up over time to the point that dredges are no longer needed.
- 2. The site is also one that is adapted to the once highly variable flows of the unregulated River Murray, and some effort needs to be made to see those highs and lows in flow pattern reinstated. It will only be with the return of environmental flows to the river, that medium-sized floods can be 'manufactured' by the river managers through the topping up of the more frequent small-floods. For recovering the ecological character of this site, the frequency of medium-sized floods (20,000–80,000 ML/day) needs to be at least once every five-years and flows over 100,000 ML/day need to occur at least once in every ten-years to 'reset' the system.



Barrage releases, rather than dredging, should be the first target to recovering the ecological character

- 3. Periods of no or very low flow were very rare under natural conditions and are extremely detrimental to the ecosystem components and processes, and therefore, the ecological character. The period of no flows through the barrages for 630 days which ended in 2003 was likely to have precipitated the widespread loss of Ruppia spp. from the Coorong lagoons and thus the current shift in ecological character. To avoid further loss in ecological functionality of the system, it is imperative that periods of no flow through the barrages do not exceed 100 days between March and August and do not exceed 30 days between August and March (see Section 6.6.3 also).
- 4. The fishways that have been installed in the barrages provide passage between the fresh and estuarinesaline units for more ecosystem components than just fish, and they also allow flow related processes to occur. A baseflow of 120ML/day is required for fishway operation, with optimal flows approaching 900 ML/day (Higham, pers. comm.). This water needs to be delivered in a pattern that mimics the natural pattern of early season tributary inflows, a lull, and then summer flows from the River Murray as water makes its way from the headwaters to the lakes. Flows need to be provided between August and February at least, but optimally all year round to allow for the full suite of flow-related ecosystem processes.
- 5. There is also a need to have water available for strategic on-site water manipulations to benefit ecosystem health and Ramsar Significant Biological Components. This may include specific allocations to freshen parts of the system when necessary, to support fish breeding or Ruppia recruitment. Specifying the volume needed for these outcomes is the role of the site managers through the development of the new site management plan. Once determined these allocations should be formally recognised under The Living Murray Initiative as a 'Ramsar site contingency allocation'

LAC 3 and 4 above can be met most of the time under current river flows and with improved barrage operation strategies (see Section 6.6.3), and so could be implemented immediately. In the opinion of the authors, returning flows to the site that will provide for LAC 1 is the matter of greatest urgency in terms of ecological character restoration. The alteration to the ecological character of the site, and the Coorong lagoons in particular, is not a subtle change although it may have occurred incrementally over many years. Reversing the current change in ecological character will take time, careful management and, above all else, significant additional water. The 500 GL/year being pursued under

the First Step Decision of The Living Murray Initiative is needed as soon as possible at this site to help slow this change in ecological character. However, the case presented above strongly suggests that the return of 500 GL/year will be insufficient to see the trend in ecological character change taking place at this site fully reversed. The health of this Significant Ecological Asset and Ramsar wetland will be reliant on further allocations within the next few years that can see the limits of acceptable change above, and the Asset Plan targets, achieved.

Traffic light assessment



The change in the ecological character of this Ramsar site is largely a consequence of reduced flows from the River Murray. Delivery of the 500 GL First Step decision of the Living Murray Initiative is urgently needed to help slow these changes, but additional flows will be are needed to keep the Murray Mouth open without dredges, to prevent extended periods of no or low flow, to allow for more frequent medium sized flood and for strategic on-site water manipulations.

6.6.3 Barrage Operating Strategy

Barrage Operation status

- the five barrages, that separate the freshwater of Lake Alexandrina from the more saline waters of the Coorong and Murray Mouth Estuary were built between 1935 and the mid-1940s
- the barrages were built on a limestone 'reef' that lies at about 0.35 m AHD. The spill height of the barrages is at approximately 0.83m AHD (that is, 83cm above sea level) and contain 593 independently operable gates in total. This gives an operational band for the barrages between lake levels of 0.35 m AHD and 0.83 m AHD
- on occasions winds and tides can cause a reverse head to develop where water levels on the seaward side of the barrages are higher than the lakes and thus seawater enters Lake Alexandrina over the barrages, or at least severely restricts barrage operation options
- the barrages represent the major control mechanism (lever) in the system and can be managed to assist in keeping the Murray Mouth open. Barrage operation, however, also varies lake levels and thus operators need to be mindful of potential impacts on both sides of the barrages when making decisions.



The barrages are a key management lever for the Coorong and Lakes

Comparing the historical and current situations

When River Murray flows over the South Australian border are forecast in April-May each year, decisions have to made about how best to operate the barrages. The barrages have been traditionally operated with a 'fill and spill' philosophy resulting in relatively static water levels. There is a target maximum fill of 0.75m AHD (for managing barrage structural integrity) and a minimum of 0.65m AHD at the beginning of the irrigation season to ensure that lake levels do not drop below 0.45 m AHD; the threshold below which irrigator off-takes begin to be affected. Significant impacts on irrigators occur if lake levels drop below 0.35 m AHD at any time during the irrigation season. Generally, the barrages are opened to allow lake levels to drop before the forecasted peak river flows come and then the peak is used to fill the lakes to a target level of 0.75 m AHD. Persistent lake levels of 0.55m AHD are also avoided because at this height wind and wave induced erosion of the lakeshore is promoted due to geomorphology of the soils (see Section 6.2). Under this regime, the MDBC can provide water to lake irrigators for the whole irrigation season in 95% of years.

A new Barrage Operating Strategy (BOS) is being developed under the Asset Plan (DWLBC, 2005) that will be more focused on providing for ecological benefits. This BOS will comprise of a set of rules and guidelines designed to provide flows within an 'ecological envelope' that caters for a range of ecosystem components and processes based upon fresh, estuarine and saline indicator species preferences for flow.

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

Barrage operation can mitigate high salinities in the lakes and in parts of the Murray Mouth Estuary and the northern end of the North Lagoon. Discharges of salt out of the Murray Mouth is the only natural way for mobilised salt to leave the Murray-Darling Basin (see Section 6.1).

Turbidity and sedimentation (Section 6.2):

Barrage operation can mitigate high turbidities in the lakes, although lake levels of 0.55 m AHD can accelerate erosion thereby increasing turbidity. These releases are a major source of sediments, nutrients and carbon to the Coorong and the Murray Mouth Estuary. Discharges out of the Murray Mouth are the only natural exit for sediments from the Basin.

Keystone species (Section 6.3):

Barrage operations are the major management tool for re-establishing and maintaining the water regime and physico-chemcial environments required for keystone species, and they are being used as indicator species for the development of the new BOS (see above). Static lake levels have simplified and reduced the extent of the keystone freshwater aquatic vegetation communities.

Water levels (Section 6.4):

Releases through the barrages reduce Lakes Alexandrina and Albert levels and thus water levels of the tributaries (see Section 6.6.1). Water levels in the Coorong are indirectly affected by barrage operations via Murray Mouth openness (see Section 6.4 and below).

Habitat availability (Section 6.5):

Barrage operations are the major management tool for re-establishing and maintaining suitable habitat-scale water regime and physico-chemcial environments in the freshwater units and the Murray Mouth Estuary. Disconnection or untimely drying out of critical tributary and lake island habitats can have serious adverse impacts on the diversity and abundance of significant taxa, such as Southern and Yarra Pygmy Perch and Murray Hardyhead, which are under-represented and important members of the food web.

Flows (This section):

Timing and pattern of barrage openings needs to be designed to provide ecological benefits as well as keeping the Murray Mouth open. Current thinking suggests that a trickle flow would better maintain the mouth in an open state than pulse flows and this is compatible with current thinking on fish and aquatic plant recruitment and other ecological needs (Asset Plan, DWLBC, 2005.). It is desirable for release strategies to vary from year to year to allow for the needs of different biota. For some of the euryhaline, estuarine and diadromous fish species (see Section 5.6), moon phase or flow patterns can also act as triggers for pre-spawning or migratory behaviour and this also needs to be factored into barrage operations.

Asset Plan 2005 targets

The Asset Plan contains 20 interim targets for water delivery to, within and from the site. Of these 20 targets, 18 describe barrage operations as the major action required to achieve the target, and the others require lake level manipulation which is also primarily controlled by barrage releases.

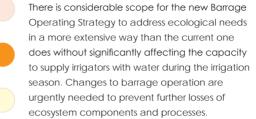
Limits of acceptable change

No limits of acceptable change are indicated here as it is assumed the new Barrage Operating Strategy (BOS) will accommodate all those that relate directly to the timing, duration and volumes of these releases. It is anticipated the new BOS will be based on the flow preferences of indicator species and the individual LAC recommended in this report. See also the LAC recommended in the preceding section relating to River Murray flows.



A different perspective of the barrage

Traffic light assessment



6.6.4 Murray Mouth opening

Murray Mouth status

- · the Murray Mouth is a tidal inlet restricted by the accumulation of dune material on the flanking spits of Sir Richard Peninsula and Younghusband Peninsula (Bourman and Harvey, 1983 cited in MDBC, 2002)
- it is located in the high-energy environment of the Southern Ocean, with deposition of sediment (sand) inside the mouth a function of tidal action counterbalanced by outflows from Lake Alexandrina through the barrages, and water levels in the Estuary area
- the area is highly dynamic, and it has been estimated that the mouth has migrated in an east-west direction of approximately 6-8 kms in the past 3,000 years. Single storm events can shift massive amounts of sand (MDBC, 2002) and the location, size and shape of the mouth, and the adjacent Estuary, are variable; being dictated by a combination of river flows, tidal flows and ocean and coastal processes (Jensen et al., 2000; MDBC 2002)
- the capacity of tidal flows to transport sand into the mouth area is a power function of the tidal velocity, so even low or small river flows have the potential to reduce the sediment load being carried into the mouth by the tide (MDBC, 2002)
- · river regulation and water resource development of the River Murray catchment (resulting in reduced river flow at the mouth), as well as the construction of the barrages has lead to a progressive silting of the Murray Mouth, such that it closed for the first time in 1981, about 7,000 years since formation (see Section 6.6.2)
- modelling suggests that barrage releases of a minimal volume of 2,000 ML/day are required to keep the Murray Mouth open and Section 6.6.2 shows that flows of less than this volume dominate the flow regime under MDBC 'cap' conditions
- · dredges have been operating continuously in the Murray Mouth since October 2002 to keep the mouth open and allow for connectivity between the Coorong and the Southern Ocean
- · tidal exchange through an open Murray Mouth is a critical system driver, being responsible for processes such as mixing of the water column, salinity balance between sea water and freshwater inflows, longitudinal extent of tidal signal and inundation and exposure of mudflats and intertidal marshes
- tidal exchange also plays a role in controlling water clarity by the flushing of fine river sediments (which are the main contributors to turbidity—see Section 6.2) to the ocean. Incoming tides deposit significant loads of sand, which smother mudflats but do not contribute to turbidity.

Comparing the historical and current situations

Prior to European settlement, discharges from the River Murray system out of the mouth exceeded 2,000 ML per day, more than 95% of the time (Sim and Muller, 2004) which kept the Murray Mouth open with river water. Geomorphological studies support this by showing that the Murray Mouth has been open for at least 7,000 years (Bourman and Gell, Expert Panel). The mouth closed for the first time in 1981 and within 24 hours the sand had built up to higher than the 1956 flood level, suggesting that even the 1956 flood (the largest flood post-European settlement) would not have cleared the sand from the mouth. The mouth had to be cleared mechanically and then was kept open by flows greater than 2,000 ML/day until the early 2000s. Between 2000 and 2002, the Murray Mouth almost closed again during the longest period of barrage closure on record (630 days ending in September 2003) and since 9th of October 2002 dredges have been operating to pump sand out of two channels (one leading from the mouth to the Goolwa channel and the other to the Coorong) and onto the ocean beach. The dredged channels keep the mouth open and provide 'fresh', oxygenated sea water to the Coorong lagoons. See photographs on the following page.





Murray Mouth—as it was in February 1987 and then in April 2004, with the two dredges maintaining narrow flow paths to the sea

If the Murray Mouth is blocked or severely restricted, the tidal signal in the Murray Mouth and North Lagoon is depressed, the hydrological connection is reduced or lost, and hence the amount of sea water brought into the Coorong is greater than that drained back to sea on any tidal cycle. Therefore, water levels in the Coorong steadily increase over winter and spring, inundating mudflats at critical times for waders. During summer, major changes in the physico-chemical environment occur, such as increased salinity (through evaporation), increased water temperature (inducing thermal stratification) and decreased dissolved oxygen, to lethal levels. Changes to the physico-chemical, and thus biological environment of the magnitude induced by the restricted Murray Mouth directly impacts on all ecosystem components and processes in the Murray Mouth Estuary and Coorong lagoons, and is a major contributor to the loss of Ruppia spp. and the subsequent induction of a shift on ecological character.

Shuttleworth et al., (2005) used bathymetric surveys to estimate the rate of in-filling from sand ingress and therefore the amount of river water required to exit the mouth to maintain it in an open state without on-going dredging. The calculated minimum volume required is 1000 GL per year. This is based on the Shuttleworth et al., (2005) estimates of sand ingress (June 2000 to May 2003) being equal to 100,000 m³ per annum, and modelling of additional river flows needed to reduce sand ingress over a 13-year model simulation yielding a coefficient of 10,000 m³ of river water per m³ of sand.

As stated by Shuttleworth et al., (2005) this could be used to assess the relative costs of dredging versus the multitude of benefits resulting from maintaining an open mouth with river flows rather than dredges, recognising also that discharging an additional 1,000 GL of river flow out of the mouth would have substantial and urgently needed ecological benefits throughout the whole Ramsar site. In addition to the ecological benefits described here from having an open Murray Mouth, for every 1,000 GL of river water that passed out to sea (assuming this water had a salinity of 1,000 EC) 560,000 tonnes of salt would be removed from the Murray-Darling Basin each year. This would have significant benefits for domestic, commercial and industrial river users as well as the rivers ecosystems.

Until river flows through the Murray Mouth are increased to a minimum of 1000 GL/year delivered at a minimum of 2,000 ML/day, the system will be reliant on dredging to keep the mouth open and to maintain exchange between the ocean and the Coorong.

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

An open Murray Mouth is the primary driver of salinity levels, particularly those above sea water concentrations, in the Coorong Lagoons. This is also the case for the Murray Mouth Estuary although freshwater inputs are also primary drivers there.

Turbidity and sedimentation (Section 6.2): An open Murray Mouth allows for transport of sediments and turbid water out of the mouth to sea, thereby mitigating turbidity levels in the Estuary and Coorong. Rates of sedimentation in the Coorong are a primary driver of mudflat condition, and thus wader food supplies. Keystone species (Section 6.3):

Ruppia spp. are highly dependent on the openness of the Murray Mouth and suitable conditions deteriorate rapidly if the Murray Mouth closes, or is severely restricted.

Water levels (Section 6.4):

The openness of the Murray Mouth is a key determinant of water levels in the estuarine-saline units because reduced tidal exchange leads to the Coorong being 'pumped' up on each tidal cycle.

Habitat availability (Section 6.5):

An open Murray Mouth is critical for habitat availability particularly access to mudflats by waders and connectivity between the sea and the Coorong for fish passage. If the Murray Mouth is closed or severely restricted, the Ramsar Significant Biological Components will not be supported and continued losses will be seen.

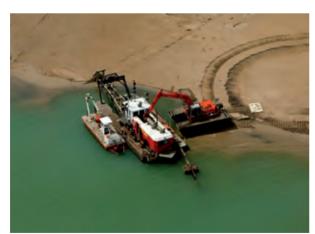
Flows (This section):

Flow through the system from the river to the sea (and from the South Lagoon to the sea) is dependent on an open Murray Mouth allowing discharge of flows or differential head pressures.

Asset Plan 2005 targets

In order to achieve its objective of an open Murray Mouth 100% of the time, the Asset Plan (DWLBC, 2005) has an interim diurnal tidal ratios target of (cf. Victor harbour) of 0.5 at Goolwa and 0.2 at Tauwitcherie.

The plan recognises that without additional water for the site, the dredges will need to continue to operate to achieve these tidal ratios.



Dredging in action

Limit of acceptable change

Murray Mouth to be kept open, preferably by flows discharging from Lake Alexandrina so that the other benefits from these freshwater inflows can be experienced through more natural functioning of the wetland complex. To achieve this, River Murray discharges to the sea need to be increased to a minimum of 1000 GL/year delivered at a minimum rate of 2,000 ML/day. See also LAC recommended in relation to River Murray flows in Section 6.6.2.

The Asset Environmental Management Plan (see above) proposes a diurnal tide ratio (cf. Victor harbour) of 0.5 at Goolwa and 0.2 at Tauwitcherie. Based on current understanding this is considered the absolute minimum required to sustain the ecological character of the Murray Mouth, Estuary and the Coorong.

Traffic light assessment







In terms of maintaining the ecological character of this Ramsar site the current situation with the mouth of the Murray being kept open with dredging is not considered optimal and is likely to lead to on-going degradation of the Ramsar site, albeit slower than if the mouth were closed. While dredging may be essential during current low river flows, it only mimics some of the ecological functions needed. Maintaining the mouth open with natural flows brings with it the full suite of ecological components and processes need to restore the ecological character of the site.

6.6.5 Inflows from the Upper South East Drainage Scheme

Upper South East Drainage Scheme (USEDS) status:

- · drainage works commenced in the South East of South Australia shortly after European settlement in the 1850s (England, 1993)
- · extensive drains were built across the Lower South East agricultural district in the 1960s and 1970s to drain water from the ephemeral and permanent wetlands of the region to the sea to allow for agricultural development of the drained land
- in the late 1990s and early 2000s, open cut drains were dug through the Upper South East agricultural district but rather than discharging directly to sea, these drains discharge to Morella Basin, where they are held prior to regulated release to the South Lagoon via Salt Creek. This water may still ultimately discharge to sea if flows are great enough to induce flow from the southern end of the South Lagoon to the Murray Mouth
- as at 30 September 2005, approximately 200 kilometres of open cut drains had been completed across the Upper South East, together with the assessment and upgrade of existing drains (DWBLC website, March 2005) (See Figure 31 adjacent)
- the Upper South East Drainage Scheme has released water into the South Lagoon five times since 2000, as follows:
- 1. 4,400 ML between August and December 2000 (typically 50ML/d).
- 2. 10,000 ML between October and December 2001 (average 200 ML/d, peak flow of 800 ML/d).
- 3. 5,500 ML between March and May 2003 (average 100 ML/d) (Everingham et al., 2005).
- 4. 10,696 ML between Spring 2003 and June 2004 (approx. 100 ML/d for first few months then 20ML/d).
- 5. 10,237 ML between October 2004 and April 2005 (130 ML/d until December then 20 ML/d).
- Jensen and Nicholson (1993) estimated the normal volume of the Southern Lagoon of the Coorong to vary between 93,000 ML (summer) and 152,000 ML (winter), which places the above release volumes at six to 11% of the total volume (Everingham et al., 2005);

· USEDS inflow water quality is generally better than that in the South Lagoon which receives this water, but salinity and turbidity mitigation impacts in the South Lagoon from these releases are very localised and do not persist long after releases cease (see Sections 6.1 and 6.2 for details).

Comparing the historical and current situations

Prior to European settlement, the South Lagoon was brackish (less saline than the sea) with some areas near the junction with the North Lagoon rising to hypersaline concentrations after periods of low flow (as indicated by diatom assemblages, see Gell and Haynes, 2005). Inflows from freshwater soaks and the water courses to the south-east of the site were the dominant freshwater drivers of the South Lagoon which flowed through the North Lagoon to the Murray Mouth along the preferential central channel described below by the Ngarrindjeri spokesmen and the fishing families (Sections 6.1 and 7).

River Murray inflows were preferentially channelled out of the Murray Mouth under natural hydrological conditions and thus did not influence the southern Coorong directly, except possibly during periods of very high flow when water backed-up at the mouth and was pushed south. The main role of the River Murray in supporting 'Coorong health' is maintenance of an open Murray Mouth and thus connectivity with the Southern Ocean (see Section 6.6.4)

The timing of River Murray floods compared with South East and freshwater soak inputs is difficult to pinpoint, but given that:

- 1. River Murray inflows to the site peaked in later spring to early summer (because of long transitional times from headwaters in NSW and Victoria).
- 2. That inflows from the South East would have also peaked at this time.
- 3. Inputs from freshwater soaks were relatively permanent and peaked in early autumn and winter when sea levels are highest.

It is likely that flows from the South East were consistent and strong enough to prevent significant flows of River Murray water into the Coorong but rather would have added to the river flows being discharged out the mouth.

Ngarrindjeri community

Flows from the South East once flowed along a clear channel of faster moving water in the centre of the lagoons all the way from Salt Creek to the Murray Mouth and would provide flushing flows for the Coorong Lagoons.

Frank Gibbs—Coorong fisherman and hunter from the 1930s to present

Water would rush in down at Salt Creek from the South East. It came like a torrent. It sounded like a train, roaring down. (See Sections 6.1 and 7 for further details).

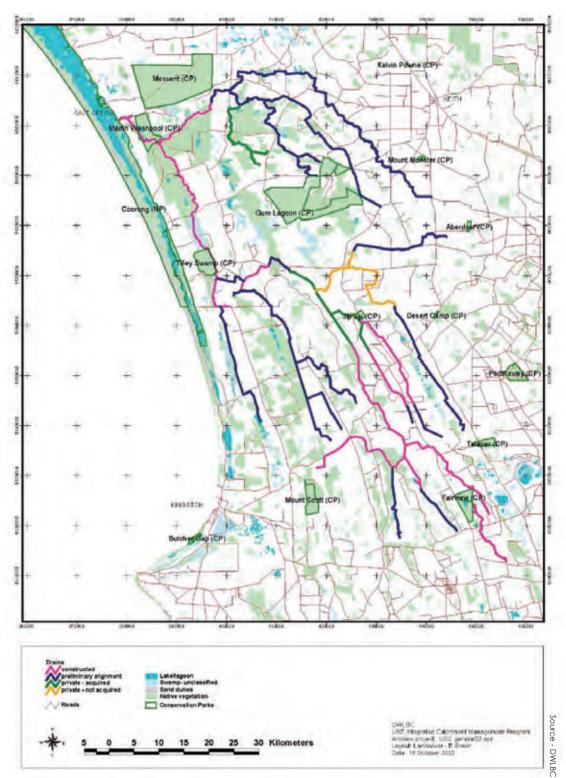


Figure 31 - Upper South East Drainage Scheme

Gell and Haynes (2005) report that diatom analysis of core samples from the Coorong reinforce earlier suggestions by Bourman et al., (2000) that an estimated 70% of River Murray water flowed down the Goolwa Channel to the Murray Mouth under natural hydrological conditions, and that relatively little made its way directly into the Coorong. Gell and Haynes (2005) conclude that 'The influence of River Murray water on the Coorong, is typically very small, and confined to the north-western end of the North Lagoon.' And further that '... it appears more likely that the role of the River Murray has been to maintain the mouth, mostly via flows along the Goolwa Channel, allowing for tidal influx of marine water into the Coorong.' (Gell and Haynes, 2005). Their assessment is also that prior to European settlement, the presence in the core samples of diatom and ostracod taxa that prefer salinities of around 5,000 mg/l indicate that the South Lagoon had regular freshwater input, most likely from the south east.

The reduction in fresh water inflows, coupled with restriction of the Murray Mouth, has seen the South Lagoon converted into a permanently hypersaline system with current salinity concentrations exceeding four times that of sea water. The salinity regime in the South Lagoon in the late 1970s to early 1980s ranged from less than 20 ppt to 80 ppt (approx = 33,000–133,000 EC). Salinities increased after the 1981 mouth closure up to 140 ppt (approx = 230,000 EC) in late summer (Geddes, 2003). Decreased tidal exchange and flushing has also resulted in an increase in turbidity and nutrients in the Southern Lagoon, impacting negatively on submerged vegetation in favour of phytoplankton (Lamontagne et al., 2004).

Inflows from the USEDS are being used to try to mitigate the highly saline and turbid conditions in the South Lagoon. As indicated above, since August 2000, drainage water has been released from a regulated storage basin (Morella Basin) into the South Lagoon of the Coorong at Salt Creek (see Figure 31). Inflows are capped by a release limit of 40 GL/y on a ten-year rolling average to manage reductions in salinity that may be induced in the South Lagoon. To date, flows in the order of 5-15GL/y have been released (see above), with inflow salinities ranging from 15-30,500 mg/L (approx = 23,300 to 47,450 EC), which have only had minor, localised salinity impacts in the southern end of the South Lagoon that do not persist long after releases cease to flow (Everingham et al., 2005).

Paton (2005) notes that while there have been discharges into the South Lagoon from the USEDS via Salt Creek over the last 3-4 years this has not resulted in any long-term reduction of salinity, although he also notes that these

releases have typically been less than 10 GL annually. Paton urges caution in moving to release the predicted flows (or more) from the USEDS when coupled with adequate environmental flows from the River Murray, fearing it may have a 'significant negative effect'. Concerns were also raised by some of the long-term fishing families interviewed as part of this project (see section 7.2). They expressed concern that the USEDS water may be unsuitable because of the increased relative contribution of groundwater (rather than surface water) compared to historic inputs and because it is held for too long in Morella Basin and is 'dead' when it arrives into the Coorong. They are also concerned that because the freshwater soaks have declined in pressure and quality that this will also see the USEDS water being a comparatively high proportion of inflows compared to natural. These are concerns that need to be carefully addressed.

While it is acknowledged that redirected groundwater and surplus surface water from the USEDS may be a source of fresher inflows for the South Lagoon, it needs to be recognised that this water may bring with it risks to the South Lagoon and that at present it also provides ecological benefits at other sites, such as in the watercourses from which it is drained. A risk management approach needs to be taken to ensure other assets are not degraded to provide for the South Lagoon and that community concerns are addressed.

Implications for other primary determinants of ecological character

Salinity (Section 6.1):

The USEDS inflows have the potential to mitigate high salinities in the South Lagoon but to date have not been great enough in volume or duration to induce significant spatial or temporal changes.

Turbidity and sedimentation (Section 6.2): USEDS inflows may mitigate turbidities in the South Lagoon but to date have not been great enough in volume or duration to induce significant spatial or temporal changes. Potential impacts on sedimentation and resuspension are likely to be event-specific and particularly noticeable in high flow periods when turbulence may occur.

Keystone species (Section 6.3):

Ruppia spp. growth and reproduction may be enhanced by USEDS inflows in the area immediately surrounding the Salt Creek—South Lagoon confluence.

Water levels (Section 6.4):

There is no evidence to suggest that USEDS inflows to date have impacted on water levels but these do increase they may limit wader access to mudflats that are inundated to too great a depth.

Habitat availability (Section 6.5):

USEDS inflows have the potential to re-establish estuarine ecosystem components and processes in the southern section of the Coorong, at least in patches around the Salt Creek-South Lagoon confluence.

Flows (This section):

If USEDS inflows become great enough, they may reestablish the flow from the southern end of the Coorong to the Murray Mouth as described by the Ngarrindjeri community (Section 7).

Asset Plan 2005 targets:

The Asset Plan (DWLBC, 2005) does not specify which water will be used to achieve the 20 flow-related interim targets it has, although the Plan does recognise USEDS along with other inputs, such as River Murray flows, as water delivered to the site that can be used to achieve these targets.

Limits of acceptable change:

No LAC is recommended here as the possible use of USEDS water would be aimed primarily at improvements to the salinity, turbidity and keystone Ruppia species in the South Lagoon in particular. The LAC recommended for salinity (Section 6.1.2), turbidity (Section 6.2.2) and keystone plants (Section 6.3.2) are relevant here.

Any escalation of USEDS water discharges should be delivered in a natural seasonal pattern, peaking during late winter/spring. Inter-annual variation with large and smaller flow years would reflect former natural regime, although the related LAC (see above) should be the key driver for decision making.

Traffic light assessment USEDS inflows have the capacity to mitigate salinity and turbidity levels in the South Lagoon especially, and also benefit the keystone Ruppia species, but care needs to be taken to ensure the quality of this water is appropriate and that its delivery is done to mimic more natural flow regimes.

Perspectives of the Ngarrindjeri and long-term stakeholders



The description of ecological character also took into account the advice and insights provided by the Ngarrindjeri indigenous community, and also by a number of long-term fishermen and their families.

Perspectives of Indigenous and other long-term stakeholders

The views expressed below are not necessarily those of the authors of this report. However they do provide an invaluable long-term, oral history 'dataset' of how the Coorong and Lakes wetland system has changed over the past 50-60 years. The opinion voiced most strongly by all those interviewed is that the system today is a far cry from what it was 50 years ago, and even 30 years ago. These are all people with intimate first-hand knowledge of the 'health' of the Coorong and Lakes and their views have been treated accordingly by the authors.

■ 7.1 Ngarrindjeri community perspectives on ecological character

7.1.1 Introduction

As was outlined in Section 2.4, in addition to applying what could be described as a science-based approach to describing the ecological character of the Coorong and Lakes Ramsar site, the project team also recognised the value of seeking the views of the Ngarrindjeri community to gain an appreciation of how they, through centuries of association with the wetland, understood and described its ecological character.

The Ramsar Convention has always recognised cultural connection between Indigenous and local people with their wetland systems; indeed, Ramsar's 'wise use' concept seeks to embody this relationship on a foundation of ecologically sustainable use. As indicated in Section 1, the Ramsar Convention at its most recent global meeting (November 2005) further strengthened its recognition of this linkage with an amendment to the definition of ecological character, such that is now refers to this being '... the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time' (see Section 1). In this context, ecosystem benefits are defined in accordance with the definition of ecosystem services as used by the Millennium Ecosystem Assessment; which includes recognition of so-called 'cultural services', among others (see Appendix B).

At Ramsar's 9th Conference, Resolution IX.21 entitled, 'Taking into account the cultural values of wetlands' was adopted. Significantly it records that the Ramsar signatory governments have agreed '... that in the application of the existing criteria for identifying Wetlands of International Importance, a wetland may also be considered of international importance when, in addition to relevant ecological values, it holds examples of significant cultural values, whether material or non-material, linked to its origin, conservation and/or ecological functioning (Paragraph 12)'. These cultural characteristics are outlined in paragraph 15 of the same resolution as follows:

- 1. Sites which provide a model of wetland wise use, demonstrating the application of traditional knowledge and methods of management and use that maintain the ecological character of the wetland.
- 2. Sites which have exceptional cultural traditions or records of former civilizations that have influenced the ecological character of the wetland.
- 3. Sites where the ecological character of the wetland depends on the interaction with local communities or indigenous peoples.
- 4. Sites where relevant non-material values such as sacred sites are present and their existence is strongly linked with the maintenance of the ecological character of the wetland.

Both of these very recent reflections, and global policy statements, by the Ramsar Convention provide an even stronger mandate for documenting the views of the Ngarrindjeri community in this description of ecological character. The long and close association of the Ngarrindjeri community with this system makes them experts in their own right and, as revealed below, their insights into how the 'health' of this system has changed over recent times is set against a very long 'dataset' of indigenous knowledge.

7.1.2 Ngarrindjeri connection to the Coorong and Lakes

'The Ngarrindjeri vision for Yarluwar-Ruwe Sea Country has always been and remains the same. The waters of the Seas, the Kurangk (Coorong), the Rivers and inland waters are all life giving waters. Our Ancestors taught us how to respect and understand the connections between the lands, waters and beyond. The places where fresh and salt waters mix, are places of creation, where life dwells in abundance and where our Ngaitijes breed. Ngarrindjeri people have rejoiced to see the return to Ngarrindjeri Seas of Kondoli our Whale Ancestors. Some of our Ngaitjies have not returned to our land and waters. We mourn the loss of our friends. We fear for animals, fish, birds and all living things in our seas and water-ways.



Coastal indigenous site

Ngarrindjeri know that our Ngaitjies travel to other parts of this country and overseas countries and Ngaitjies from overseas travel to our lands and waters. And therefore we have a Cultural responsibility to care for each others Ngaitijes, to care for each others Ngaitijes is to care for each others lands and waters.

The land and waters is a living body. We the Ngarrindjeri people are part of its existence. The land and waters must be healthy for the Ngarrindjeri people to be healthy, Ngarrindjeri say if Ruwe (land) dies, the waters die our Ngaitjies (friends) die, and then the Ngarrindjeri will surely die.' (Statement provided by Ngarrindjeri NRM Working Group, December 2005.)

7.1.3 Observations on ecological character and how it has changed

The following has been prepared by Kerri Muller of the project team, based on meetings with members of the Ngarrindjeri NRM Working Group, community members and elders, at the Lower Murray Nungas Club on Wednesday 7th of September and at Coorong Wilderness Lodge on 16th of November 2005. This report was accepted for inclusion in the report as it appears below by George Trevorrow as Chair of the Ngarrindjeri NRM Working Group in January 2006.

All Ngarrindjeri knowledge presented in this report remains the property of the Ngarrindjeri Nation and must not be used without permission from Ngarrindjeri Tendi, Ngarrindjeri Native Title Management Committee and Ngarrindjeri Heritage Committee.

To assist the readers of this report to connect the views of the Ngarrindjeri community with scientific descriptions, in relevant places in the text of the preceding sections, some of the key observations recorded below have been repeated. Where this has occurred the relevant text is shaded yellow in these earlier sections.

THE COORONG Major changes

- · under natural conditions, the ecology of the Coorong would switch from freshwater species (e.g. cod, callop, ducks) during periods of high inflows from the River Murray and the South East to more marine species (e.g. seals, eels, flying fish) during periods of low inflows and/or high seas. This switch happened almost every year
- · the Coorong is being lost from both ends. The lack of flows in the River Murray has closed the Murray Mouth and prevented the Coorong from naturally draining to the sea. The lack of flows from the South East has reduced freshwater inputs to the southern end of the Coorong and has thus reduced the flow-through and hence water quality in both the North and South Lagoons
- flows from the South East used to flow along a clear channel of faster moving water in the centre of the lagoons all the way from Salt Creek to the Murray Mouth and would provide flushing flows for the Coorong Lagoons
- the loss of inflows from the River Murray and South East are also causing an increase in salinity
- a major decline in water quality (primarily silt and salt) began from the late 1960s-early 1970s and by 1975 the system was showing signs of major ecological decline
- · there has been a loss of, or severe decline, in Ngarrindjeri food species (eggs, birds, fish, yabbies)
- swan weeds (Ruppia spp., Lamprothamnium sp.) which provided food and a nursery for fish and birds, have been lost
- siltation of deep holes in the Coorong lagoons with mud from River Murray water has lead to a loss of swan weeds and decreased numbers of fish spawning and birds feeding in the Coorong lagoons
- the number of freshwater soaks (only freshwater available for fauna on the peninsula) has been reduced and in the remaining soaks salinity is increasing and there is decreasing yield
- both terrestrial and aquatic animals are dependent on the Coorong lagoons for food, shelter and water. Emus and kangaroos are often seen swimming across the Coorong channels between the mainland and the peninsula as an example of habitat connection.

Swan Weeds (Ruppia spp., Lamprothamnium sp.)

Swan weeds (Ruppia spp., Lamprothamnium sp.) once formed dense beds across the whole of the Coorong lagoons all the way to Salt Creek. They were the key to the whole system. They are now almost entirely gone with some small patches left at Kungair and Noonameena. The loss of the beds of swan weed from the Coorong



The Ngarrindjeri name for Murray Cod is 'pondi'

lagoons has lead to the loss of fish and birds because they relied on the swan weed for food and as nursery areas. The red berried swan weed (*Lamprothamnium* sp.) has been gone from the Coorong since the late 1970s. It used to feed Coorong mullet and would act as an indicator to Ngarrindjeri fishermen looking to catch the mullet that schools of fish would soon be moving through to eat the herries

The main swan weeds (*Ruppia* spp.) were still abundant in the late 1970s and have only been lost in the last 20 years. Bundles of *Ruppia* sp. would wash up along the shores of the Coorong lagoons after storms, forming small pools behind them. Congolli would become trapped in the bundles of swan weed and in the pools, making them easy to collect. The fish would stay alive and fresh in the bundles of swan weed for days.

Freshwater inputs of silt are important for the growth of the swan weeds because it replenishes the nutrients they need but too much silt kills them. The main cause of the loss of swan weeds is the siltation of the Coorong Lagoons with mud that has come in from the River Murray water. In the South Lagoon, the swan weeds once grew extremely well, even though they were a long way from the River Murray inputs, because of the freshwater inputs from the South East which drained into the Coorong at Salt Creek along natural watercourses. These watercourses have been altered since European settlement so that less water enters the South Lagoon and the water drains to sea, primarily through Drains L and M. This needs to be changed so that the South East water flows into the South Lagoon once again.

Note: historical inflows from South East consistent with Gell and Haynes (2005).

Fish

Hardyhead fish are an important part of the ecosystem, providing food for larger fish and birds. Hardyheads were found throughout the Coorong system all the way down to Salt Creek in the late 1970s but now they are almost gone with only small populations around Pelican Point (no further south than Long Point).

These small fish are declining because of poor water quality, a lack of swan weed and a lack of food. The decreasing mesh size used by commercial fishermen to catch decreasing populations (and thus the decreasing fish sizes of target species like Coorong Mullet), and consequent increased intensity of fishing over short periods, is also reducing small fish numbers and those of juvenile larger fish such as mulloway, bream and flounder.

Yellow-eye Mullet and bream are still around, but in reduced numbers. Fish numbers are thought to have decreased because of the siltation of deep holes and sandy beaches that were important locations for fish breeding and feeding. The fish species that have been lost from the Coorong have not been replaced by other species (despite the marine connection being maintained by the dredges) because there is no food to support any types of fish.

Birds

Bird numbers, both resident and migratory species, have declined dramatically and breeding of all species is very low, even for pelicans and seagulls. Of particular note is the loss of Black Swans and Eastern Curlews. In the 1960s, the water of the Coorong lagoons was black with swans and now they are rarely seen due to the lack of their preferred 'swan weed' food. Today they stay in the freshwater areas around the lakes in order to get food from the submerged plant beds on the fringes of the lakes. Swans are also seen in paddocks getting green feed now because of the lack of swan weed in the Coorong. Similarly, Eastern Curlews were seen every year in large numbers in the Coorong Lagoons but now only a few are seen near the Murray Mouth.

The eggs of many bird species are important food sources for Ngarrindjeri people particularly swans, ducks, seagulls and emu eggs. Snipes are also good food, particularly for teaching children to hunt as they are easily caught. Snipe numbers have dropped dramatically since the 1970s.

The freshwater soaks and inflows to the South Lagoon supported thousands of ducks in the 1950s—so many that the water of the South Lagoon would be black with ducks and there was enough harvest to support a duck processing factory at Salt Creek. These ducks were hunted with large guns mounted on the front of boats to 'blow-up' the enormous flocks rather than shooting at individual birds.

Freshwater soaks

Freshwater soaks and fresh groundwater upwellings are important sources of freshwater to the Coorong lagoons. They are the only source of fresh water for fauna on the Younghusband Peninsula and an important source on the mainland side of the lagoons.

The soaks on the mainland side have become too salty to drink and many have dried up. On the Peninsula, the soaks are still drinkable but the salinity is rising and they are not as plentiful as they were.

Wildlife on the Peninsula are now struggling to get water. Emus and kangaroos on the Peninsula now need to dig down 20cm or more into the soaks for water. This suggests a major decline in the pressures of the soaks as they used to bubble up in summer as the water levels in the lagoons dropped. When the freshwater soaks and upwellings were more active, the water would look like it was 'full of diamonds' as the fresh, cool water would rise in 'bubbles' from the sandy floor. The soaks used to support all the water needs of both the aquatic and terrestrial animals of the Coorong as well as providing the Ngarrindjeri people themselves with drinking water.

A small, orange-coloured fish would lie dormant (as eggs) in the mud of the freshwater soak areas for years at a time waiting for good conditions when they would hatch in great numbers. It is unknown which fish species this was, but it is believed that it is now extinct as they were last seen in the late 1970s. The soaks were also full of long, pink worms and were a good place to find Red-bellied Snakes which are now all but gone due to lack of nursery habitat.

Islands between Lake Alexandrina and the Coorong

The islands are extremely important nurseries particularly because of their location at the junction of the fresh water of the Lakes and the saltier water of the Murray Mouth Estuary.

The Ngarrindjeri have very strong spiritual connection to the islands which feature heavily in their creation and teaching stories. Hindmarsh and Mundoo Islands are now very important nursery areas and represent the last major breeding sites for birds and fish since the late 1970s, when the capacity of the North and South Lagoons to provide nursery environments started to severely decline due to reduced inflows and the 1981 closure of the Murray Mouth. Lake water needs to be allowed to flow over the low points of the islands to allow the wetlands to function properly and cattle grazing needs to be managed to minimise damage to bird nests, fish nurseries and water quality.

THE LAKES

Major changes

- · under natural conditions, the Lakes were always fresh with aquatic plants extending right out into the lakes and providing nurseries for massive populations of freshwater birds, fish and other animals
- freshwater plants and animals now depend on the nurseries around the edge of the lakes (fringing wetlands) for survival

- the lack of flows in the River Murray and grazing of the lakeshores has lead to a major decline in water quality and the muddy water has caused the loss of native plants from the main bodies of the lakes. Muddy water now also enters the Coorong and is filling in deep holes and killing the swan weed
- the loss of inflows from the River Murray is also causing an increase in salinity
- the regulation of the River Murray and the loss of regular floods means that too much pollution is held in the catchment which comes down in big floods and kills the fish in the lakes
- a major decline in water quality (primarily silt and salt) began from the late 1960s-early 1970s and by 1975 the system was showing signs of major ecological decline and could no longer provide fresh drinking water. Swimming in the lakes ended in the 1980s
- · there has been a loss of, or severe decline, in Ngarrindjeri food species particularly large freshwater fish such as Murray Cod which is also an important fish in Ngarrindjeri lore and teaching stories (now locally extinct)
- reeds used for weaving have declined and the on-going use and accumulation of pesticides in reedbeds presents a health risk to Ngarrindjeri weavers who chew the reeds before weaving.

Water quality

The water quality of the Lakes is the major cause for concern. Up until the late 1960s/early 1970s, the waters of both lakes were drinkable without treatment. Ngarrindjeri people kept swimming in Lake Alexandrina up until the mid to late 1980s when blue-green algal blooms became more prevalent and prevented safe swimming. From the late-1970s, all water needed for domestic use was being 'trucked in' to Ngarrindjeri communities and homes. The Lakes are now muddy and polluted from agriculture, cattle grazing and carp feeding and full of algae which makes water in the lakes undrinkable. Swimming is no longer enjoyed because the water is foul-smelling and the muddy water contaminates the skin leaving it smelly and stained yellow.

Nurseries

Ngarrindjeri people refer to freshwater wetlands as 'nurseries' in recognition of the important role these areas play in providing food and shelter for many types of animals, and in particular safe shelter for the young. Submerged plants in these nursery areas are critical for food and shelter for animals and their young.

Reeds

Reeds are very important to Ngarrindjeri people because they provide nursery habitats for many fish, birds and other animals but also as a fibre for basket weaving and other traditional craft.

The main species of reed used for basket weaving is the spiny flat-sedge (Cyperus gymnocaulus). It is favoured over other reed species for weaving because of its strong fibres and the long length of stem (1 to 1.5m lengths are needed). When the reeds are harvested, the Ngarrindjeri are careful to leave behind the growing shoots to ensure the population continues. The abundance of this reed has declined and the length of the stems has reduced due to less variation in water levels, poor water quality, European farming practices (e.g. ploughing and use of herbicides), cattle grazing and trampling and competition with other reeds that prefer stable water levels. The Ngarrindjeri weavers are now subject to health risks if they chew the reeds because of high levels of pesticides used along watercourses.

Yabbies

Yabbies were a plentiful food source up until the 1970s when water quality and flow patterns changed and the effects of cattle trampling the lakeshore became apparent.

Yabbies used to be large, sweet and blue-coloured and now they are very few in number and those that are caught are bad-smelling, muddy and black from living in poorly oxygenated sediments. The shores of the Lakes and the mud banks were once full of holes, some big enough to put a foot into and 'pump' out, bringing the yabbies to the surface. Cattle trampling leads to lakeshore erosion and infilling of these yabbie holes and is a major threat to yabby populations.

Murray crays were also an important source of food for Ngarrindjeri people as well as birds and large fish. They are now thought to be locally extinct and haven't been seen since the late 1970s.

Fish

There has been a widespread loss of large fish particularly Murray Cod, Callop, Blackfish, Tench (introduced) and Catfish since the 1970s. Carp are the only fish that are now caught consistently in the Lakes. Callop appear to have returned in small numbers about 3-4 years ago presumably because the Carp are targeted and fished out of the Lakes. Lots of Carp move through the fish passage in Tauwitcherie Barrage which may be an opportunity to control them.



The leaves of Phragmites australis are also used for basket making

Table 23 - Common, Ngarrindjeri and scientific names for local flora and fauna		
Common name	Ngarrindjeri name	Scientific name
Fish		
All fish	mame	
Murray Cod	pondi	Maccullochella peeli
Catfish	pomeri	Tandanus tandanus
Callop	pilarki	Macquaria ambigua
Bony Bream	tukkeri	Nematalosa erebi
Silver Perch	tjiri, tcheri	Bidyanus bidyanus
Birds		
Black Swan	kungari	
All ducks	woemye	
Plants		
Ribbon weed	pantaruki	Triglochin procerum

Bony Bream are almost gone from the lakes; very few are still seen, whereas they were once plentiful. When the barrage gates have been open in recent years, Bony Bream have been caught in the Coorong but only small ones, the big ones are not caught anymore. Bony Bream are important in Ngarrindjeri lore and the creation story associated with how the Bony Bream was created tells of the need to not be greedy and is an important lesson.

Cattle grazing

The grazing of cattle on the lakeshore is seen as one of the major threats to the ecology of both the Lakes themselves and the Coorong which receives the muddy water from the lakes. Cattle not only impact on the lake edge but also wade or swim out to islands in the lakes to feed on reeds and other water plants. In so doing, the cattle trample nests and eggs, or eat the reeds needed for nesting, and are therefore a major risk to successful breeding for some bird species. This trampling and feeding also causes an increase in the silt entering the Coorong lagoons which kills off the swan weed (Ruppia spp.) and fills in the deep fish holes.

Road cuttings

Road cuttings around and through wetlands associated with Lake Albert are also seen as major threat to habitat connection and water flow through.

■ 7.2 Long-term stakeholders

7.2.1 Introduction

In addition to seeking insights, and an historical perspective of the Coorong and Lakes Ramsar site from the Ngarrindjeri community, three retired or semi-retired fishermen and some of their family members were interviewed for this part of the report by Kerri Muller on 16th and 17th February 2006. Those interviewed were:

- Mr Frank and Mrs Joyce Gibbs and family of Meningie. Coorong fishing family for over 70 years
- Mr Bob Hera-Singh of Meningie. Coorong fishing family since the depression (1940s)
- Mr Neil and Mrs Nancy Ferguson of Kingscote and Woods Well. Long-term resident of the South East of South Australia and fishing family for 30 years.

These people were chosen as a cross-section of fishing families with different periods of exposure to the Coorong environment. Resources limited further investigation, but it is likely that interviewing other families will yield similarly valuable information about other parts of the system including the lakes and tributaries. In undertaking these interviews, open questions about changes over time were asked allowing free flowing conversation and then followup questions regarding the detail surrounding areas of ecological interest such as timing of inflows or changes in fish species assemblages were asked. In the case of Mr Hera-Singh, he had prepared a written summary of his experiences prior to the interview which served as a basis

for the interview. The following captures the memories of these families as it was told and no attempt has been made to seek consensus of views.

The long and close association of these fishing families acts as a sample of the knowledge of the fishing community. As major beneficiaries of the Coorong ecosystem for over 70 years these family members are 'experts' in their own right and their insights into how the health or ecological character of this system has changed over recent times are founded on local fishing and hunting knowledge as well as a respect and deep understanding of the cycles of nature that play out. These observations are often overlooked in scientific descriptions and add to the Ngarrindjeri perspectives (documented in Section 7.1 above) as a significant oral history evidence base. As with the Ngarrindjeri perspectives, in relevant places in the text of the preceding sections, some of the key observations recorded below have been repeated. Where this has occurred the relevant text is shaded yellow in these earlier sections.

Frank Gibbs—Coorong fisher and hunter from the 1930s to the present

Frank lived at Policeman's Point from before the barrages were built until his recent retirement to Meningie. He remembers the following, with prompts from Joyce and his adult children, on 16th February 2006 at his home:

General condition and flows

- the mixing of fresh and salt water is needed, naturally mixing, that's how it all works
- timber grew all the way down and people would sell the timber. It grew all the way from the Murray Mouth to Pelican Point and there was enough to cut and sell back then
- wherever we would see bulrushes we would dig and there would be water. All along the ocean dunes there was water if you knew how to look for it. It was fresh, fresher than rain water, or at least as fresh
- water would rush in down at Salt Creek from the South East. We once had to move a Model T-Ford out of a swamp at Martins Washpool because we heard the water coming and we had to get to high ground. It came like a torrent. It sounded like a train, roaring down
- the freshwater springs would run a lot of water in, easily as much as Salt Creek. It was really fresh
- the three big problems are the barrages, the springs not running and no water coming in at Salt Creek.
 This is what changed the system
- it was a beautiful place, I still think it's beautiful even though it's smelly water now. It just needs attention

- Salt Creek was a lot of water, naturally running in, and the soaks would easily add up to as much again.
 If you dig (about 30cm down) you can still see the (ground)water flowing
- loss of the water from the South East has done more damage than anything else to this end of the Coorong
- the Coorong always looked clear after big flows.
 Water works with the wind. In with winds, out with winds. It's different in winter and summer
- we need a trickle of water all the time. The springs helped a lot with that, always running. We need the barrages more open to move more water out
- coral bombies are growing everywhere, on all the old fences and sunken bottles.

Fish

- bream haven't been seen in spawning condition down at Salt Creek for over 70 years
- mullet would always spawn around Easter time, but not since the barrages were installed
- the Murray Mouth was blue and clear, you could see schools of fish. We would get 3-4 tonnes of fish per drag, right down to Salt Creek. It was good fishing
- 1956 was a good year for Coorong fish. The flood freshened the Coorong for a good few years. Silver Bream came with the flood
- it was so hard to hold those nets as a child, there were so many fish in them
- there were congollis by the thousands, but they are gone now as are the tench, the Black Bream and the tcheri (Ngarrindjeri name for Silver Perch, freshwater fish)
- we never had outboards, just oars, and one night we aot 360 flounder with spears
- the white bait (hardyheads) have gone from the Coorong too, we don't see them anymore. We always had Bony Bream too
- carp and redfin are now competing in the Lakes, eating the bait fish
- now, the mullet are all skinny and we don't see bream in the creeks anymore
- we would get up on the crows nest of the boat and spot black patches of mulloway. There were 20-30lb fish right up to Salt Creek and behind Salt Creek Island which was very deep back then. Those deep holes were breeding areas for fish and always held mulloway.

Rirds

- there were masses of birds, thousands of them, ducks and swans mostly all the way to Salt Creek; a place that also used to be the best place to catch Mulloway and bream. They would teem around Salt Creek Island
- it was a paradise for ducks and swans, paradise
- more than 30 freshwater springs would run off the Hummocks (Younghusband Peninsula) into the Coorong. Every one running into the Coorong, just like you see on Fraser Island. There were so many ducks and swans feeding on the wire weed that it kept the channels from these springs open and flowing
- the soaks (springs) are very important. So many of them ran in and there were so many ducks, guns were set up on a trench alongside the channel with strings. Pull the strings, shoot down the channels (channels running from the springs into the Coorong). It was black with ducks. Made a living from ducks and from mulloway and mullet in the lakes
- we used to hear swans flying all night—it kept us awake
- the causeway near the Lake (Albert) always had good ducks and swan nests in the reeds there
- swans used to feed in groups of 80-90. We could see the schools of whitebait. We cursed wire weed because we would get balls of it stuck in the nets and clog them. (Frank laughs and shakes his head in irony)
- · Princes Soak, Tun Tun and Bul Bul were all good, but the springs were right through and they were places to shoot ducks.

Aquatic plants

- wire weed was everywhere, thick. It had red berries on it and the ducks loved it, fed on it. It was very thick all the way from Pelican Point to Salt Creek
- I've seen a little bit of wire weed in the last 12 months near Rabbit Island
- wire weed died out because of no flows from the South East, the springs and the barrages. Wire weed will bring back the fish and birds but there's no oxvaen now
- · the wire weed is what we need, water at right temperature and clear. The birds and fish will come they are not stupid. Emus dig to reach water and keep alive. Ducks and swans know where wire weed is, if we get it back they will come.

Bob Hera-Singh—Coorong fisher and hunter from the 1940s to the present

Bob's written notes

- my first recollection of the Coorong was when I was three years old living in a hut made from 44 gal tar drums with hessian walls
- my father walked off a farm he was share-farming during the depression. Decided to go fishing
- we moved up and down the Coorong with our family, fishing, erecting a shack. Fish till they shifted. Then we got an old farm house to rent on the Coorong (Pickards) where the family stayed
- I was in the boat fishing at a very early age and spent all my time with Dad fishing, trapping, and hunting, with no fridges, only enough ice for fish (which came from Adelaide packed in a bag of sawdust)
- we would get a fortnights correspondence schooling which we did in two days then back to the Coorong, up until I turned 20 (getting a Government job, for PMG), but I often fished after work, most weekends, and certainly all the holidays, during this time my father and three brothers all held fishing licenses
- my association with the Coorong has been for 60-odd years and I have seen it choking up very slowly, areas where we drag netted, set nets over large sandy bays are now covered with coral
- deteriorating water quantities and qualities from both ends will certainly put an end to bird life and fishing along with the many other users of the Coorong.

Coorong problems

- 1. Changes include deterioration of water quality in the South Lagoon due to no river flows to recharge the lagoons to be fish sustainable. (Also from) diverting the natural flows of water from the South East that came over ground through a chain of swamps from Kingston and suspect underground from there as well. This vast amount of water now empties into the sea by various drains. The new drains recently dug only bring a trickle of salty water into the Coorong would take a minimum of three wet years to gauge success of this drain.
- 2. Clearly in the 1940-1970 era fishing was thriving, plenty of mullet. Fish that like good quality water (e.g. flounder, bream, mulloway, congolli) were caught in very large numbers and were trucked to Melbourne Markets. No flounder, bream or mulloway have been caught in recent years. Mullet numbers have tapered off catching less and less. The last three years none whatsoever due to poor water quality and lack of oxygen in water*. Even the weed has stopped growing. We have a family shack by the South Lagoon and visit it very regularly trying to catch fish but to no avail.

- 3. It has only been in the last 6-12 months that the bird life has reappeared (in the South Lagoon) probably due to: high seas and flooding of flats near the Mouth early in the season; high influx of visitors to Mouth area (now with boat access) and most of all the appearance of the brine shrimp which provides a food chain. Note there are no fish eating birds around except the gulls which are eating the brine shrimp.
- 4. A bottle neck situation has occurred in the Narrows. Roughly from the end of Hacks Point to the Needles, the water is very shallow and no fish will enter this to travel to the South Lagoon. In summer when the water level is low it empties (from the South Lagoon) into the North Lagoon but as soon as winter comes and brings fresh water in it pushes the same poor quality water back into the South Lagoon. So it never gets flushed out.

*Data to back up these historical records is available in terms of fish catch data (later provided by Bob for 1976 to 1984). Bob notes that important statistics can be supplied by fishermen on bird numbers and movements, gathered daily (vital importance to Ramsar monitoring).

Comments from interview—17th February 2006 at Bob's home

The above notes acted as a basis to the interview with questions centred on gaining clarity and expanding on the above:

General condition and flows

- the river flows have also dropped. There is not enough water now to push into the South Lagoon and sweeten the Coorong. From Lake Albert to the Murray Mouth can be sweetened if flows are timed with high winds and moon tides
- Coorong was always sweetened by high River Murray flows. It could stand a few years without big flows but it needed regular sweetening
- · fish and birds go hand in glove. Birdlife need good water, fish need good water
- · boating is also impacted. Needles is now the furtherest south you can go. During winter seas the Coorong is a foot higher, which allows for passage of boats
- coral is a major obstruction. Channels are still there and deep but you need to know what's happening
- the last 3-5 years has been a real down turn. We need a trickle flow out the Mouth all the time that makes sense for the Mouth but we also need big flows which are important to sweeten the Coorong
- (Water from) the South East can also be a big influx,

- but there are lots of dams holding back good water
- land clearance and groundwater are big issues for the South Lagoon. Princes Soak was important. Every mile or so there were discharge points they would change with changes in groundwater levels
- the boobiallas had natural 'knees' that we would use as boat braces. We ran out of wattle at one point but the birds sitting on telegraph wires brought in more, introduced from the South East along the wires
- · once the cattle went the boobiallas came back
- sandhills around the big soaks like 'Tun Tun' were bare. They often had middens and no bushes between the Coorong and the beach. There was lots of petrified wood on the Peninsula, but it has all become overgrown
- at the Murray Mouth end there were less vegetated dunes and lots of bare sand hills from cutting timber and grazing
- land clearance of the mainland has lead to dryland salinity as well and that has had a big impact, lifting the water table at the Salt Creek end. Perhaps the water is being held too long in Morella Basin as well. which 'poisons' it. The trickle from the South East is less than the soaks would have been on their own.

Fish

- · water is now too bad for hardyheads
- bream and flounder both spawn in half strength sea water, so they need the Coorong sweeter to breed. Both require good water
- we used to hook flounder and could get wheat bags full at a time and fish until you ran out of bait
- Sea Bream haven't been seen for about 20 years. The odd time you can still get flounder, but in the early 1950s and 1970s they were very prolific
- there are plenty of mullet at times, but they are not getting past the Needles. South of there the water looks the colour of red bricks. Something in the water is making it pink or red. It could be brine shrimp but they won't last long. Seagulls have been feeding on brine shrimp but no other fish eating birds are
- mullet are scarce around Easter when everyone wants to fish. They spawn in the warmer months, around February
- · we used to get ten boxes per day of Congolli, with about 30kg per box, and the salmon were really thick. In mid-summer, we always had fish, but in the last 20 years we don't catch fish in summer anymore. The water is too hot maybe, except when there are big pushes of River Murray water. Then there are fish in the South Lagoon
- estuarine fish spawning needs big flows

mulloway spawn on the edge of the continental shelf and then drift into the coast so by the time they get to the Coorong they are big enough to fend for themselves. Adult mulloway would move in in midto-late summer when the water was warm and lots of feed around, especially if the barrages were also open. The bigger mulloway come in to wash in fresh water to clean up fungus under their scales and other marine parasites. Other fish do it too. It keeps them healthy.

Birds

- Swan Island used to be covered in swan nests. The last swan nests on the Coorong. Haven't nested there for 12 years. There are still a few swans breeding around the Lakes but nowhere near what there were and none on the Coorong. If you go south of Pelican Point you might see 50 pelicans on a good day, there used to be thousands
- right up until a few years ago, pelicans were still breeding in good numbers on Pelican Island but now there are very few and they are unlikely to successfully fledge. Seagulls also used to nest so densely on the islands that you couldn't walk for eggs. We used to eat swan and seagull eggs as tucker. One swan egg was about 6 chook eggs. My Mum used to bake cakes with them and split them up
- we used to be given two shot cartridges and told by Dad to get six ducks. It taught us to be patient and shot was valuable during the Depression. We only shot what we needed, no fridges and freezers. Not like these days, people take too much. It was easy to get six ducks with two shots because we would get close and when the ducks took off they would blot out the sun there were so many
- mountain ducks would stay at the freshwater soaks all day but teal would only come and drink at change of light (dawn and dusk)
- freshwater soaks would teem with ducks and swans. It was clean clear water in the Coorong. Kurrawong, a property south of Salt Creek. Out from there were 10-foot deep holes with water flowing in from the South East, underground. It's now dry and grazed
- there were clouds of grebes until 3-4 years ago too
- 1–2,000 shags would dive at once on a school of fish, particularly when the wind stirred up the mud, plants and fish. The numbers of seagulls and shags increased because of lack of predators
- I used to shoot at pelicans to scare them off (the nets), now I am building them roosts
- the 1956 flood cut off the main road at McGrath's Flat and the birdlife was very thick, mainly ducks. The ducks still come down to the Coorong during the



The Ngarrindjeri name for Black Swan is 'kungari'

- day to eat brine shrimp. I've watched them through binoculars. Chestnut teal, they are not timid, but we don't see swans
- pelicans now are concentrated around the fishing huts where they know they will get a feed. They treat my son like a god when he comes in with a catch. They follow boats to get the by-catch. We keep it for them rather than putting it overboard where it would just feed the billions of coral crabs and big Stingrays.

Aquatic plants

- the water weeds were so thick. Blanket weed would come to the top and was green. It's still around here and there. Wire weed was what the birds thrived on. Haven't sent that for a long time. Sometimes bits of plant get washed up that look like young wire weed, but I don't see it growing anywhere anymore
- we used to row. There were no motors at first and then
 ones with long props. My job was to jump off the side
 and pull off the wire weed from the prop. We used to
 get mulloway by pushing apart the wire weed with
 our oars and fishing below the holes. We would get
 big mulloway. The mulloway from Stoney Well/Woods
 Well to Salt Creek and around the islands were always
 fatter and heavier for their length than ones from the
 ocean. They got fat living under the wire weed
- blanket weeds can still be seen in front of Tauwitcherie barrage, near Stoney Well and Noonamena Road.

Neil and Nancy Ferguson—long-term residents of South East, Coorong fishing 30 years

Interview conducted at Neil and Nancy's shack at Woods Well on the shores of the South Lagoon on 17th February 2006.

General condition and flows

- if we fix the bottom end of the Coorong, the rest will be fixed along the way
- if they don't do something with this soon, it will all be gone
- discussions centred around water quality data
 collected by Bruce Nicholson of Water Data Services
 in March 2003 from Woods Well to Salt Creek. Neil
 assisted because the waters are treacherous; they
 are full of coral reefs. These data show salinities in the
 range of 147,000 to 164,800 EC, thermal stratification,
 decreasing dissolved oxygen with water depth to as
 low as 2.25 mg/L in the benthic waters and 0.25 mg/l
 at the bottom of the profile and turbidity in the range
 of 13.12 to 22.41 NTU. These data were collected
 for DWBLC

- in summer, South East winds push water north and tides are one metre lower. Then around Easter Coorong water rises before the rains because the higher tides push groundwater out of the dunes and into the Coorong
- but now there is no oxygen in the water. It's not so much the salt as the silt that's the big problem. This is the first year we have had brine shrimp
- the USEDS water is an unnatural mix too little surface water now and too much salty groundwater. The water goes green, held back too long. It needs to be freshened up and pushed up from Bakers. Water put in at Salt Creek needs to be good because it cant get out
- there is no way out for the silt and salt, so if bad water comes in from South East you're pushing one problem onto another
- same story as Lake George: Lake George and Drain M are a good comparison to the South Lagoon and Salt Creek drains
- the oxygen runs out down the bottom and needs to be freshened
- coral is a problem growing on old car wrecks, underwater
- the problem with the Coorong is the lack of good flows from South East, the water that does come is dead and the lack of flows from the north, the River Murray.

Fish

- the poor water is creeping north and no fish have been caught south of Noonameena this year. There have been no fish since 2003, about the same time as the water was let in from the South East Drainage Scheme. The water was bad, poisoned because it sat too long and is salty groundwater anyway. Fish don't grow in that water so it shouldn't go into the Coorong. That water is dead. We need healthy water
- about 10 years ago mullet were caught in August for about three weeks down at Salt Creek but not anymore
- the swamps of the South East don't support fish any more, the redfin have died out
- big flounder have not been seen down here since the 1970s. A few little ones were around about eight years ago
- about the time of the March 2003 sampling (see above) there were lots of dead whitebait (hardyheads) on the shore
- the taste of the fish has changed too. Coorong mullet is muddy now, we don't buy it anymore, tastes better from the sea now.

Birds

- · ducks still sit around the soaks but they are becoming foul smelling and full of black mud
- the rocky shore lines have been covered with a foul smelling black mud and silt with white crust on it only in the last few years. We used to play golf on it. When the water level was down the rocks were so clean
- the pelicans are still breeding on Pelican Island, but there are not many at all now and they have to fly to the Lakes to get a feed, so lots of the young ones are dying from lack of food. Not many are making it now
- 2003 was the major turning point. Before then pelicans would move around here in mobs of 40-50. Oystercatchers stopped nesting about two years ago too, no feed.

Aquatic plants:

- Widgeon weed (a type of samphire) has little seeds that look like Phalaris grass seeds. The ducks love them. It grows where the water is still the freshest. White seed, long and thin like a carrot seed but longer. Ducks thrive on it. They sieve the seeds from the mud
- the other weed grows underwater and that hasn't been around for the last few years. It dies off in September and floats around.



The Ngarrindjeri name for all ducks is 'woemye'

Consolidated limits of acceptable change, 'traffic light' assessments and conclusions



To enable an overall appreciation of the Report, all its assessments and conclusions related to the primary determinants of ecological character are presented in this section. Much of the information is tabulated for ease of reference.

■ Consolidated limits of acceptable change, traffic light assessment and conclusions

In Sections 4, 5 and 6 of this report various elements of the description of ecological character have been presented. These have also included numerous quotes from the oral history perspectives of the Ngarrindjeri community and the three long-time fishermen and their families who were consulted as part of the project (see Section 7).

To assist the reader with gaining a complete overview of these conclusions, Table 25 assembles the limits of acceptable change and rationale statements from these earlier sections.

Also to assist readers with appreciating the full scope of the conclusions of this report, the traffic light assessments applied throughout have been consolidated in Table 26.

The order of presentation in the tables begins (appropriately) with what in this report are called the primary determinants of ecological character, and these are then followed by consideration of the twenty-three different wetland types found in the system and then, finally, the Ramsar Significant Biological Components.



Fish in the Coorong area have depleted in numbers

8.1 Challenges presented by this project

The Tender documentation for this project indicated that the outcome being sought was, 'a comprehensive description of the ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar site.' In taking-on this task, the project team did not foresee several aspects of the project which have proven very challenging, and which it is felt should be conveyed through this report.

8.1.1 Determining the 'given point in time' for this description

As foreshadowed in Section 2.3, while the expectation of the project team at the commencement of this study was that the date of Ramsar designation, November 1985, was the logical timeframe around which to base this description of ecological character, the strongly vocalised view from a number of those that participated in the consultative workshops (in December 2005) was that this was inappropriate. Their rationale being that the site had been in ecological decline for at least 20-30 years prior to the Ramsar listing and by using 1985 as the benchmark condition, the project team would be 'setting the bar' too low when defining ecological character and its associated limits of acceptable change.

While the issue of the current condition of the Ramsar site is addressed below, suffice it to say here that the project team formed the view, based on its own investigations, and discussions with the Indigenous and other long-term stakeholders (see Section 7 and below), that there is good evidence to support the view that the 1985 condition was a degraded one, certainly much degraded from what the system was during the youth of some of those consulted. To gain a clearer understanding of this former condition, the reader is urged to consult Section 7 of this report. Some extracts from that section are provided below along with some rather eerily accurate words from the publication The Coorong—past, present and future by Dr. John Nove in 1973

The Ngarrindjeri community perspectives on the overall health of the Coorong and Lakes (see Section 7.1) A major decline in water quality (primarily silt and salt) began from the late 1960s-early 1970s and by 1975 the system was showing signs of major ecological decline.

The water quality of the lakes is the major cause for concern. Up until the late 1960s-early 1970s, the waters of both lakes were drinkable without treatment. Ngarrindjeri people kept swimming in Lake Alexandrina up until the mid to late 1980s when blue-green algal blooms became more prevalent and prevented safe swimming. From the late-1970s, all water needed for domestic use was being 'trucked in' to Ngarrindjeri communities and homes. The lakes are now muddy and polluted from agriculture, cattle grazing and carp feeding, and full of algae which makes water in the lakes undrinkable. Swimming is no longer enjoyed because the water is foul-smelling and the muddy water contaminates the skin leaving it smelly and stained yellow.

Some perspective of long-time fishermen and their families (see Section 7.2)

The Coorong was always sweetened by high River Murray flows. It could stand a few years without big flows but it needed regular sweetening (Bob Hera-Singh—Coorong fisher and hunter from the 1940s to the present).

If they don't do something with this soon, it will all be gone (Neil and Nancy Ferguson—long-term residents of south-east, Coorong fishing 30 years).

The wire weed is what we need, water at right temperature and clear. The birds and fish will come, they are not stupid. Emus dig to reach water and keep alive. Ducks and swans know where wire weed is, if we get it back they will come (Frank Gibbs—Coorong fisher and hunter from the 1930s to the present).

And from Dr. B. John Noye, 1973 in The Coorong—past, present and future

'It is my firm belief that stagnation has been slowly occurring in South Lagoon, due to man-made changes which occurred at each end of the Coorong about the 1940's (Barrages at Murray Mouth end and SE Drainage scheme and land clearance at southern end -Ed.). Fortunately, Nature has given us a respite in the form of the present River Murray floods which will dilute and flush out some of the poor quality water which has accumulated at the south-eastern end of these lagoons. We must make full use of our good fortune and commence a complete interdisciplinary investigation at once, to determine the true situation and the necessary action to be taken. It would be a disaster if another unique part of our Australian heritage were to be lost forever because we make no effort to convince those who spend our money on our behalf, that a tiny measure of this should be used to ensure that the Coorong deteriorates no further."

It is appreciated that in contrast to the views of the Coorong community, from a legal perspective, those applying the Commonwealth EPBC Act may have no alternative than to use the condition of the site as it was on 1 November 1985 as its benchmark, rather than an earlier time when the system was in better condition.

In describing the ecological character of the site the authors were cognisant of these two differing perspectives. It should be acknowledged that laws and community aspirations do not always align and this may well be a case in point. The ecological character benchmarks recommended in this report (and as summarised in Table 25) will be described by some as 'aspirational' and by others as 'overly conservative'. Either way, if they are acted on, it is the view of the authors that the incremental decline in the 'health' of this system, which the evidence suggests began in the 1950s, should plateau and slowly turn around. How far along that pathway of recovery back to the condition it once was will be a decision taken by high level decisions makers, as will be the rate at which that recovery takes place.

8.1.2 Current condition of the Coorong and Lakes Ramsar Wetland

At the beginning of this study it was not expected that the project team would feel compelled to articulate its view on the current condition of the site. As indicated above, the expectation was that November 1985 was the benchmark date. However, throughout the project, it became evident as the information was drawn together, that the ecological character has altered so much, and that these changes are accelerating and rapidly approaching the point of irreversible change in some parts of the system, that it would be irresponsible of the authors not to express their concerns.

Every effort has been made to make the recommended limits of acceptable change provided throughout this report (and summarised in Table 25—concept explained in Figure 4 on page 9) robust and based on historical data and sound ecology. For the six primary determinants of ecological character (see Section 6), all of those where an LAC was recommended are outside their limits, and in many cases not by a small margin. Simply put, this is a system that is under significant stress, and has been for some years.

Reference to Table 26 presenting the consolidated traffic light assessments supports this point of view also. The traffic light assessments, designed here to provide an overview of the risk, threat or vulnerability of the various system attributes examined by this study breakdown as shown by Table 24, Figure 5 on page 11 explains these categories, but in simple terms green means 'nothing to worry about' and red means the threats 'are present and acting in a seriously detrimental way'. Of the 54 traffic lights assigned to key functions and attributes of this system by this project, nearly half are 'red' and one-third 'amber', leaving less than a quarter of them in the 'yellow' or 'green' categories.

The traffic lights are in many ways analogous with the dials and gauges in the cockpit of a 767 aircraft; they provide information on how well the vital functions of that highly sophisticated piece of technology are performing. For this complex wetland system they do the same thing. Red traffic lights are those that would raise alarm for the pilot, as they should for the managers of this site and the State and commonwealth Governments.

These conclusions will not surprise those that know the Coorong and Lakes well and have had long associations with it; a point made above in Section 8.1.1. However, this is the first attempt to document a comprehensive understanding of ecological character, and it has confirmed the long-held views of these local stakeholder and researchers that the system has been in noticeable decline for at least 40-50 years and possibly for as long as 100 years (see Sim and Muller, 2005).

Significantly, from the perspective of the obligation both the Australian and South Australian Governments have under the Ramsar Convention to retain the ecological character of the site, it is clear that these incremental changes have been accelerated and exacerbated by water extractions that are too high for the system to be able to sustain itself through the recent drought conditions, as it would have under natural conditions. The drought didn't cause the change in ecological character, it simply brought it forward.

It is true that the changes to the ecological character of the site are proceeding faster in some parts than others. As indicated in Sections 6.3 and 6.5, the Coorong lagoons, once a predominantly estuarine environment with some hyper-saline portions, particularly favoured by wading birds and with a great diversity of fish species, are rapidly transforming into more and more turbid and saline systems. This is seeing the rapid loss of the keystone plants species (Ruppia spp.) and with it declines in much of the biota and habitats of the Coorong that justified Ramsar listing.

Table 24 - Summary of traffic light ratings				
Traffic light category	Tally from Table 26	% of total	% of total	
Red	24	45.3		
Amber	18	32.1	77.4	
Yellow	9	17.0		
Green	3	5.6	22.6	
Total	54	100	100	

To summarise the situation, the Coorong ecosystem is becoming increasingly simplified as the loss of Ruppia continues; this being a consequence of escalating salinities, increasingly turbid waters and inappropriate water levels. All of these are essentially determined by River Murray flows into and through the system, and historically, by flows from the south-east of South Australia. Algae and brine shrimp, more typical of a marine environment, have become dominant biota in the South Lagoon and the southern portion of the North Lagoon since spring 2005. The loss of Ruppia, the keystone aquatic plant of this part of the Ramsar site, and with it the small hardyhead fish, is signalling a significant change in how the Coorong functions and the habitats it has to offer.

The components and processes of the estuarine Coorong ecosystem are now only supported in a 30km stretch from the Goolwa barrages to Pelican Point, which represents less than 25% of the original estuarine ecosystem area. All of this indicates that a comprehensive shift in ecological character is underway. Without significant and urgent intervention it may prove irreversible. For this reason, the authors are recommending below that the Coorong lagoons and Murray Mouth be proposed for listing as a critically endangered ecological community under the Commonwealth EPBC Act.

The changes to the lakes environments are proceeding at a slower pace, but, like the Coorong, they are being negatively impacted upon by sediments and increasing salinity and turbidity. Again, in simple terms, the lack of flows is seeing the whole system become a sink for salt and silt. This is also a direct consequence of the reduced inflows from the River Murray that once provided regular freshening flows that also discharged salt and silt out to sea through the Murray Mouth.

Perhaps of greatest concern is that the overall health of the system is in decline; a view indicated by the 'traffic lights' and reinforced by Dr Mike Geddes (among others) who has studied this wetland system since before it was Ramsar listed. After his field assessment of the ecological health of the North and South Lagoons of the Coorong in July 2004, he wrote as follows:

Almost all of the species of plants and animals collected in 2003 and in the 1980s were collected in this survey. However, the plants and animals in the Coorong showed lower diversity, restricted distribution and lower abundances than had been observed in the 1980s. The biota of the Coorong is and has been under great salinity stress and populations have

decreased in numbers and retreated to small, more favourable areas, especially in the Murray Mouth. In the South Lagoon the biota was extremely limited. Only small patches of R. tuberosa were seen, small numbers of hardyhead fish seined and small numbers of chironomids collected. No micro-crustaceans were seen. This is the poorest biodiversity and abundance record for the South Lagoon. The occurrence of the brine shrimp Pararternia zietziana reflects the extremely high salinities reached in the South Lagoon in 2003/04.

Overall, the ecological health of the Coorong in July 2004 was very poor. It is likely that the biodiversity of plants and macro-invertebrates was lower than in 2003. The poor ecological health indicated by the plants and invertebrates will mean the environment is sub-optimal for larger animals, especially birds and fish. The aquatic birds of the Coorong depend on its productivity for their foraging (Paton 2002). Waders, ducks and piscivorous birds would all be adversely affected by the poor ecological health of the Coorong. Populations of commercial and small native fish will also be adversely affected. (Geddes, 2005)

In Section 6.6.2, it was observed that in terms of flows to assist restoring the ecological character of the system, there were five primary requirements as follows:

- 1. Sufficient water to keep the Murray Mouth open without dredging.
- 2. Increased frequency of medium-sized or better floods to flush and 'freshen' the system.
- 3. Reduced duration and frequency of no-flow periods which are extremely detrimental to the system.
- 4. Sufficient water to optimally operate the fishways and provide habitat connectivity between fresh, estuarine and saline units.
- 5. The opportunity to have the so-named here 'Ramsar site contingency allocation' water available to allow managers scope for strategic on-site water allocations to benefit the Ramsar Significant Biological Components.

Keeping the Murray Mouth open at all times with barrage releases rather than dredging should be the first target to recovering the ecological character (see Section 6.6.2 and 6.6.4) of this site. To this end, a secure allocation of at least 2,000 ML/day needs to be made for the Murray Mouth at least during surplus flow periods to allow for the dredges to be intermittently stopped whilst river flows are great enough to keep the mouth open. This allocation should then build up over time to the point that dredges are no longer needed. It is noted that a simplistic costbenefit analysis, that examines financial considerations

only, may indicate that retaining the dredges is a preferred option over securing the water necessary to keep the mouth open with flows. However, if the value of the full suite of ecosystem and other benefits that would come from the flow option were factored in, then it should be the clearly preferred approach. The CSIRO are currently investigating these more difficult to quantify values through their Healthy Country Flagship Program and the Coorong, Lakes and Murray Mouth Ecology Cluster program. This data should be available in 2006 to undertake a better, triple bottom line-based cost-benefit analysis of dredging operations.

Operation of the fishways and reductions in duration and frequency of no-flow periods can be effectively achieved with water that is currently available at the site in most years. This can be done by improving river and barrage operations and utilisation of storages, such as Lake Victoria, to mimic higher flows or extend flow events.

This system formed in response to variability of flows (see several comments from stakeholder in Section 7). That variability has now been lost, in large part, and the once reasonably frequent medium to large floods that flushed and freshened the system are becoming less and less frequent through the combined impacts of upstream water diversions and climate. It will only be with the return of sufficient flows to the river, that medium-sized floods can be 'manufactured' by the river managers through the topping up of the more frequent small-floods. For recovering the ecological character of this site, the frequency of medium-sized floods (20,000–80,000 ML/day) needs to be at least once every five years and flows over 100,000 ML/day need to occur at least once in every ten years to 'reset' the system.



Dredging machinery at the Murray Mouth

It is also clear from historical accounts (see Section 7), and indicated by recent core sampling and diatom analysis (Gell and Haynes, 2005), that in the past the South Lagoon of the Coorong received significant natural flows from the South East region. These served to help freshen that end of the system, considering that it is 140 kilometres from the Murray Mouth. According to the Ngarrindjeri spokesmen (see Section 7.1), flows from the South East used to flow along a clear channel of faster moving water in the centre of the lagoons all the way from Salt Creek to the Murray Mouth and would provide flushing flows for the Coorong Lagoons. These flows are no longer provided. The construction of the Upper South East Drainage Scheme now regulates these flows and discharges only small volumes into the South Lagoon based on a ten year rolling average. Some Coorong stakeholders have expressed concerns about the impact this water may have on the ecology of the southern end of the system given that it is 'drainage' water and comes from an agriculture zone with significant dryland salinity issues. Any attempt to use this water to try to reduce the hyper-salinity being experienced in the South Lagoon will need to ensure the water is of a suitable quality. These issues are being investigated by the Department of Water, Land and Biodiversity Conservation at present (see Everingham et al., 2005).

The conclusions are therefore that the Coorong portions of the Ramsar site are critically endangered and that there are clear signs of concern that the lakes will follow the same pathway without significant management intervention. It is the recommendation of the authors that, in accordance with Article 3.2 of the Ramsar Convention, these findings be communicated to the Secretariat of the Convention, and, that consideration be given to including the site onto Ramsar's Montreux Record of sites where change in ecological character is occurring, or has taken place.

8.1.3 Urgent need for a data 'warehouse'

In order to build a comprehensive description of the site it was necessary to consult widely, and most notably, with a number of State Government Agencies, many of which have direct management roles with aspects of the Coorong and Lakes. While high levels of cooperation were experienced, it remained a major impediment to this project from the outset (and even until its end) that much of the data relating to the ecological character of the site is housed across these agencies, it is not simple to access, not well integrated, or even well known among the day-to-day practitioners involved with this site. Our strong recommendation is that a full inventory of these data holdings, and those held by researchers and the

Murray-Darling Basin Commission, be conducted as soon as possible with a view to building an integrated and comprehensive data 'warehouse' for the Coorong and Lakes. This will serve several purposes. It will assist those that take on followup work to this report and will help to identify strengths and weaknesses in the current data gathering approaches being used. It may also facilitate more integrated management actions among the various arms of government.

8.1.4 Building on and refining the conclusions of this report

Related to the foregoing section, it is the view of the authors that this report would be best published in a loose-leaf binder so that as new data and findings come forward they can be incorporated into this description of ecological character through updated sections. Like a plan of management, this report should be considered 'adaptive' and be able to accommodate new information as it is presented. It is also true that throughout the report many 'knowledge gaps' have been identified with the indication that in the future, investigations of these will lead to the strengthening or development of limits of acceptable change. The report needs to be able to evolve and improve as further investigations are completed.

8.1.5 Merging of Asset Plan and Ramsar Plan processes

Another issue that provided some challenges for the project team (but did also assist in other ways) is the parallel processes in place for planning how to manage the Coorong and Lakes Ramsar site. As one of the Significant Ecological Assets under The Living Murray Initiative, an Asset Environmental Management Plan was prepared for this site and released in June 2005 (and then adopted formally in November). This coincided with the time when the data gathering for the description of ecological character began in earnest and so this provided some help with locating information and designing the approach taken. However, it is unclear at this time how the description of ecological character will be used in the revision of the Asset Plan, commencing now. There is considerable overlap between them, understandably. The ecological character description considers the needs of additional biota such as threatened species and ecological communities (for example) in more depth than the Asset Plan, which focuses on fish and birds, although its overall aim is to achieve 'A Healthier Lakes and Coorona estuarine environment'

The intention is that this description of ecological character will now be used to underpin the revision of the existing Ramsar Management Plan for the site, and this will be happening in parallel (it is understood) with the ongoing revisions of the Asset Plan for the same area. The authors of this report urge that consideration be given to merging these processes so that one plan is developed that serves the needs and expectations of both The Living Murray Initiative and the Ramsar site managers. Such a move would be welcomed by the local stakeholders as well, we believe.

■ 8.2 Recommendations

It is the view of the authors that the findings of this report justify the following operational and administrative actions by the South Australian and Commonwealth Governments:

Operationally:

- 1. Pursue, as a matter of high priority, the measures needed to be able to meet the limits of acceptable change recommended by this report, and, in particular, those specified in relation to flows in Section 6.6.2, as summarised below:
- sufficient water to keep the Murray Mouth open without dredging
- increased frequency of medium-sized or better floods to flush and 'freshen' the system
- reduced duration and frequency of no flow periods which are extremely detrimental to the system
- sufficient water to optimally operate the fishways and provide habitat connectivity between fresh, estuarine and saline units
- the opportunity to have so-named here 'Ramsar site contingency allocation' water available to allow managers scope for strategic on-site water allocations to benefits the Ramsar Significant Biological Components.
- 2. Ensure that barrage operations in the critical period until additional flows can be provided are directed at ensuring no further reduction in the area of the remnant 25% of the former estuarine habitat now found only from the Goolwa barrages to Pelican Point.
- 3. Accelerate the examination of the feasibility and ecological merits of using water from the Upper South East Drainage Scheme to reduce the very high salinities of the South Lagoon in the short term.

Administratively:

- 4. In accordance with Article 3.2 of the Ramsar Convention, the findings of this study be communicated to the Secretariat of the Convention, and, that consideration be given to including the site on Ramsar's Montreux Record of sites where change in ecological character is occurring, or has taken place.
- 5. The Coorong lagoons and Murray Mouth portion of the site be nominated immediately for listing under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 as a critically endangered ecological community.
- 6. The Commonwealth Government allocate significant new resources under its \$36 million National Biodiversity 'hot spots' initiative to see a range of the highest priority remedial actions directed at restoring ecological character undertaken immediately.
- 7. The South Australian Government, with the Murray-Darling Basin Commission and the Commonwealth Government, undertake a full inventory of relevant data holdings (including those held by researchers), with a view to building an integrated and comprehensive data 'warehouse' for the Coorong and Lakes.
- 8. The South Australian Government, with the Murray-Darling Basin Commission and the Commonwealth Government, agree to merge the planning and implementation processes for the Asset Environmental Plan and the Coorong and Lakes Ramsar Management Plan.
- 9. Publish this report as loose leaf folder, signaling the intent to see it continuously improved as new information comes to light.



Murray Mouth and Mundoo Channel

	onsolidated limi		
Element of ecological character	Limit(s) of Acc	eptable Change recommended	Page in the Repo
Primary determ	inants of ecologica	ıl character	
Salinity	Freshwater units	Lake Alexandrina Salinity maintained below 700 EC, based on a five year average. This allows for periods of higher salinity during low flows as would have been experienced naturally. Based on the data for Milang (see Appendix H), the 10 year average EC since 1971 have been as follows: 1971–1980: 672 EC; 1981–1990: 769 EC, 1991–2000: 693 EC, and the 2001–2005: 1062 EC. Lake Albert Salinity maintained below 1400 EC, based on a five year average. This allows for periods of higher salinity during low flows and for the fact that Lake Albert is always more saline than Lake Alexandrina since it has no flow-through. This LAC is based on the data for three sites in Lake Albert recorded in 1995–1997 (see Appendix H). Tributary wetlands LAC should be set for each tributary based on historical and other data. For the four tributaries where such data has been examined here (see above and Appendix H) it is apparent that each should be treated separately. For these, the following are recommended based on preliminary analysis only at this time. Monitoring salinities at point of discharge into the lake is recommended to confirm these limits: Tookayerta Creek: Salinity maintained below 500 EC at summer or drought peak, based on a five year average Finniss River: Salinity maintained below 2,400 EC at summer or drought peak, based on a five year average Currency Creek: Salinity maintained below 2,500 EC at summer or drought peak, based on a five year average Bremer River: Salinity maintained below 2,500 EC at summer or drought peak, based on a five year average. Groundwater salinities feeding the tributary wetlands not to exceed 1,500 mg/l (= approx. 3000 EC) to maintain the full complement of freshwater obligate fishes and plants	168
Furbidity and sedimentation	Estuarine- saline units Freshwater units	(see Sections 5.6.1). Murray mouth and Estuary Salinity not to exceed 58,000 EC (sea water) with parts below 39,000 EC. These are based on Table 21, for the period 1981–2000. North Lagoon Salinity ranging from 8,000–60,000 EC for most of the time, with the following limits: Northern end: Salinity not exceeding 50,000 EC (at Long Point) in the summer peak. Southern end: Salinity not exceeding 100,000 EC (at McGrath Flat) in the summer peak. South Lagoon Seasonal and spatial variability: Salinities around 30,000 EC in some parts in winter/spring with the following limits: Northern end: Salinity not exceeding 100,000 EC (at Villa dei Yumpa) in the summer peak. Southern end: Salinity not exceeding 130,000 EC (at Sandspit Point) in the summer peak. Lake Alexandrina Turbidity maintained below 70 NTU based on a five year average. This allows for periods of bidder turbidities during high flows. Record on the data for Milanes (see Appendix III), the	171
		of higher turbidities during high flows. Based on the data for Milang (see Appendix H), the average annual NTU level for the 18 years from 1983–2000 has been 76.2 NTU, with a range of <1 to 390 NTU. Lake Albert Turbidity maintained below 50 NTU based on a five year average. This allows for periods of higher turbidities during high flows. This is based on the historical and more recent data provided in Appendix H. Tributary weflands Unlike salinities (see Section 6.1) which seem to vary between tributaries, for the three tributaries able to be considered here (see above and Appendix H) turbidities were quite consistent, and low by comparison with the lakes. The LAC is therefore to maintain turbidity in the tributaries at less than 12 NTU based on a five year average to allow for periods of higher turbidities during high flows.	

Element of ecological character	Limit(s) of Acco	eptable Change recommended	Page in the Report
Primary determin	nants of ecologica	l character	
Turbidity and sedimentation (Continued)	Estuarine- saline units	There is relatively little long-term data available at present upon which to base LAC for turbidity, apart from that indicated above, and also what is known about the light transmission requirements for the reproduction and growth of the <i>Ruppia</i> keystone species (see above and the following section). These have been used to recommend the following limits.	179
		Murray Mouth and Estuary Secchi disc transparency depths of no less than 2 m.	
		North Lagoon: Secchi disc transparency depths of no less than 90cm. To encourage <i>R. megacarpa</i> return and expansion back to former distribution (see above and Section 6.3).	
		South Lagoon: Secchi disc transparency depths of no less than 90 cm. To encourage <i>R. tuberosa</i> return and expansion back to former distribution (see above and Section 6.3).	
Keystone species	Freshwater units	Areal extent: Given their critical role in the functioning of the freshwater units, any further loss of these keystone species would be a matter for great concern. As such, the limit of acceptable of change is 0% of areal extent, even though it is acknowledged that at present we do not know that extent. Surveys and mapping to set that baseline should be a high priority. Ideally, the management target should be to reinstate these keystone species to areas they have been lost from during the past 20 years, at least. Consultations with long-term stakeholders should assist with gaining this understanding, and for target setting within the Ramsar plan for the site, similar to that done for the keystone species in the estuarine-saline units (see below).	183
		Connectivity: As noted above, these keystone species are critical habitat for biota, and as such it is vital that efforts be made to reinstate connectivity between these areas so that the problem of habitat fragmentation can be addressed. The LAC is recommended as 0%, although, as with areal extent above, it acknowledged that surveys and gaining an historical perspective are high priority so that this LAC can meaningful, and used to set management targets.	
	Estuarine- saline units	Given their critical role as keystones of the ecological character of the estuarine-saline units, the apparent loss of <i>Ruppia megacarpa</i> from the North lagoon and the significant decline of <i>R. tuberosa</i> in the South Lagoon is a matter of grave concern for this Ramsar site.	185
		The Asset Plan's interim targets provide a starting point for management action, and these will be verified or modified once further work is done on the predictive mapping for both Ruppia species (see Figure 24). As noted above, observations by local stakeholders and long-time researchers suggest that the predictive map produced for R. megacarpa may well reflect the former extent of the species in the North Lagoon.	
		Irrespective of the estimates of the former areal extent and the targets set by the Asset Plan, the LAC for these keystone species has to be 0%. Any further loss cannot be tolerated if the ecological character of the estuarine and saline system units is to be recovered.	
		As was noted for the keystone species of the freshwater units (see Section 6.3.1), these species are critical habitat for biota, and a primary food source for many of the Ramsarsignificant birds and fish of this site. As such, it is vital that efforts be made to reinstate connectivity between these areas so that the problem of habitat fragmentation can be addressed. The LAC for connectivity is recommended as 0%, although, as with areal extent above, it is acknowledged that surveys and gaining an historical perspective are high priority so that this LAC can meaningful, and used to set management targets.	

Element of ecological character	Limit(s) of Acc	eptable Change recommended	Page in the Repor
Primary determi	nants of ecologica	l character	
Water levels	Freshwater units	Lake levels need to be drawn down in summer and raised in winter in order to mimic natural, seasonal variations, thereby reducing erosion and allowing for expansion of more complex ecological communities. The current proposal contained in the Asset Plan (DWLBC, 2005—see above) is to have a rate of rise and fall of no more than 2 cm per day in the pattern described below (see Figure 26). This is being tested at present and developed as on-going work of the Lakes and Coorong Environmental Flows Working Group (multi-agency, convened by DWLBC). Until this further work is done, no LAC is recommended.	190
	Estuarine- saline units	Coorong lagoon levels need to vary with a natural pattern of high water levels in winter and low in summer. Seasonal, short-term and tidal patterns are lost if there is insufficient inflow or connectivity to the Southern Ocean via the Murray Mouth and thus an open Murray Mouth at all times is essential. LAC: Murray Mouth Open 100% of the time, preferably via river flows than dredges. In terms of LAC for water levels, variation across time and space and absolute depths at critical times, are the key parameters. The Lakes and Coorong Environmental Flows Working Group (multi-agency, convened by DWLBC) have developed the proposed ideal hydrograph (Figure 27). This proposal integrates the Asset Plan targets into an ecological envelope of target water depths throughout the year and will be tested in terms of capacity to achieve the hydrograph and observed ecological outcomes from delivery. Until this further work is done, no LAC is recommended.	194
Habitat connectivity	Freshwater and Estuarine- saline units	Lake Alexandrina No further reduction in habitat availability. Reduced turbidity and maintenance or restoration of habitat connections are considered critical for listed species and underrepresented habitats. Lake Albert No further reduction in habitat availability. Reduced turbidity is essential for plant growth and improved hydrological connectivity between the Lakes via the Narrung Narrows is essential for the integrity of this otherwise closed part of the system. Tributary wetlands and Hindmarsh Island: No further reduction in habitat availability. Maintaining or restoring habitat connectivity is required to maintain and enhance isolated remnant fish, plant and bird populations and allow for migration of species between habitats to escape adverse local conditions. Murray Mouth and Estuary, North Lagoon and South Lagoon: No further reduction in habitat availability. Appropriate management targets for restoring ecological character are: Reinstatement of the former estuarine habitats of the Coorong, which it is estimated currently sit at 25% of the former coverage (see Sections 6.3.2 and 6.4.2). This is a matter of some urgency Interim target for Ruppia as contained as interim targets in the Asset Plan (see above).	198
Water regime	Inflows from the Eastern Mount Lofty Ranges (EMLR) tributaries of Lake Alexandrina	No greater than 30% of winter run-off to be taken from each sub-catchment, as per the River Murray Catchment Water Management Plan (2003). Patterns of inflows need to be protected. In particular, disconnection or untimely drying out of critical tributary habitats should be avoided, particularly given the high diversity and abundance of significant taxa utilising these habitats (see Section 6.6.3). Groundwater pumping policies (such as zones of influence) that limit pumping on a spatial and seasonal basis and improved delivery of low to medium flows are needed to prevent truncation of flow events and adverse changes in water regime and water quality.	202

Table 25 - Cor	isolidated limit	s of acceptable change (continued)	
Element of ecological character	Limit(s) of Acce	ptable Change recommended	Page in the Repor
Primary determin	ants of ecological	character	
Water regime (Continued)	Inflows from the River Murray	If has been beyond the scope of this project to specify the minimum annual flow that is needed for retaining the ecological character of the Coorong and Lakes Ramsar site (refer to The Living Murray Foundation Report (MDBC, 2003) and work of the Expert Reference Panel (Jones et al., 2002)). The clear indications from the conclusions drawn and reflected throughout his report (see Section 8) is that the ecological character of his site has changed significantly since the time of Romans itsing and that urgent remedial actions are needed. These changes are to a large extent flow-related and thus the following acts as a guide to river manages to reverse the change in ecological character: 1. The Coorong and Lokes is a site that is strongly influenced by water levels; these being a product, in large part, of freshwater inflows and tides. Keeping the Murray Mouth open at all times with bearage releases strether than dreading should be the first target to recovering the ecological character (see Section 6.6.4 below) of this site. To this end, a secure allocation of at least 2.000ML/day needs to be made for the Murray Mouth of least during surplus flow periods to allow for the dredges to be intermittently stopped whilst river flows are great enough to keep the mouth open. This cillocation should then build up over time to the point that dredges are no longer needed. 2. The site is also one that is adapted to the once highly variable flows of the unregulated River Murray, and some effort needs to be made to see those highs and lows in flow pattern reinstated. It will only be with the return of environmental flows to the river, that medium-sized floods can be "manufactured" by the river managers through the topping up of the more frequent small-floods. For recovering the ecological character of this site, the frequency of medium-sized floods (20,000–80,000ML/day) needs to occur at least once in every ten years to reset the system. 3. Periods of nor very low flow were very rare under natural conditions and are extremely	205

Element of ecological character	Limit(s) of Acceptable Cha	nge recommended	Page in the Repor
Primary determi	nants of ecological character		
Water regime (Continued)	Barrage Operating Strategy	No limits of acceptable change are indicated here as it is assumed the new Barrage Operating Strategy (BOS) will accommodate all those that relate directly to the timing, duration and volumes of these releases. It is anticipated the new BOS will be based on the flow preferences of indicator species and the individual LAC recommended in this report. See also the LAC recommended in the preceding section relating to River Murray flows.	212
	Murray Mouth opening	Murray Mouth to be kept open, preferably by flows discharging from Lake Alexandrina so that the other benefits from these freshwater inflows can be experienced through more natural functioning of the wetland complex. To achieve this, River Murray discharges to the sea need to be increased to a minimum of 1000 GL/year delivered at a minimum rate of 2,000 ML/day. See also LAC recommended in relation to River Murray flows in Section 6.6.2. The Asset Management Plan (see above) proposes a diurnal tide ratio (cf. Victor Harbor) of 0.5 at Goolwa and 0.2 at Tauwitcherie. Based on current understanding this is considered the absolute minimum required to sustain the ecological character of the Murray Mouth, Estuary and the Coorong.	215
	Inflows from the Upper South East Drainage Scheme	No LAC is recommended here as the possible use of USEDS water would be aimed primarily at improvements to the salinity, turbidity and keystone <i>Ruppia</i> species in the South Lagoon in particular. The LAC recommended for salinity (Section 6.1.2), turbidity (Section 6.2.2) and keystone plants (Section 6.3.2) are relevant here. Any escalation of USEDS water discharges should be delivered in a natural seasonal pattern, peaking during late winter/spring. Inter-annual variation with large and smaller flow years would reflect former natural regime, although the related LAC (see above) should be the key driver for decision making.	218
Wetland types			
Freshwater system units	D - Rocky marine shores ; includes rocky offshore islands, sea cliffs	5% (areal extent)—there is relatively little area of this type and while the full ecological roles are yet to be defined, an LAC of 5% is applying the precautionary approach.	42
	E - Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks	0% (areal extent)—there is little area remaining, and it provides habitat diversity for waterbirds in particular.	43
	M - Permanent rivers/ streams/creeks; includes waterfalls	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat connectivity)—habitats with fresh, variable water regimes are critical for connections across time and space.	44
	N - Seasonal/ intermittent/irregular rivers/streams/creeks	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat connectivity)—important wetland type in Hindmarsh Island assemblage.	45
	O - Permanent freshwater lakes (over 8 ha); includes large oxbow lakes	5% (areal extent)—these areas play important ecological roles. 0% (tributaries water regime—see Section 6 also)—the patterns and volumes of EMLR tributaries need to be maintained to maintain these habitats.	46

Element of ecological character	Limit(s) of Acceptable Chai	nge recommended	Page in the Report
Wetland types			
Freshwater system units (Continued)	P - Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat connectivity)—important location near confluences and thus connection between ephemeral and permanent habitats.	47
	Ss - Seasonal/intermittent saline/brackish/alkaline marshes/pools	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat availability)—connections between habitats of varying salinities, in good condition, across time and space are considered critical, particularly connections with wetland types Tp, O, W, Xf and Ss.	48
	Ts - Seasonal/intermittent freshwater marshes/ pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	5% (areal extent)—this type plays important ecological roles. 0% (habitat availability)—once dominant type now restricted to confluences. Critical for habitat connectivity and Ramsar Significant Biological Components.	50
	Tp - Permanent freshwater marshes/ pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water- logged for at least most of the growing season	5% (areal extent)—this type plays important ecological roles. 0% (habitat availability)—all aspects of habitat availability considered important for maintaining species assemblages. Maintaining connectivity between Tp, O, W, Xf and Ss types is considered essential.	51
	W - Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic solls	5% (areal extent)—this plays important ecological roles. 0% (habitat connectivity)—connections between Tp, O, W, Xf and Ss considered essential.	54
	Xf - Freshwater, tree- dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic solls	2% (areal extent whole site)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (areal extent Hindmarsh Island)—critical location and under-represented type. 0% (habitat connectivity)—critical connections to types Tp, O, W, Xf and Ss.	55
	4 - Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)	None indicated as these are not natural wetlands. Note: 'Wyndgate' property on Hindmarsh Island contains flooded agricultural land managed for Cape Barren Geese (see Section 5.5.1).	56
	6 - Water storage areas; reservoirs/barrages/ dams/impoundments (generally over 8 ha)	None indicated as these are not natural wetlands.	57
	9 - Canals and drainage channels, ditches	10% (areal extent)—these are not natural wetlands but are considered important habitat because type is now rare in freshwater units.	58
Estuarine- saline units	A - Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits F - Estuarine waters; permanent water of estuaries and estuarine	5% (areal extent)—this plays important ecological roles.	66

Element of ecological character	Limit(s) of Acceptable Cha	nge recommended	Page in the Report
Wetlands types			
Estuarine- saline units (Continued)	D - Rocky marine shores ; includes rocky offshore islands, sea cliffs	2% (areal extent)—there is relatively little area of this type, it is under threat from sedimentation and it plays important ecological roles.	67
	E - Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.	68
	G - Intertidal mud, sand or salt flats	2% (areal extent)—while there is significant area this is vital for wading birds.	69
	H - Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes	2% (areal extent)—there is relatively little area and it plays important ecological roles.	70
	I - Intertidal forested wetlands: includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	0% (areal extent)—there is little area, this a vulnerable type and plays important ecological roles.	71
	J - Coastal brackish/ saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea	2% (areal extent)—while there is significant area, it plays important ecological roles. 0% (Murray Mouth and Estuary)—the unique 'cove' features are considered critical remnant habitats.	72
	K - Coastal freshwater lagoons; includes freshwater delta lagoons	0% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.	74
	M - Permanent rivers/ streams/creeks; includes waterfalls	0% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles.	75
	R - Seasonal/intermittent saline/brackish/alkaline lakes and flats	5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connects to types G, W, Ss and Xf at high elevations around the lagoon.	76
	Ss - Seasonal/intermittent saline/brackish/alkaline marshes/pools	5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connects to types G, W, R and Xf at high elevations around the lagoon.	77
	W - Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on	5% (areal extent)—this type plays important ecological roles. 0% (habitat connectivity)—connects to types G, R, Ss and Xf at high elevations around the lagoon.	78

Element of ecological	Limit(s) of Acceptable	Change recommended	Page in the
character			Repor
Wetlands types	_		I
Estuarine- saline units (Continued)	Xf - Freshwater, free-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	2% (areal extent)—there is relatively little area, this is a vulnerable type and plays important ecological roles. 0% (habitat connectivity)—connects to types G, R, Ss and W at high elevations around the lagoon.	79
	Y - Freshwater springs; oases	0% (areal extent)—there is little area remaining, these are a vulnerable type and play and important ecological role.	80
Ramsar Significa	ınt Biological Components		
Endangered and vulnerable plant species	as endangered and vu precautionary approac	whedged gap of comprehensive survey data at present, these species are listed ilnerable species either nationally or within South Australia. Therefore, applying a ch, the limit of acceptable change is recommended as 0%, meaning that any losses ution fluctuations should be considered unacceptable until such time as further surveys a contrary view.	84
Swamps of the Fleurieu Peninsula	listed, and even today Further work is urged to Ramsar site so that app setting limits of accepts 1. Areal extent—as a c 2. Condition of the wet	blish the areal extent of this wetland type at or around the time the site was Ramsarthere are strong caveats placed on the estimated areal extent currently (see above). It confirms the extent of this critically endangered ecological community within the propriate planning and management can be provided. From the perspective of able change there are three primary considerations: In ritically endangered ecological community this is recommended as 0%. It is recommended at present, and wetland remnants or pockets—no further loss of dryland habitats connecting wed.	87
Mount Lofty Ranges Southern Emu-wren	habitats it relies upon (see are strong cavear currently (see preceding the habitats required by management can be primary considerations: 1. Population size—the present. Until such tirtunderstood, the present understood, the present intended to mean the present of Fleuri and Condition of the Fleuri and Condition of the Fleuri are strong cavear are strong cavear and condition of the Fleuri are strong cavear are strong cavear and cavear are strong cavear are strong cavear and cavear are c	blish the size of the population of this species or the Fleurieu Peninsula swamp see preceding section) at or around the time the site was Ramsar-listed. Even today sits placed on the estimated areal extent of the Fleurieu Peninsula swamp habitating section). Further work is needed to confirm both the population size and extent of yithis endangered species within the Ramsar site so that appropriate planning and provided. From the perspective of setting limits of acceptable change there are four settimate is 80–160 and natural variability of this within the population is not known at me as a more precise population estimate is possible and natural variations are better cautionary approach suggests a 0% limit of acceptable change. In this context this is not no actions should be permitted that may threaten this small population. eu Peninsula swamp habitat—see above. Wrieu Peninsula swamp habitat—see above. Ben wetland remnants or pockets—no further loss of dryland habitats connecting these	91
Orange- bellied Parrot	site at or around the tin of likely habitat (see abof this modeling, nor the determine both the pothe Ramsar site so that setting limits of acceptate 1. Population size—no apopulation estimate precautionary appromean that no action 2. Areal extent of primothis information is coan endangered spechange is appropriate 3. Condition of the prindabitats are known.	blish the size of the population of this species using the Coorong and Lakes Ramsar ne the site was Ramsar-listed. While there has been work done to estimate the extent love), the authors have not been able to gain authoritative advice on the veracity e size of the population that overwinters in the site today. Further work is needed to pulation size and extent of the habitats required by this endangered species within appropriate planning and management can be provided. From the perspective of able change is appropriate: estimate of the population using the site today is available. Until such time as a precise is possible and natural variations within that population are better understood, the bach suggests a 0% limit of acceptable change. In this context this is intended to has should be permitted that may threaten this small population. The provided, then this can be used to establish a robust limit of change. For cies with a total national population estimated at 150 birds, a 0% limit of acceptable interes. The provided is the provided of the provided of the primary habitats—no suitable limits of acceptable change can be indicated until these the primary habitats—this may or may not be a factor. No suitable limits of acceptable cated until these habitats are known.	95

Element of ecological character	Limit(s) of Acceptable Change recommended	Page in the Report
Ramsar Signific	ant Biological Components	
Southern Bell Frog	There is so little known about the distribution, abundance and habitat preferences of this species in the Ramsar-listed area, thus it is not possible to make any recommendations on Limits of Acceptable Change at this time. Once this information is available, there are four primary considerations as follows: 1. Population size—a precise population estimate is needed and some understanding of the natural variations within that population. 2. Areal extent of primary habitats—mapping of the primary habitat areas is needed to ensure appropriate management of these. 3. Condition of the primary habitats—maintaining the condition of the primary habitats is vital for protecting this species within the Ramsar site. 4. Connectivity between primary habitats—this may or may not be a factor.	101
Gahnia vegetation association	It is not possible to establish the areal extent of this vegetation association (Type W) at or around the time the site was Ramsar-listed, and even today the area indicated (900 ha) is considered an estimate until further detailed ground surveys are completed. From the perspective of setting Limits of Acceptable Change there are three primary considerations: 1. Areal extent—while the full areal extent is yet to be confirmed the association is provisionally listed as a vulnerable ecosystem within the agricultural district of South Australia. Given this, the precautionary approach indicates that a limit of acceptable change of 0% is appropriate until further information is obtained that may or may not alter this. 2. Condition of the vegetation association—no suitable limit of acceptable change can be recommended at present. 3. Connectivity between the vegetation association—this may or may not be a consideration depending on the findings of future research to establish the full ecological roles.	105
Breeding, wetland- dependent birds	At present there is no systematically collected information to indicate the size, distribution, annual or seasonal variations and success of these breeding populations within the Ramsar site, thus making it impossible to set meaningful limits of acceptable change across this range of species. Once more systematic surveys are conducted to map and assess the full extent of breeding areas it should be possible to set limits of acceptable change. Depending on the species this may set LAC of between 0 and 10%. For species such as Australasian Bittern and Hooded Plover, that are threatened species, either nationally or at State level, it is expected the LAC would be 0%. An important element of these surveys will be to determine if species breed there every year, two or three years out of five, or only very occasionally. This will allow LAC to be developed that can indicate when managers need to be concerned should a certain species discontinue breeding activities at the site. Surveys will also identify the primary breeding habitats and allow LAC to be developed that consider, for example the areal extent and condition of inland shrublands, reedbeds, rushes, tussocks and grasslands etc. At present, LAC have been set for each wetland type found within the Ramsar site (in Section 4) and these will provide an interim indication for managers until more detailed breeding habitat data is collected.	108
	The data from Paton (2005b) suggest that for several fish-eating species, breeding effort in the South Lagoon has declined considerably in recent years, apparently coincident with declines in the population of hardyhead fish. This includes Australian Pelican, Fairy Tern and Hoary-headed Grebes. Oral history accounts from the Ngarrindjeri community and three of the long-term fishing families also raise concerns about pelicans, Black Swans, oystercatchers and Silver Gulls. On face value these may seem not to allow for the setting of robust limits of acceptable change. However, the reduction and possible cessation of pelican breeding in the South lagoon is notable in this context, as are Paton's (2005b) observations for Fairy Tern and Hoary-headed Grebe; indicative as they seem to be of the loss of hardyhead fish from this part of the Coorong. Equally, the observed reduction in swan numbers and breeding success, linked to the documented decline in 'swan weed' (Ruppia tuberosa) (see Sections 5.4 and 6) is also strongly indicative of a major change in the ecological character of the South Lagoon. For these species, the limits of acceptable change need to reflect a continuation of their breeding effort	
	and success at or near that witnessed around the time the site was Ramsar-listed in 1985. It has not been possible for this project to source any such data and so it is recommended that this be part of the followup actions. At the very least it should be recognised that the decline or cessation of breeding activities by these species in the South Lagoon indicates the need for urgent remedial action to recover the former ecological character.	

Element of ecological character	Limit(s) of Acceptable Change recommended	Page in the Report
Ramsar Significar	ıt Biological Components	
Wading birds, including migratory species	For this assemblage of wading species within the wetland-dependent bird community of the Coorong and Lakes Ramsar site, there are a number of limits of acceptable change that need to be considered: 1. Population sizes—survey data to date can be used only to indicate trends and it is not possible to use it to set robust limits of acceptable change. The data is also, in most cases, highly variable and this wide natural variation also hinders the setting of LAC. It is recommended that future surveys focus on the following wader species: Sharp-tailed Sandpiper, Red-necked Stint, Curlew Sandpiper, Banded Stilt, Greenshank, Red-necked Avocet and Red-capped Plover, to establish meaningful LAC. In the interim, the LAC should be to see these populations retained at or better than their 2000 levels as recorded in Paton (2005b). For these species, those population estimates for the Coorong were as shown below (see page 135). It is recognised that these are somewhat arbitrary but they are provided in the interest of providing an interim LAC until more systematic surveys can provide stronger data on which to base them. 2. Distribution and breeding success of certain species—see Section 5.3. 3. Habitat/food availability and condition—There are a number of levers, components and processes that impact on the availability and condition of habitat and food items for these species. These are considered in Section 6.	120
Cape Barren Goose	The species breeds away from the Coorong, on Kangaroo Island and other offshore Islands further to the west. It is not possible to establish the size of the population of this species at or around the time the site was Ramsar-listed in 1985. In recent years, the population size of the Ramsar site and immediately adjacent areas has been estimated at approximately 4,000 (Tim Wilson, pers comm.). Further work is required to determine both the population size and extent of the habitats required by this rare species within the Ramsar site so that appropriate planning and management can be provided. From the perspective of setting limits of acceptable change, there are four primary considerations: 1. Population size—the estimate is approximately 4,000 however natural variability of this figure is not known at present. Until such time as a more precise population estimate is possible and natural variations are better understood, the precautionary approach suggests a 5% limit of acceptable change, noting the generalist foraging behaviour of the species. 2. Areal extent of primary habitats used by the species. Not known at present. 3. Condition of the primary habitats used by the species. Not known at present, although see wetland type 4 in Section 4.1.4 (page 24). 4. Connectivity between primary habitats used by the species assuming this is an important factor in sustaining the population. Not known at present.	134
Obligate freshwater fish species	It is not possible to establish the population sizes for these species either around the time the site was Ramsar-listed or today. Further survey work is needed to provide robust estimates of population sizes and the extent of the habitats each rely upon. From the perspective of setting limits of acceptable there are four primary considerations: 1. Population sizes—these cannot be determined at present although of concern are the suggestions by Wedderburn and Hammer (2003) that a number of the smaller species either have patchy or quite restricted distribution, making them potentially vulnerable. Until such time as a more precise population estimate is possible and natural variations are better understood, the precautionary approach suggests a 0% limit of acceptable change for those species with restricted or patchy distribution, and 5% for those are more widespread and less specialised in niche requirements. 2. Areal extent of primary habitats—see Section 4.1 where these are identified by wetland type and LAC indicated. 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively. 4. Connectivity between primary habitats—as noted above, for some of these species there is concern that habitat patches are becoming isolated and some types are becoming less common due to the simplification of the lake environments caused in large part by the lack of flow and water level variations. This means that areas showing greater habitat diversity, such as the upper reaches of the Finniss River, the entrance to Waltowa Swamp, and drains entering Lake Alexandrina, are becoming more and more important for some species. In Section 4.1.4 (and see also Sections 6.3–6.5) this is noted under the relevant wetland types and LAC have been indicated.	135

Table 25 - Co	nsolidated limits of acceptable change (continued)	
Element of ecological character	Limit(s) of Acceptable Change recommended	Page in the Report
Ramsar Significa	int Biological Components	
Diadromous fish species	It is not possible to establish the population sizes for these species either around the time the site was Ramsar- listed or today. Further survey work is needed to provide robust estimates of population sizes and the extent of the habitats each rely upon. From the perspective of setting limits of acceptable change there are four primary considerations: 1. Population sizes—these cannot be determined at present although, as noted above, six of these seven species are being considered for inclusion on the South Australian list of species of conservation concern. Given this, the precautionary approach suggests a 0% limit of acceptable change for these species, meaning they warrant consideration in the operations of the barrages and fishways to ensure passage, either upstream or down, when it is required. 2. Areal extent of primary habitats—too little is known of the habitat needs of these species at present to allow a LAC to be recommended. 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively. 4. Connectivity between primary habitats—as noted above, the primary consideration for these species is to be able to move through the barrages at certain times. The fishway and barrage operating strategy make some allowance for these needs at present.	149
Euryhaline or estuarine species	It is not possible to establish the population sizes for these species either around the time the site was Ramsar-listed or today. Further survey work is needed to provide robust estimates of population sizes and the extent of the habitats each rely upon. From the perspective of setting limits of acceptable change there are three primary considerations: 1. Population sizes—these cannot be determined at present although, as noted above, several of these species appear to have undergone considerable declines over the past 30–40 years and some, such as the Small-mouthed Hardyhead, more recently. Given this, the precautionary approach suggests a 0% limit of acceptable change for these species, meaning they warrant priority consideration in the management of this site and actions are needed to address apparent population reductions. The decline of Small-mouthed Hardyhead is of special note given its key role as a food item for waterbirds. This decline, associated with the loss of the keystone <i>Ruppia</i> aquatic plant species is considered further in Sections 5.4 and 6.3. 2. Areal extent of primary habitats—too little is known of the habitat needs of these species at present to allow a LAC to be recommended. However, as noted above, the decline of keystone <i>Ruppia</i> aquatic plant species is likely to be a primary factor in the declines of these species, and so warrants immediate management intervention. LAC in relation to <i>Ruppia</i> have been provided in Section 6.3. 3. Water quality—see Sections 6.1 and 6.2 where LAC are indicated in relation to salinity and turbidity, respectively.	155
Marine stragglers	No limits of change are recommended due to knowledge gaps. As noted, the increased presence of these species in the system probably indicates a change in ecological character within the Coorong. As the system becomes more saline with Murray Mouth restrictions and reduced freshwater in-flows over the barrages, it may become more conducive to marine species visitation. There is anecdotal evidence that this is the case (see Section 7.2).	163

Element of ecolo	gical character	Traffic light	Rationale given for traffic light assessment(s)	Page in the Repor				
Primary determinants of ecological character								
Salinity	Freshwater units	•	Both lakes are at present routinely (and greatly) exceeding recommended salinity levels and this is contributing to the loss of keystone species and other freshwater species as well as threatening ecosystem services (irrigation, stock and human drinking water supplies etc.) Increasing salinity levels in the tributaries threaten under-represented habitats and biota and must be arrested as soon as possible to ensure the full complement of ecosystem components and processes remains.	168				
	Estuarine-saline units		More favourable salinities and more extensive areas of estuarine habitat need to be reinstated. Current conditions are leading to losses of species (including keystones), habitats and ecosystem processes and if salinities are not reduced urgently, the ecological character of the Coorong will change, possibly irreversibly. The Murray Mouth and Estuary and the northern end of the North Lagoon have become core refuge areas for the estuarine species, habitats and ecosystem processes.	171				
Turbidity and sedimentation	Freshwater units		Knowledge of turbidity and sedimentation processes is poor even though this appears to be a major factor in loss of keystone species and changes in species assemblages, nutrient cycling and food web dynamics. Priority management attention required.	177				
	Estuarine-saline units		Knowledge of turbidity and sedimentation processes is poor even though this appears to be a major factor in loss of keystone species and changes in species assemblages, nutrient cycling and food web dynamics. Urgent management attention required.	179				
Keystone species	Freshwater units		There is an urgent need to secure the core keystone species populations (whether they be in natural or human-made wetland types) and extend their range to ensure on-going provision of the environments needed to support freshwater ecosystem components and processes. The loss of, or severe decline in, keystone species population is considered a fundamental change in ecological character.	183				
	Estuarine-saline units		There is an urgent need to secure the core keystone species populations around the Murray Mouth Estuary and the northern end of North Lagoon and extend their range to ensure on-going estuarine ecosystem functionality. The loss of, or severe decline in, keystone species populations is considered a fundamental change in ecological character. It is estimated that in these units keystone species coverage is less than 25% of original.	185				
Water levels	Freshwater units		Lake levels are a key determinant of all ecosystem components and processes. The current regime is counter-seasonal to the natural one and too static to support the full complement of the lakes' biota. Species reliant on variable water levels are under-represented and at risk of local extinction.	190				
	Estuarine-saline units		The recent closure/restrictions of the Murray Mouth created adverse water levels in the Coorong which showed the vulnerability of the whole ecosystem to water levels. There is an urgent need to re-establish the ecosystem components and processes that were damaged by high water levels in the early 2000s.	194				
Habitat connectivity	Freshwater and Estuarine-saline units	•	Restoration of habitat availability is required as a priority action. In particular, the full suite and extent of habitat types, needs to be restored and connections between habitats (particularly through the barrages and the lakes islands) need to be improved as soon as possible. Re-establishment of estuarine conditions in the Coorong lagoons is critical for restoration of ecological character.	198				

Element of ecolo	ogical character	Traffic light	Rationale given for traffic light assessment(s)	Page in the Report				
Primary determinants of ecological character								
Water regime	Inflows from the Eastern Mount Lofty Ranges (EMLR) tributaries of Lake Alexandrina		Assuming the cap on water resource development is implemented within five years, flows should remain at a level appropriate to support tributaries' biota and benefit Lake Alexandrina by supplementing River Murray inflows. The 'amber' level is recommended given the uncertainty about groundwater pumping limits, the observed recent increases in salinity to above keystone species thresholds, and the critical importance of these wetlands to future restoration of ecological character at a Ramsar site scale.	202				
	Inflows from the River Murray		The change in the ecological character of this Ramsar site is largely a consequence of reduced flows from the River Murray. Delivery of the 500 GL First Step decision of the Living Murray Initiative is urgently needed to help slow these changes, but additional flows will be are needed to keep the Murray Mouth open without dredges, to prevent extended periods of no or low flow, to allow for more frequent medium-sized flood and for strategic on-site water manipulations.	205				
	Barrage Operating Strategy		There is considerable scope for the new Barrage Operating Strategy to address ecological needs in a more extensive way than the current one does without significantly affecting the capacity to supply irrigators with water during the irrigation season. Changes to barrage operation are urgently needed to prevent further losses of ecosystem components and processes.	212				
	Murray Mouth Opening		In terms of maintaining the ecological character of this Ramsar site, the current situation with the mouth of the Murray being kept open with dredging is not considered optimal and is likely to lead to on-going degradation of the Ramsar site, albeit slower than if the mouth were closed. While dredging may be essential during current low river flows, it only mimics some of the ecological functions needed. Maintaining the mouth open with natural flows brings with it the full suite of ecological components and processes need to restore the ecological character of the site.	215				
	Inflows from the Upper South East Drainage USEDS Scheme		USEDS inflows have the capacity to mitigate salinity and turbidity levels in the South Lagoon especially, and also benefit the keystone Ruppia species, but care needs to be taken to ensure the quality of this water is appropriate and that its delivery mimics more natural flow regimes.	218				
Wetland types								
Freshwater system units	D - Rocky marine shores ; includes rocky offshore islands, sea cliffs		The ecological roles of this wetland type are poorly understood, it has limited areal extent and the rocky shores are threatened by cattle grazing, therefore a precautionary approach of rating this type as under threat has been applied. If it is found that this habitat is critical habitat for Ramsar or other significant biota it should be changed to 'amber' unless habitat condition and threat assessment at the time shows otherwise.	42				
	E - Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks		Only 1 ha of this wetland type remains and thus this type is extremely vulnerable to loss from the Ramsar site. It is an important part of habitat variability and connectivity. Given its location on the lake shore near a major township, it is considered to be under immediate and extreme threat from a range of direct and indirect anthropogenic factors.	43				

Element of ecological character		Traffic Rationale given for traffic light assessment(s) light		Page in the Repor			
Wetland types							
Freshwater system units (continued)	M - Permanent rivers/streams/creeks; includes waterfalls	•	This wetland type is considered to be under extreme threat and highly vulnerable. This rating is based on the combined factors of the high ecological value of this wetland type and immediate risks of damage from anthropogenic factors such as land and water resource development. The variable water regimes and habitats available in these wetland types support under-represented species assemblages and Ramsar Significant Biological Components (RSBCs). Combined with other island habitats and the Murray Mouth Estuary these wetlands are the 'jewel in the crown' of the modern Ramsar site.	44			
	N - Seasonal/ intermittent/irregular rivers/streams/creeks		Similar to Type M above, Type N wetlands are also considered to be under immediate threat and extremely vulnerable to land and water resource development. These channels are critical connectors of various habitats and vital for maintaining the ecological functionality of the island habitats.	45			
	O - Permanent freshwater lakes (over 8 ha); includes large oxbow lakes		Type O wetlands are abundant in the Ramsar site but those with clear, cool water, as in the tributaries unit, are rare and under extreme threat from water resource development and increasing lake turbidity levels. Fringing lake habitats support species assemblages that once extended much further into the lake and thus are important and extremely vulnerable remnants. The turbidity of the main lake bodies needs to be below 90 NTU and the abundance and health of variable water regime dependent biota higher for the rating to be 'green'.	46			
	P - Seasonal/ intermittent freshwater lakes (over 8 ha); includes floodplain lakes		The wetlands are important remnants of the pre-European lower River Murray system that support RSBCs and other species of note. They are considered to be under extreme threat and highly vulnerable because of relatively small area, location near areas of intensive human activities and capacity to support under-represented ecosystem components and processes.	47			
	Ss - Seasonal/ intermittent saline/ brackish/alkaline marshes/pools		Important wetland type in the freshwater units assemblages that connect various other wetland types. They are under threat from grazing and altered water regime. These habitats are also considered extremely vulnerable because they occur at the top of the seasonal variations in groundwater levels and thus are vulnerable to reduced hydraulic pressure and also because of trampling of brittle vegetation and pugging of anoxic soils by cattle.	48			
	Ts - Seasonal / intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes		Once the dominant type, these wetlands are considered to be under extreme threat because they are high elevation wetlands dependent on variable flows and floods. They are also considered vulnerable because they connect important habitats and support ecological processes and components that are dependent on variable water regime and flooding.	50			
	Tp - Permanent freshwater marshes/ pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water- logged for at least most of the growing season		Urgent need to reverse the simplification of the emergent vegetation communities around the lake shore that has resulted from static regulated lake levels to ensure on-going provision of habitat for RSBCs and other species. Diverse emergent and submerged wetland vegetation are considered keystone assemblages for the freshwater units. Given the above, plus poor current condition and diversity, and high exposure to human activities, these wetland types are considered to be under threat and extremely vulnerable.	51			

Element of ecological character		Traffic light	Rationale given for traffic light assessment(s)	Page in the Report			
Wetland types							
Freshwater system units (continued)	W - Shrub-dominated wetlands; shrub swamps, shrub- dominated freshwater marshes, shrub carr, alder thicket on inorganic soils		Samphire communities cover relatively large areas of both the fresh and estuarine-saline units. They are however under threat from activities such as cattle grazing and alterations to groundwater and surface water dynamics. Although abundant, these wetlands are not given a 'green' rating primarily because of threats from land and water resource development to habitat connectivity between wetlands of this type and types Tp, O, Xf and Ss.	54			
	Xf - Freshwater, free- dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils		These trees are under extreme threat of local extinction due to their poor current condition at most freshwater remnant sites supported by River Murray flows. Once a dominant wetland type, the trees, and the species dependent on them (e.g. birds of prey), are considered extremely vulnerable, based on the lack of regular recruitment and their very small areal coverage. Local replanting efforts require additional resources to be truly effective at arresting the decline.	55			
	4 - Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)		A 'green' rating has been given to this wetland type because it is not under threat but rather promoted by human activities, particularly by the active management of 'Wyndgate' to provide wetland habitats of this type for Cape Barren Geese (see Section 5.5.1).	56			
	6 - Water storage areas; reservoirs/ barrages/dams/ impoundments (generally over 8 ha)		Dams of this nature are common in the landscape surrounding the Ramsar site, and as are Type 4 wetlands (see above), they are promoted by human activities rather than threatened.	57			
	9 - Canals and drainage channels, ditches		Although constructed, these channels are valued for providing fresh, flowing, clear, cool habitats that are now under-represented at this Ramsar site. These sites support RSBCs, particularly small native fishes (see Section 5.6.1). They are threatened by dredging, infilling and the shutting down of pumps during critical flow periods.	58			
Estuarine- saline units	A - Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits F - Estuarine waters; permanent water of estuarines and estuarine systems of deltas		Estuarine waters once dominated the whole Coorong, Murray Mouth and Estuary area and are now restricted to just those times and places where freshwater inflows are great enough to reduce salinities to significantly below that of sea water. Consequently, this wetland type now acts as refuge for estuarine species and is considered extremely vulnerable. It is also considered to be under extreme threat from on-going low flows from the River Murray causing increasing salinity and turbidity and effective loss of estuarine conditions.	66			
	D - Rocky marine shores; includes rocky offshore islands, sea cliffs		This wetland type is ecologically important. The rocky, intertidal pools and shores are under threat from smothering due to the high rates of sedimentation occurring in the Coorong. Vulnerability is considered high because of the relatively thin tidal band occupied by this type and the relatively low areal extent.	67			
	E - Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks		This wetland type is considered to be under threat from wind and water erosion, exotic plant domination and recreation impacts. They are also vulnerable systems because of their dynamic morphology.	68			

Element of ecological character		Traffic lights	Rationale given for traffic light assessment(s)	Page in the Report					
Primary determinants of ecological character									
Estuarine- saline units (continued)	G - Intertidal mud, sand or salt flats		This wetland type is vital for waders and is considered to be under extreme threat from increased sedimentation and changes to the organic carbon and sediment profiles. These sites are also extremely vulnerable because of the short life cycles and species-specific salinity tolerances of the decomposers and the macroinvertebrates that utilise these habitats and provide feed to waders (see Sections 5.4 and 6.3).	69					
	H - Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes		This wetland type once dominated the tidal influenced units and is now under-represented. As such it represents an extremely threatened and vulnerable refuge area for ecosystem processes and components that will be relied upon to expand into other areas of the Ramsar site once estuarine conditions are restored.	70					
	I - Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests		These critical remnants are considered threatened by altered water regime and increased salinities and vulnerable due to low rates of recruitment and relatively old age and poor condition of many trees. There is an urgent need to rehabilitate this wetland type and provide missing habitats for colonial birds and birds of prey.	71					
	J - Coastal brackish/ saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea	•	The miniature 'coves' described in the Murray Mouth and Estuary unit are unique, poorly described and considered highly important habitats that are vulnerable because of their morphology and dependence on localised recharge-discharge rates. The coastal saline waters that form the North and South Lagoons may cover a vast area but they are in such poor condition as to be likely to undergo an irreversible shift in ecological character within the next few years unless there is significant management intervention in the near future. Immediate reductions in salinity and turbidity levels and re-establishment of <i>Ruppia</i> spp. beds are required to prevent this occurring (see Sections 6 and 8).	72					
	K - Coastal freshwater lagoons: includes freshwater delta lagoons		These wetlands are the only source of freshwater for many terrestrial species as well as being important habitats per se. The remaining springs are considered extremely vulnerable because of their dependence on undisturbed recharge-discharge processes and their declining quantity and water quality. They are also considered under extreme threat from land and water resource development and altered surface-groundwater interactions.	74					
	M - Permanent rivers/streams/creeks; includes waterfalls		Salt Creek is undergoing another period of change in water regime due to regulation of flows from Morella Basin and it contains significant stands of <i>Gahnia</i> sp. (see Section 5.2.1). Based on this, it is considered extremely vulnerable and under extreme threat.	75					
	R - Seasonal/ intermittent saline/ brackish/alkaline lakes and flats		Although covering a large area, this wetland type is still considered vulnerable because of dependence on close connections with other habitats, and the need for high lagoon levels and/or winter rainfalls for inundation.	76					
	Ss - Seasonal/ intermittent saline/ brackish/alkaline marshes/pools		This type of wetland is well represented in area but is still considered to be vulnerable. This is based primarily on threats to the maintenance of habitat connectivity between these wetlands and Types G, W, R and Xf at high elevations around the South Lagoon. This rating takes into account that this type is partly found within Coorong National Park, and that these areas receive management attention.	77					

Element of ecological character		Traffic lights	Rationale given for traffic light assessment(s)	Page in the Repor				
Primary determinants of ecological character								
Estuarine- saline units (continued)	W - Shrub-dominated wetlands; shrub swamps, shrub- dominated freshwater marshes, shrub carr, alder thicket on inorganic soils		The mosaic of <i>Gahnia</i> sp. (see Section 5.2.1) and <i>M. halmaturorum</i> represents vital habitat that is considered to be under threat due to this wetland type's reliance on freshwater inflows and the likely conversion from W to Ss if inflows reduce. These wetlands are also considered vulnerable because the species assemblages are under-represented at a State level, have very fine tolerances for water regime and are difficult to re-establish if lost.	78.				
	Xf - Freshwater, tree- dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils		Large areas of this wetland type remain around the South Lagoon but they are considered to be under threat from land and water resource development and vulnerable because they represent the only wetland tree in the bulk of the Ramsar site and as such perform a myriad ecosystem processes.	79				
	Y - Freshwater springs; oases	•	There has been a marked decline in the number of active soaks—see comments from the Ngarrinjeri community and long-term stakeholders—and the quality and quantity of water in those that remain. These soaks are considered to be under immediate and extreme threat of loss as a habitat type and vulnerable to changes in groundwater dynamics, reduced recharge in recent years and surface disconnection by animals digging for water. Their loss would be catastrophic to the terrestrial and aquatic fauna of the Younghusband Peninsula in particular.	80				
Ramsar Signific	ant Biological Components							
Endangered an plant species	nd vulnerable		Despite the lack of comprehensive data, this rating is recommended taking into consideration the endangered and vulnerable status of the species concerned and applying the precautionary approach. Surveys are recommended as a high priority to clarify the situation and, if indicated, to introduce specific management interventions.	84				
Swamps of the	Fleurieu Peninsula		While there remain caveats on the estimated areal extent of this ecological community within the Ramsar site, this rating is given taking into consideration that the community is listed as critically endangered and that recovery actions are underway. Without the latter, the rating would be 'red'.	87				
Mount Lofty Rar	nges Southern Emu-wren		While there remain caveats on the estimated population size and areal extent of its primary habitat within the Ramsar site, this rating is given taking into consideration that the species is listed as endangered and that recovery actions are underway. Without the latter, the rating would be 'red'.	91				
Orange-bellied	l Parrot		While the population size and areal extent of its primary habitats within the Ramsar site remains unknown, this rating is given taking into consideration that the species is listed as endangered nationally and that recovery actions are underway. Without the latter, the rating would be 'red'.	95				
Southern Bell Fr	og		Despite the lack of comprehensive data, this rating is recommended taking into consideration the vulnerable status of the species concerned and applying the precautionary approach. The traffic light assessment for many of the likely habitats of this species within the Ramsar site (see Section 4.1) is also a factor. Surveys are recommended as a high priority to clarify the situation and, if indicated, to introduce specific management interventions.	101				

Element of ecological character	Traffic light	Rationale given for traffic light assessment(s)	Page in the Repor
Ramsar Significant Biological Components	;		
Gahnia vegetation association		While the areal extent of this association is considered approximate, this rating is given taking into consideration that the Coorong and Lakes Ramsar site is thought to contain 96% of the remnant populations within the South Australian portion of the Murray-Darling Basin. Further surveys and studies are needed as a priority to clarify the status and management needs of this association.	105
Breeding, wetland-dependent birds		Urgent action is needed to provide the ecological conditions that support waterbird breeding, in particular, to arrest the declines of the key food items <i>Ruppia tuberosa</i> and Small-mouthed Hardyhead (see Section 6).	108
Wading birds, including migratory species	•	Urgent intervention is warranted based on survey data and the findings of Paton (2005a, b) and Geddes (2005) in particular. Their data clearly show how the ecological character of the North and South Lagoons have changed, and are continuing to change, in ways that are detrimental to the waterbird (and fish—see Section 5.6.3) communities. The loss of keystone aquatic plant species and key food items such as hardyhead fish indicate this part of the Ramsar site is critically endangered, and warrants listing as such under the EPBC Act (see Section 8).	120
Cape Barren Goose	•	There are no indications at present that this species, despite being rare in South Australia, is facing any immediate threat, or that the population has declined over recent years. Being a generalist feeder, less reliant on aquatic resources than other birds from this site, and breeding on off-shore islands may have insulated this species from some of the impacts noted for other bird species in the preceding sections. Further investigations are needed to set robust LAC for the aspects referred to above.	134
Obligate freshwater fish species		Population numbers are not confirmed although some of the smaller species have restricted distributions and increasingly isolated habitats. This assessment level is therefore recommended to reflect a precautionary approach and that some of the important key habitat areas are known to face threats (see Section 4.1.4).	
Diadromous fish species	•	Population numbers are not known although six of these seven species are being considered for inclusion on the South Australian list of species of conservation concern. This assessment level is therefore recommended to reflect a precautionary approach and that being able to move through the barrages is a critical life history strategy for these species.	149
Euryhaline or estuarine species	•	While population numbers are not known, oral history information, some commercial fishing data and scientific studies indicate serious declines in the populations of a number of these species over the past 30-40 years. The decline of Small-mouthed Hardyhead is of special note given its key role as a food item for waterbirds. This decline is considered to be associated with the loss of the keystone <i>Ruppia</i> aquatic plant species (see Sections 5.4 and 6.3).	155
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Recommended monitoring framework



The Ramsar Convention and the Commonwealth Government's Environment Protection and Biodiversity Conservation Act 1999 encourage the establishment of a comprehensive monitoring program. This section details the objectives, considerations and the recommended or existing programs for monitoring the change of ecological character.

■ 9.1 Introduction

Section 1 of this report noted that for Wetlands of International Importance (Ramsar sites), the fundamental management obligation is to retain the ecological character. Signatory governments are expected to have documented ecological character and have in place procedures to detect if any threatening processes are likely to, or are, altering the ecological character. The Commonwealth Government's Environment Protection and Biodiversity Conservation Act 1999 provides legal force to this primary Ramsar Convention obligation.

In the preceding sections of this report, the ecological character of the Coorong and Lakes Ramsar site has been described and established benchmarks with limits of acceptable changes ascribed to each, where possible. This should provide the site managers with the basis for developing a comprehensive range of management targets to pursue through the revision of the management plan for the site. In this Section, a monitoring program framework is recommended which is designed to give the site managers the best possible, and earliest indications, that the ecological character of the site has, or may be, changing.

The development of this monitoring framework has taken into consideration the targets set in the Asset Plan for this site under the Living Murray Initiative (DWLBC, 2005). At the time of preparing this report, a monitoring program for the Asset Plan was under development and it is hoped that these two processes can be aligned in the future to avoid duplication of effort.

■ 9.2 Objectives

As indicated above, the objectives of the monitoring program are prescribed by the requirements of the Ramsar Convention and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999—to maintain the ecological character of the site. Therefore, the monitoring program needs to be able to detect change in ecological character in order that corrective actions can be taken at the earliest opportunity.

The Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC & ARMCANZ, 2000) set out a structure for the development of aquatic monitoring programs. This systematic, scientifically sound approach encompasses all aspects of monitoring program design from the defining of the scope and setting of objectives to reporting and dissemination of information. In addition, it contains a feedback loop and recognises that the design of a monitoring program is an iterative process and recommends the refinement of earlier components on the basis of findings at a later stage (i.e. the adaptive



Murray Mouth and Estuary

management cycle of plan, do, check, review). While the detailed stages of the ANZECC & ARMCANZ monitoring framework, such as field sampling and laboratory analyses are beyond the scope of this project, the principles for the setting of objectives and study design have been adopted for the development of the monitoring program of the ecological character of the Coorong and Lakes Ramsar site.

Describing the ecological character of the Coorong and Lakes Ramsar site (see Sections 3–7 of this report in particular) key system drivers, levers and significant biological components and processes were identified and described. These form the basis of the objectives of the monitoring program. For each of these, an attempt has been made to document a benchmark condition or status with an associated limit of acceptable change LAC. Limits of acceptable change indicate the tolerance or variation that is considered acceptable without resulting in a change of ecological character (see Section 2.6). The ecological character benchmarks provided in Sections 4, 5 and 6, and summarised in Section 8 are based on a combination of data collected leading to up to and since Ramsar listing took place in November 1985. As noted in Sections 4, 5 and 6 there are many areas in which significant knowledge gaps exist, and these have been identified as key areas for further investigations.

The objectives of the monitoring program set out in below are as follows:

- 1. To gather information in order to provide, or improve, the benchmark descriptions and limits of acceptable change for the drivers, levers, components and processes of the Coorong and Lakes Ramsar site.
- 2. To detect change, or likely change, in the ecological character of the site as set out in Section 3-8 of this report; this is to be done by undertaking monitoring at three levels.
 - -ecosystem drivers and levers
 - -extent and condition of wetland types
 - -Ramsar Significant Biological Components (RSBC).

9.3 Fundamentals of monitoring

Study type and scope

ANZECC & ARMCANZ (2000) identifies three distinct study types:

- · descriptive studies which gather data to document the state of a system
- studies that measure change
- studies that improve system understanding.

As an aside, another important consideration here is monitoring of management systems and processes. These can be a vital part of the monitoring regime because it is often the management system that is failing and will ultimately be reflected by ecological damage. If the management system is robust among those with a hands-on responsibility, then risks to the managed environment can be reduced, or at least dealt with sooner.

In order to meet the objectives stated above (in Section 9.2), it is recommended that the monitoring undertaken at the Coorong and Lakes Ramsar site has the followed components:

- 1. Descriptive investigations—for the key determinants of the ecological character of the system (see Section 6), wetland types (Section 4) and RSBC (Section 5) for which there is currently insufficient data to establish benchmarks and set limits of acceptable change. Included here also are those situations where interim benchmarks and limits of change have been indicated and further investigations are needed to make these more robust.
- 2. Detection of change—for the key determinants of the ecological character of the system (see Section 6), wetland types (Section 4) and RSBC (Section 5) for which benchmarks and limits of acceptable change have already been established.
- 3. Investigations to improve system understanding for the key determinants of the ecological character of the system (see Section 6), wetland types (Section 4) and RSBC (Section 5) for which there are identified knowledge gaps that go beyond simple inventory assessments, but require cause and effect determinations in order to set limits of acceptable change.
- 4. Management system performance assessment—the establishment of an Environmental Management System compliant with ISO14001 would be the desirable endpoint, but initially this would involve review of management roles and responsibility, risk assessment, action planning and management review etc.

Note: In the monitoring program recommended in Section 9.4 below, the assessment of management system performance has not been considered, although DEH and other government agencies in South Australia and at the Commonwealth level are uraed to give it priority consideration.

Sampling sites

Environmental heterogeneity is one of the most significant determinants in the design of sampling programs (ANZECC, 2000). In order to properly capture the spatial variability within the system, the study design will require the selection of multiple sites, potentially within each of the system components. This is particularly important if the benchmarks of ecological character are to be used to measure change in the system over time. The design of monitoring programs needs to balance cost effectiveness with scientific rigour.

The selection of sampling sites for this program should be aligned with other programs in particular that being proposed under the Asset Plan.

Measurement parameters

In choosing parameters and monitoring methods, preference should be given to established techniques that have been endorsed by Commonwealth, State and regional natural resource management (NRM) agencies, where appropriate. This will ensure that the program will be compliant with the requirements of regulatory authorities and compatible with other data collected in the region and across the State.

In that regard, under the national NRM program a set of Resource Condition Indicators (RCI) are being developed to guide the establishment of monitoring approaches for each 'matter for target'. These indicators currently fall into one of two self-explanatory groups, either 'agreed indicators' or 'indicators for advice'. From a wetland perspective those condition indicators of note fall under the categories of Inland Aquatic Ecosystems Integrity (Rivers and other Wetlands), which is broken down to indicators under River Condition, Wetland Ecosystem Condition and Wetland Ecosystem Extent and Distribution (no agreed indicators as yet). There are also indicators being developed under the category of Estuarine, Coastal and Marine Habitat Integrity and significant Native Species and Ecological Communities. In addition, there are water quality-related indicators for nutrients, turbidity and surface water salinity. Together, these indicators do (and will, once completed) provide a comprehensive set of wetland-related resource condition indicators. In Table 27 following, the relevant NRM program RCIs are indicated.

Frequency

Expected variability over time, and an understanding of the key determinants of the ecological character (see Section 6) dictates sampling frequency for baseline surveys of aquatic environments. Metrics such as habitat extent can be expected to change slowly and will require less frequent sampling until events occur that are likely to cause change (e.g. floods or altered land use practices). Conversely, metrics such as water quality parameters can change very rapidly, thus patterns of change are also important. For example, seasonal changes may be important for aspects of community composition and population dynamics, while episodic events such as storms can be important for water quality.

Monitoring in response to management activities such as those flagged under the Living Murray Initiative will form an important component of the monitoring undertaken at the site.

Analysis and interpretation

Due to the complex nature of this site, it is likely that multiple programs will be needed to meet the objectives of monitoring change in ecological character. Clarification or modification of monitoring objectives is only really possible if there is a degree of understanding of the ecosystem for which the monitoring program is being designed. The use of the conceptual models developed in the Asset Plan for describing the key determinants of the ecological character (see Section 6) should form the basis for developing specific objectives relevant to components of the system and or the RSBC.

In the design of monitoring programs, conceptual models can be used to define (ANZECC 2000):

- the important components of the system and the important linkages
- the key processes
- the cause-effect relationships
- the important questions to be addressed
- the spatial boundaries
- valid measurement parameters for the processes of concern; what to measure, and with what precision
- site selection
- the time and seasonal considerations.

Models should developed for the key determinants of the ecological character of the system (see Section 6), wetland types (Section 4) and RSBC (Section 5). For each of these it is likely that a subset of objectives will be required, which detail the specifics as relevant to each model.

Data collected should be used to provide both descriptive and numerical summaries of the aspects of ecological character being measured. Descriptions and summary statistical data for each of the system components should be presented and form the basis for additional investigations as required.

It is recommended that at the completion of the baseline or investigative programs that a formal report is produced that details the results of field investigations and any additional data sourced from the literature. The distinction between these two sources, however, must be made clear and reported in a transparent manner.

■ 9.4 Recommended monitoring program

The recommended monitoring program is presented in Table 27. It is based on the key determinants of the ecological character of the system, wetland types and RSBC that form the basis of the ecological character description of the site (see Sections 3-8). Activities that relate to targets within the Asset Plan (DWLBC, 2005) have been identified as well.

As with any monitoring program, there are a number of important considerations that will need to be taken into account at a finer level of detail than this broad outline can incorporate. Each of the investigations recommended in Table 27 is in fact a discrete monitoring program in its own right. Each will need to be designed with careful consideration of field sampling sites, spatial variability, frequency, precision and accuracy, selection of appropriate methods and data interpretation. While there is much monitoring currently being undertaken in the Coorong and Lakes, none of these programs has been designed specifically to measure change in ecological character. Potential synergies will require careful investigation and a thorough assessment of each of the existing programs to determine where true overlaps occur and to identify gaps that will require additional monitoring.

Finally, monitoring is of little use if it is not linked to management actions. The Asset Plan (DWLBC, 2005) links targets to management actions and should provide the basis (in part) for the management of the system and the maintenance of ecological character. The results of the programs contained in Table 27 should each be linked back to the LAC defined in Sections 4, 5 and 6 of this report, and where necessary, action taken to ensure that the ecological character of the site is maintained. In the up-coming revision of the Ramsar plan for this site. the challenge will be to ensure complementarity (where appropriate) with the Asset Plan and its targets, while also ensuring that the ecological character of the wetland is retained through a range of additional actions.

RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Primary determin	ants of ecologic	cal character (S	ection 6)			
Water quality		I	I			
Salinity	All	Yes	Surface Water Salinity (NRM RCI)	Detection of change	Regular salinity profiles in all system units (weekly at a minimum) Evaluation of compliance with salinity LAC in each component	SA Water salinity monitorin SAMDB NRMB MATs and RCTs
				Investigations to improve understanding and inform management	Conceptual model of salinity inputs, outputs, evaporation, resultant water column profiles and thresholds for key biological assets	Living Murray Initiative
Turbidity - Sediments	All	All Potentially	Turbidity	Detection of change	Regular turbidity measurements in all system units (weekly at a minimum) Evaluation of compliance with turbidity LAC in each component	DEH Baseline Water Quality monitoring Adelaide University Coorong Health Monitorin RMCWMB Wetlands Baseline Survey SAMDB NRMB MATs and RCTs
					Establish benchmark and LAC	Turbidity of tributary wetlands and submerged aquatic beds in Lakes and Coorong components (average and variability)
			Investigation to improve understanding and inform management (sediment)	Understand balance needed between desirable sediments on mudflats and undesirable high levels of turbidity in the water column	CSIRO Water Flora a Healthy Country Flinders University research	
Turbidity - Sedimentation and erosional processes	All	Potentially		Detection of change (bathymetry)	Shoreline erosion in the lakes Changes to bathymetry in the Murray Mouth and Estuary	Goolwa to Wellington LAP shore erosion monitoring (proposed) SA Water River Murray bathymetry

			amework for the ng considered of		akes Ramsar site (c iate priority	ontinued)
RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Primary determinar	nts of ecologic	cal character (S	ection 6)			
Water quality						
Nutrients	See nutrier	nt and carbon o	cycling below			
Dissolved oxygen*	All		Dissolved oxygen and temperature (NRM RCI)	Detection of change	Regular dissolved oxygen profiles in all system components preferably early morning to capture lowest levels	RMCWMB Wetlands Baseline Survey
				Investigations to improve understanding and inform management	Dissolved oxygen trends in the tributary wetlands and critical habitats identified below determined after prolonged low flow conditions and after high flow events	
Water temperature*	All		Dissolved oxygen and Temperature (NRM RCI)	Investigations to improve understanding and inform management	Improve understanding of temperature dynamics and capacity for management to influence in each component	
PAR (Photosyn- thetically active radiation)	All		Transparency (NRM RCI)	Investigations to improve understanding and inform management	Improve understanding of PAR dynamics and capacity for management to influence in each component	
Keystone species p	opulation dyr	namics				
Submerged vegetation (Ruppia megacarpa and R. tuberosa) in the Coorong	2,3	Yes		Detection of change	Seasonal areal extent (March and November)	SARDI DWLBC Drawdown Monitoring DEH Habitat Mapping and GIS

RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Primary determinar Keystone species p			ection 6)			
Submerged and emergent macrophytes in the Lakes and tributaries	4,5	Yes		Establish benchmark and LAC	Areal extent of macrophytes (March and November)	DWLBC Drawdown Monitoring Adelaide University Coorong Health Monitoring RMCWMB Wetlands Baseline Survey
				Investigation to improve understanding and inform management	Identification of core habitats and potential for expansion	
Habitat heterogene	eity and conn	ectivity				
Mosaic of types	See below	-wetland				
Habitat connectivity	See below	—wetland type	DEH Habitat mapping program			
Water regime, inclu	ding flows an	d levels				
Freshwater inflows (River Murray)	All Yes	Yes Hydrology	Detection of change (flow regime)	Daily flow volumes into and out of all system components. Seasonal flow deviation analysis against natural flow regime	DLWBC HYDSYS database SA Water (AWQC) monitoring Murray Water	
				Detection of change (flow delivery)	Evaluate if flows provided meet requirements to restore the ecological character of the site (including compliance with LAC for salinity, habitat and fish passage)	Living Murray Initiative RMCWMB Water Allocatio Planning
Freshwater inflows (Eastern Mount Lofty Ranges)	3,2	Yes	Hydrology	Detection of change (flow regime)	Daily flow volumes Seasonal flow deviation analysis against natural flow regime	SA Water (AWQC) monitoring RMCWMB monitoring EMLR Prescription
			Investigation to improve understanding and inform management (flow delivery)	Evaluate if flows provided meet requirements to restore the ecological character of the site (including compliance with LAC for salinity, habitat and fish passage)	Living Murray Initiative EMLR Prescription SEW and Southern Pygmy Perch Recovery Plans	

			ramework for the ing considered of		akes Ramsar site (c iate priority	ontinued)
RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Primary determinar	nts of ecologic	cal character (S	ection 6)			
Water regime, inclu	uding flows an	d levels				
Water levels	All	Yes	Hydrology	Investigations to improve understanding and inform management (habitat connectivity)	Daily water levels in all components and at hydrological junctions of components Calculated seasonal water level changes Calculate an index of habitat connectivity (to be developed)	DLWBC HYDSYS database Living Murray Initiative DEH Habitat Mapping
Barrage operations	All	Yes	Hydrology	Detection of change (flow regime)	Barrage gate/ fishways opening and closing times Calculated estimates of daily flow through each gate/fishway Seasonal flow deviation analysis against natural flow regime Other parameters as advised by risk assessment	DLWBC HYDSYS database SA Water (AWQC) monitoring Murray Water Living Murray Initiative SAMDB NRMB/DWBLC Barrage Operation Risk Assessment program
Murray Mouth opening	All	Yes	Estuary mouth opening/ closing	Detection of change	Annual Murray Mouth Opening Index evaluated against objective of being open 100% time	DLWBC HYDSYS database SA Water monitoring Murray Water Living Murray Initiative SAMDB NRMB MATs and RCTs
Upper South East Drainage (USEDS) inflows to South Lagoon	3,2	Yes	Hydrology and water quality	Detection of change (water level and quality)	Daily volumes of water released from Morella Basin Salinity and water levels in South Lagoon Water quality parameters as advised by risk assessment	DEH Upper South East Risk Assessment program

Section 6
* This monitoring could be done in conjunction with that for salinity and turbidity without great additional cost

			ramework for the ing considered of		ıkes Ramsar site (c iate priority	ontinuea)
RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Primary determina	nts of ecologic	cal character (S	ection 6)			
Water regime, incl	uding flows an	d levels				
Groundwater		Potentially	Hydrology	Establish benchmark and LAC	Confined and unconfined water levels, salinity and hydraulic gradients	DLWBC OBSWELL databas RMCWMB groundwater monitoring program
				Investigation to improve understanding and inform management	Surface -groundwater interactions in the Ramsar site, particularly where critical for habitat maintenance	CSIRO Water for a Healthy Country
Wetland types, ext	ent, condition	and connectivi	ty (Section 4)			
Twenty-three wetland —Section 4.14 and 4.2.4	All	Potentially	Wetland extent and distribution	Detection of change	Areal extent of wetland type (every five years or after flood flows of more than 50,000 ML/d)	DEH Habitat mapping program
	All	Potentially	Wetland condition	Establish benchmarks and LAC, and then monitor	Determine 'condition' indicators for each type	
	All	Potentially	Connectivity between types	Establish benchmarks and LAC, and then monitor.	Identify zones of connectivity and prioritise these for monitoring and management intervention, as required	DEH Habitat mapping program
Ramsar Significant	Biological Co	mponents (Sect	ion 5)			
Given their icon sto	atus, priority co	ould be justified		esources to gaining	an improved understa	ate monitoring programs. nding of the dynamics within
Endangered and vulnerable plant species— Section 5.1.1	2,3,4,6 deter- mined by habitat type	No	Significant native species	Establish benchmarks and LAC, then detection of change	Areal extent and distribution of endangered and vulnerable plant species within the Ramsar site Habitats required by endangered and vulnerable plant species within the	DEH Habitat mapping program Various recovery plans as detailed in Section 4.4.1

RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs		
Ramsar Significant Biological Components (Section 5)								
Swamps of the Fleurieu Peninsula —Section 5.1.2	6	No	Significant native communities	Establish benchmarks and LAC, then detection of change	Areal extent and condition of the ecological community within the Ramsar site	Southern Emu-wren Recovery Team		
Mount Lofty Ranges Southern Emu-wren —Section 5.1.3	6	No	Significant native species	Establish benchmarks and LAC, then detection of change	Population of Emu-wren in the Ramsar site Areal extent of critical Emu-wren habitat	Southern Emu-wren Recovery Team		
Orange-bellied Parrot—Section 5.1.1	1,2,3,4,5	No	Significant native species	Establish benchmarks and LAC, then detection of change Descriptive baseline	Population of Orange-bellied Parrot within the site Identify critical habitats for Orange-bellied parrots within the Ramsar site	Orange-bellied Parrot Recovery team		
Southern Bell Frog—Section 5.1.5	4	No	Significant native species	Establish benchmarks and LAC, then detection of change Descriptive baseline	Population of Southern Bell Frog within the site Identify critical habitats for Southern Bell Frog within the Ramsar site	RMCWMB Wetlands Baseline Survey Waterwatch		
Gahnia vegetation association —Section 5.2.1	All possibly	No	Significant native communities	Establish benchmarks and LAC, then detection of change	Areal extent and distribution of the Gahnia vegetation association (annually)	DWLBC Drawdown Monitoring		
Waterbird breeding habitats within the Ramsar site —Section 5.3	All	Potentially	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Areal extent of preferred breeding habitats: reedbeds, shrublands and grasses mostly Population dynamics of breeding waterbirds within the site	DEH Habitat mapping program DEH Waterbird and wade numbers in the southern Coorong National Park		

RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Ramsar Significant B	Biological Co	mponents (Sect	ion 5)			
Migratory and other wader habitats— Section 5.4	All	Yes	Estuarine, coastal and marine habitat extent and distribution	Detection of change. Refine benchmarks and LAC	Targeted surveys to provide finer level of detail on available waterbird habitats across the whole site Areal extent and suitability of habitat types Population dynamics of migratory and other waders within the site	DWLBC Drawdown Monitoring DEH Waterbird and wader numbers in the southern Coorong National Park
Other significant waterbirds within the Ramsar site (Cape Barren Goose)—Section 5.5.1		No	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Critical habitats for other significant waterbirds within the Ramsar site Population dynamics of other significant waterbirds within the site	DEH Cape Barren Geese monitoring program
Obligate freshwater fish habitats—Section 5.6.1	4,5,6	Yes	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Habitat requirements of the freshwater fish of the Ramsar site Population estimates	SARDI Murray Barrage Fish Passage Program DEH Habitat mapping program
Diadromous fish habitats—Section 5.6.2	All	Yes	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Habitat requirements of the diadromous fish of the Ramsar site. Population estimates	DWLBC Drawdown Monitoring DEH Habitat mapping program.
Euryhaline and estuarine fish —Section 5.6.3	1,2,3	Yes	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Habitat requirements of the euryhaline and estuarine fish of the Ramsar site Population estimates	DWLBC Drawdown Monitoring DEH Habitat mapping program
Marine stragglers —Section 5.6.4	1,2,3	Yes	Estuarine, coastal and marine habitat extent and distribution	Establish benchmarks and LAC, then detection of change	Population estimates of marine stragglers within the site	DWLBC Drawdown Monitoring

RSBC	System units	Overlap with Asset Plan target	NRM Resource Condition Indicator /attribute (see Section 9.3)	Type of monitoring	Information required	Potentially relevant existing programs
Nutrient and carbo	n cycling					
Nutrient cycling	All	Yes		Establish benchmark and LAC	Bioavailable nutrients (NH4, NOx, PO4) in the sediment and water column of each system component	DEH Baseline Water Quality monitoring Adelaide University Coorong Health Monitoring RMCWMB Wetlands Baseline Survey
				Investigation to improve understanding and inform management	Nutrient cycling and the impact of nutrient enrichment on the biota of the Ramsar site is a major knowledge gap	

SYSTEM UNITS

1 - Murray Mouth and Estuary; 2 - North Lagoon; 3 - South Lagoon; 4 - Lake Albert; 5 - Lake Alexandrina; 6 - Tributary wetlands



Cape Barren Geese, one of the Ramsar site's few well-managed bird species

Cited references and other reading



A wide array of publications, published papers, organisations and people were consulted in the development of Ecological Character: Coorong, Lakes Alexandrina and Albert Wetland of International Importance.

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Appendix A: Australian Ramsar Management Principles (EPBC Act, 1999)

The Commonwealth Government's Environment Protection and Biodiversity Conservation Act 1999 (see section 1) seeks to encourage the preparation of management plans for Ramsar sites in Australia and that such plans comply with the Australian Ramsar Management Principles. These principles are presented below.

A management plan for a declared Ramsar wetland should:

- (a) describe its ecological character; and,
- (b) state the characteristics that make it a wetland of international importance under the Ramsar Convention: and
- (c) state what must be done to maintain its ecological character; and
- (d) promote its conservation and sustainable use for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem; and
- (e) state mechanisms to deal with the impacts of actions that individually or cumulatively endanger its ecological character, including risks arising from:
 - (i) physical loss, modification or encroachment on the wetland; or
 - (ii) loss of biodiversity; or
 - (iii) pollution and nutrient input; or
 - (iv) changes to water regimes; or
 - (v) utilisation of resources; or
 - (vi) introduction of invasive species; and
- (f) state whether the wetland needs restoration or rehabilitation; and
- (g) if restoration or rehabilitation is needed explain how the plan provides for restoration or rehabilitation; and
- (h) provide for continuing monitoring and reporting on the state of its ecological character; and
- (i) be based on an integrated catchment management approach; and
- (j) include adequate processes for public consultation on the elements of the plan; and
- (k) be reviewed at intervals of not more than 7 years.

Appendix B: Ecosystem services of the Coorong and Lakes Ramsar site

The following is based on the definition of ecosystem services as promoted by the *Millenium Ecosystem Assessment*, and as now endorsed for use under the Ramsar Convention through Resolution IX.1 of the 9th Conference of the Contracting in November 2005.

Ecosystem service	Details	Source
Provisioning services		
Wetland products	Water source for irrigators (horticulture, viticulture)	1
	Drinking water supply (Augmentation of Adelaide's water supply)	1
	Commercial and recreational fisheries	1
	Commercial cockle industry	1
	Grazing	1
Regulating services		
Maintenance of	Flood mitigation	2,3
hydrological stability	Groundwater interactions	2
Water purification	Removal and dilution of wastewaters from irrigation areas, urban areas and septic tanks	Ex
Coastal shoreline and river	Reduce impacts of wind and wave action and currents	Ex
bank stabilisation	Prevent erosion by holding sediments with plant roots	Ex
Sediment and nutrient retention	Flood retardation and sediment and nutrient deposition	Ex
Local climate regulation	Local climate stabilisation, particularly in relation to rainfall and temperature	KG
Climate change mitigation	Sequestering of carbon	KG
Biological control of pests and diseases	Support of predators of agricultural pests (for example ibis feeding on grasshoppers)	Ex
Cultural services		
Recreation and tourism	Boating and water-skiing	1
	Fishing (see above also)	1
	Bird watching and sightseeing	1
	Swimming, picnicking and camping	3
Cultural values	Aesthetics, amenity	Ex
	Cultural and spiritual significance for the Ngarrindjeri people	Ex
	Educational and research site	Ex
Supporting services	•	
Food web support	Nutrient cycling	KG
	Primary ecosystem production	Ex
Ecological values (as presented in the draft	Representative of a unique ecosystem (globally, nationally and regionally)	2
revised Ramsar Information	Supports a large variety of ecological communities	3
Sheet – see Appendix C)	Supports a number of globally and nationally threatened species and communities	2
	Supports a high diversity of species and assemblages important for conserving biodiversity at the bioregional scale	3
	Supports animal taxa at critical stages of their lifecycle and during drought	2,3
	Supports significant numbers and diversity of wetland-dependent birds, including migratory species listed under the JAMBA and CAMBA agreements.	2,3
	Supports significant numbers and diversity of native fish, including migratory species.	2,3

Sources:

- 1= management plan for the site;
- 2 = Ramsar Information Sheet (See Appendix C);
- 3 = Asset Plan (DWLBC, 2005);
- Ex = Expert opinion recognition that the services occurs at the site but may not have been actually listed in a key document;
- KG = Knowledge gap see below.

Appendix C: (Draft Revised) Information Sheet on Ramsar Wetlands (RIS)

Name and address of the compiler(s) of this form:	South Australia Department of Environment and Heritage. Contact: Tim Wilson, Senior Ramsar Officer, Coorong and Lower Lakes Regional Conservation, South East, Department for Environment and Heritage, Telephone: +61 8 8555 0296 Email: wilson.timj@saugov.sa.gov.au		
Date this sheet was completed/updated:	Site designated 1 November 1985 RIS update March 2006		
3. Country:	Australia		
4. Name of Ramsar site:	The Coorong, and Lakes Alexandrina and Albert Wetland, South Australia		
5. Map of the site included?			
5a) hardcopy	a) Yes		
5b) digital (electronic) format	b) Yes		
6. Geographical coordinates:	Latitude: (approx.) 35 degrees 18'S to 36 degrees 33'S.; Longitude: (approx.) 138 degrees 46'E to 139 degrees 50'E.		
7. General location:	The mouth of the River Murray, South Australia.		
8. Elevation:	Sea level		
9. Area:	140,500 ha. (approx.)		
10. Overview:	The Coorong is a long, shallow brackish to hypersaline lagoon more than 100 km in length that is separated from the Southern Ocean by a narrow sand dune peninsula. The Lakes Alexandrina and Albert form the mouth of the River Murray and are comprised of fresh to brackish/saline waters. Wetlands specifically included are: Lake Alexandrina including Tolderol, Mud Islands and Currency Creek		
	Game Reserves, otherwise mainly Crown Lands. 76,000 ha.		
	Lake Albert. Mainly Crown Lands. 16,800 ha.		
	 Coorong - mainly covering Coorong National Park and Game Reserve, otherwise mainly Crown Lands. 47,700 ha. 		
	The site is one of Australia's icon wetlands and biodiversity 'hot-spot' supporting critically endangered, endangered, threatened and vulnerable species and ecological communities. It is also supports extensive and diverse waterbird, fish and plant assemblages; reliant on its complex mosaic of wetland types.		
	The area is a popular recreational site, while also supporting a range of commercial activities related to tourism and commercial fishing most notably.		
	The Ngarrindjeri Indigenous people have a long association with the Coorong and Lakes and the site has great cultural significance for them. They retain these close links with the wetland and its biodiversity through these cultural links.		

11. Ramsar site criteria met by the site:

The site qualifies as a Ramsar site against the following criteria (as provided in full below along with justification for their application in each case):

Note: at the time this site was designated (in 1985) the two fish-related criteria 7 and 8 (see below) did not exist. This revision of the RIS has been able to establish that the site clearly qualifies against both these criteria as well. Further, in November 2005 at Ramsar's 9th Conference an additional criterion was added, as follows:

Criterion 9:

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.

At this time it is not possible to confirm that the site also qualifies against this additional criterion. It is possible that it does for some of the native fish species found within the site, but there is insufficient population data for these species at present to be able to make such a conclusion.

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12. Justification of the criteria selected under 11 above:				
Criteria for designating Wetlands of International Importance	Justification			
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 Coorong and Lower Lakes represent a unique wetland system comprising a natural wetland system with associated shoreline marshes at the mouth of the River Murray connected with the Coorong - a long, narrow wetland complex extending from the Murray Mouth to parallel coastal dunes and consisting of saline marshes, samphire, freshwater soaks and open water with a hypersaline area at the southern end. The full range of wetland types is described in section 17. This shows the presence of 23 different wetland tyypes spread across the marine/coastal, inland waters and human-made categories.			
Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	The site partially supports one critically endangered ecological community plus populations of a number of internationally or nationally threatened species included in the global 'red list' of the World Conservation Union (IUCN) or listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Full details are given in Attachment 1. In summary: Lying partly within the Ramsar-listed area are the 'Swamps of the Fleurieu Peninsula'; a critically endangered ecological community under the EPBC Act. These swamps are habitat (in part) of the endangered Mount Lofty Ranges Southern Emu-Wren. Notable among the species listed in Attachment 1 are the following fauna: Some of the notable species under this criterion are: Fauna: Orange-bellied Parrot, Mount Lofty Ranges Southern Emu Wren, Southern Bell Frog, Yarra Pygmy Perch, Murray Cod and Murray Hardyhead,. Flora: 6 wetland-dependent species, including, Silver Daisy-bush, Fat-leaf Wattle and Osborn's Eyebright.			
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.	In addition to the above-referred to species and ecological community of note, the Coorong and Lower Lakes Ramsar site also supports a large number of taxa and communities of biodiversity significance. These are detailed in Attachment 2. The vegetation association of Smooth Cutting Grasses (Gahnia spp.) has been provisionally listed as a threatened ecosystem within the agricultural district of South Australia. In addition there are the following of note; 5 waterbird species, 20 fish species and 1 plant species.			
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.	Attachment 3 sets out the details of those species that qualify the site under this criterion. It includes the following: Fish: 20 species in addition to the 20 listed under criterion 3, these including a number of migratory or diadromous species; Birds: 49 species including 25 migratory waterbird birds listed under the Japan-Australia and China-Australia Migratory Bird Agreements (JAMBA and CAMBA respectively) plus many resident species that breed within the site or rely on it for refuge during times of drought.			
Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 of more waterbirds.	This site supports well in excess of 20,000 waterbirds, at times reaching populations estimated at between 10 and 20 times greater. The significant species that comprise this large waterbird community include the 51 species listed under criterion 4 and 16 listed under criterion 6. In addition, there are a further 13 species of note as listed in Attachment 4.			
Criterion 6: A wetland should be considered	There are 16 species that have been regularly recorded in			

internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.	numbers exceeding the 1% level (see Attachment 5). Among these are the following; two grebe species, the Cape Barren Goose, Sharp-tailed and Curlew Sandpipers, three species of plover, the Banded Stilt, Red-necked Avocet and the Fairy Tern.
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.	The Coorong and Lower Lakes are considered significant for 49 fish species. Taken collectively they qualify the site under this criterion because of their biodiversity and biodisparity. The transitional environment from fresh to marine waters makes this site a unique habitat for fish species. The full list of these species can be found in Attachment 1, 2 and 3 plus Table 6.
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.	As indicated above the site is important for 49 marine, freshwater and diadromous fish species. Of these, all but 6 are considered reliant on the ecosystem in the ways specified under this criterion.

13. Biogeography:	
13a) Biogeographic region:	Murray-Darling Depression and Naracoorte Coastal Plain.
13b) Biogeographic regionalisation scheme:	Interim Biogeographic Regionalisation of Australia (IBRA) Version 5.1. Department of Environment and Heritage, Canberra.
14. Physical features of the site:	The Lakes Alexandrina and Albert form a semi-natural wetland system with associated shoreline marshes at the mouth of the River Murray and are connected with the Coorong - a long, narrow wetland complex extending from the Murray Mouth to parallel coastal dunes and consisting of saline marshes, samphire, freshwater soaks and open water with a hypersaline area at the southern end.
15. Physical features of the catchment area	The Coorong and Lower Lakes are located at the downstream end of the Murray-Darling system; Australia's largest river basin. The River Murray terminates at the Southern Ocean in South Australia, where it passes through Lakes Alexandrina and Albert, the Murray estuary, the Coorong and Murray Mouth.
16. Hydrological values:	The Coorong and Lower Lakes receive local runoff and rainfall plus inflows at the northern end of the system from the River Murray. In addition there are groundwater inputs and inflows into the South Lagoon from the Upper South East drainage scheme via Salt Creek.
	The Lower Lakes are separated from the Murray Mouth and Coorong by a system of barrages. They were constructed between 1935 and 1940 to provide fresh water for irrigation, stock and domestic purposes (MDBC 2004d). Recently, fishways were installed on Goolwa and Tauwitchere barrages to enable fish passage between the Lower Lakes and the Murray Mouth/Coorong.

17. Wetland types:

a) presence:

The Ramsar site contains those wetland types shown in the table below.

b) dominance:

Based on the calculated area of each type, the dominant types within each of the marine/coastal, inland and human-made categories are shaded.

Note: This represents the breakdown of types and their respective areas for 2005, not 1985 when the site was listed.

Marine/Coastal Wetlands	Area (ha)
A Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits.	50
D Rocky marine shores; includes rocky offshore islands, sea cliffs.	788 ⁻
E Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.	1,020#
F Estuarine waters; permanent water of estuaries and estuarine systems of deltas.	2,200

G Intertidal mud, sand or salt flats.	3,142
H Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.	536
I Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.	4
J Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.	10,128
K Coastal freshwater lagoons; includes freshwater delta lagoons.	41
Inland Wetlands	
M Permanent rivers/streams/creeks; includes waterfalls.	221
N Seasonal/intermittent/irregular rivers/streams/creeks.	200
O Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.	79,480
P Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.	120
R Seasonal/intermittent saline/brackish/alkaline lakes and flats.	1,729
Ss Seasonal/intermittent saline/brackish/alkaline marshes/pools.	1,274
Tp Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.	4,474
Ts Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.	1,037
W Shrub-dominated wetlands ; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.	4,875
Xf Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.	1,470
Y Freshwater springs; oases.	<10
Human-made wetlands	
4 Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).	1,235
6 Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).	1
9 Canals and drainage channels, ditches.	44

Types not found in the system have been deleted from the table.

The total area of wetland types is approximately 114,100 hectares. The balance of the Ramsar site (approx 26,400 hectares)is comprised of terrestrial habitat which is not classified by the Ramsar Convention.

18. General ecological features:	The Coorong
	The Coorong is a 140 km long expanse of water, separated from the Southern Ocean by a narrow coastal dune barrier. It forms part of the extensive wetland system of the Lower Murray, which covers a total area of 660 km² (AWE 2003). In addition to local runoff and rainfall, the Coorong receives inflows at its northern extremity from the River Murray, groundwater inputs and inflows into the South Lagoon from the Upper South East drainage scheme via Salt Creek.
	The Coorong is the only estuarine area within the River Murray system. It can be divided into three distinct components based on different salinity patterns - the Murray estuary, the Northern Lagoon and the Southern Lagoon
	A key feature of the Coorong is the salinity gradient, which increases with distance from the Mouth. Salinity in the Coorong changes from estuarine in the Murray estuary, influenced by freshwater flows over the barrages, to hypersaline in the Southern Lagoon.
	Murray estuary
	The Murray estuary includes the area around the Murray Mouth from the Goolwa barrage to Pelican Point and encapsulates the Goolwa, Coorong and Mundoo channels. The area is naturally estuarine, but salinity levels fluctuate

^{* =} includes 165 ha from Lake Alexandrina a freshwater part of the system.

^{# =} includes 6 ha from Lake Alexandrina and 1 ha from Lake Albert; freshwater parts of the system

widely due to barrage-regulated flow. The lagoon environment, which includes habitats such as exposed mudflats, *Ruppia megacarpa* beds and shallow waters, provides important foraging grounds for many wader species.

North Lagoon

The North Lagoon is characterised by similar conditions as the Murray estuary, with barrage releases controlling salinity. The salinity gradient increases southwards along the North Lagoon, which extends from Pelican Point to Parnka Point, where it reduces to a small bottleneck that separates it from the South Lagoon.

South Lagoon

South of Parnka Point, the South Lagoon extends past Salt Creek where it becomes a series of predominantly hypersaline ephemeral lagoons. The South Lagoon varies from estuarine to hypersaline. The 'natural' salinity of the Coorong is currently under debate, as it is believed that the Coorong is more saline now than prior to river regulation (for example, Geddes and Hall 1990).

Salinities are affected by flow over the barrages and Upper South East Drainage inflows. During times of low freshwater flow, salinity levels in the lagoon become two to three times that of seawater. Water levels, quality and temperature in the South Lagoon are influenced by tidal exchange and River Murray flows into the Northern Lagoon (EconSearch 2004a).

Murray Mouth

The Murray Mouth is a tidal inlet restricted by the accumulation of dune material on the flanking spits of Sir Richard Peninsula and Younghusband Peninsula. It is located in a high-energy environment and is extremely dynamic. The location, size and shape of the Mouth and the adjacent estuary are dictated by a combination of river flows, tidal flows and ocean and coastal processes (Harvey 2002).

Large volumes of sand are continually being moved through the Mouth by daily tides. The capacity of the tides to transport sand is dependent on two main factors – tidal velocity and wind/wave action in the immediate vicinity of the Mouth. Tidal velocity is determined by the tidal range, flow over the barrages and the existing water level in the estuary. Even small river flows counteracting the incoming tide may result in a significant reduction in the consequent sediment load in the Mouth region (Harvey 2002).

Lakes Alexandrina and Albert

Prior to European settlement, the Lower Lakes were predominantly fresh, with river water discharging to the sea and keeping the Murray Mouth clear. Saltwater intrusions into the Lake environment were not common until after 1900 when significant water resource development had occurred in the River Murray system (Sim & Muller 2004). Short-lived intrusions of saltwater would occur during periods of low flow down river resulting in a lower lake level; however it appears that only small areas of the Lakes, around the Mouth and channels, were affected.

The Lower Lakes system would have offered a mosaic of fresh, brackish, saline and hypersaline fringing wetland systems that interconnected across time and space (MDBC 2004c)." (DWLBC, 2005))

Tributary wetlands

The lower reaches of Finniss River, Tookayerta Creek and Currency Creek lie within the Ramsar site. The terminal reaches of the Finniss River and Tookayerta Creek are structurally diverse and thus support dense and diverse wetland flora, ranging from red gum and reed lined channels to broader swamps with a full complement of wetland floral assemblages below Tuckers Ford on the Finniss River.

19. Noteworthy flora

"Submerged aquatic vegetation in the Coorong is dependent on the salinity and water regime. Main species found in the Coorong include *Ruppia tuberosa* (tuberous tassel), *Ruppia megacarpa* (large-fruit tassel), *Lamprothamnium papulosum* (musk grass or stonewort), *Lepilaena* (long-fruit water mat), *Cladophora* and *Zostera* (seagrasses) (Oborne 2003). *Ruppia* is a very important species in the food chain, particularly for waders and water birds. *R. megacarpa* is found in the North Lagoon and is a seed bearing perennial plant requiring permanent water cover. *R. tuberosa* is found in the South Lagoon and is an annual plant which survives by producing seeds and turions through spring and summer, a key food source for waders and water birds (Oborne 2003).

Submerged vegetation in the South Lagoon is characterised by extensive areas

	of <i>Ruppia tuberosa</i> , <i>Lepilaena</i> and <i>Lamprothamnion</i> (EconSearch 2004a). However, these areas have greatly declined in extent and quality. These submerged plants are a critical component of the habitat as they provide a source of detritus for benthic communities and architecture for juvenile fish, invertebrate and biofilm habitat.	
	Lower Lakes	
	Submerged aquatic plant communities were once extensive in the lakes system and included species such as ribbon weed (<i>Vallisneria Americana</i>), lax-marshflower (<i>Villarsia reniformis</i>), water ribbons (<i>Triglochin procerum</i>), swamp lily (<i>Ottelia ovalifolia</i>), pondweeds (<i>Potamogeton</i> spp) and milfoils (<i>Myriophyllum</i> spp).	
	Sections of the near shore environment around Lake Albert have extensive, highly significant <i>Phragmites australis</i> and <i>Typha domingensis</i> reed beds which provide excellent sheltered habitat for a range of fish and other vertebrate species, as well as long-term rookery sites for ibis, spoonbill and cormorants (EconSearch 2004a).	
	Saline wetlands have also fringed the lakes since pre-European times, but now only exist along a limited area of lakeshore. These areas supported salineadapted plant communities such as samphire shrubland, an important feeding habitat for migratory waders, waterfowl, and water birds (EconSearch 2004a). In good condition, they support diverse faunal assemblages, and several areas of seasonally inundated swamp paperbark (<i>Melaleuca halmaturorum</i>).	
	Fresh wetland areas would have received significant fresh water inputs from Eastern Mount Lofty Ranges streams, localised runoff or from infrequent, but extensive, flooding of the River Murray and would have supported a range of submerged and emergent freshwater plant communities." (DWLBC, 2005)	
20. Noteworthy fauna	See Attachments 1-6.	
21. Social & cultural values	The area is valued for its conservation - scenic attributes and is used for outdoor recreational pursuits including: wildlife observation and studies and recreational fishing and hunting. Professional fishing occurs both along the beach and in parts of the wetland complex. The area, and particularly the Coorong, is noted for its extensive Aboriginal (traditional and archaeological), historic and geological sites. The Ngarrindjeri people continue to have a close association with the area. Note: some of the northern islands within the Coorong lagoon are not part of the Coorong National Park but are reserved for use by Ngarrindjeri people. "The Ngarrindjeri are culturally and spiritually part of the Lower Murray, Lakes and Coorong region, and the Ngarrindjeri lands are crucial for the survival of	
	the Ngarrindjeri people. The fish, birds and other living things are the Ngartj (totems) of the Ngarrindjeri people, with which they have a strong spiritual connection and a responsibility to protect. This totemic relationship is deep embedded in Ngarrindjeri culture and spirituality, and provides a unique perspective on Ramsar values and the maintenance of habitats (NRWG 19 (DWLBC, 2005).	
22. Land tenure/ownership		
22a) site:	The area is mostly Crown Land (water) and National Park and Game Reserves. Lakes Alexandrina and Albert are surrounded mainly by private property.	
22b) surrounding area:	The Coorong is surrounded by National Park and Freehold Land. The Lakes and Tributaries are surrounded by Crown Land and Freehold land	
23. Current land (including water) use		
23a) within the Ramsar site:	Conservation, recreation: camping, boating, duck hunting (not over entire area; in game reserve only), water storage and extraction, grazing and cropping, urban/residential development	
23b) surrounding area or catchment:	Grazing and light farming in adjacent areas. Most of the edge of Lakes Alexandrina and Albert is used for farming, with tourist development in several areas. Development is otherwise restricted under the State Planning and other Acts and most of the area is in its natural state.	
24. Factors (past, present or potential)	adversely affecting the site's ecological character	
24(a) at the site:	"Studies over time indicate that the environmental health of the Asset has greatly declined. Geddes (2003) found that the biodiversity and productivity of the Coorong was at an historical low point. A comparison with the flora and fauna collected in the 1980s showed that the distribution and abundances of a	

	variety of species was greatly reduced. Populations had decreased in numbers and retreated to small, more favourable areas, especially around the Murray Mouth. Geddes' survey showed the poorest biodiversity and abundance record for the South Lagoon.
	Loss of the natural flow regime has had a huge impact. The natural longitudinal salinity gradient of the lagoons is now absent, reflecting the long period of limited exchange of water with barrage inflows and high evaporation in the South Lagoon. Geddes concludes that persistently high salinities probably represent a historically high salinity regime in the South Lagoon. A dramatic decline in the number of water birds utilising the Asset has been observed over the last twenty years (AWE 2003). There is also evidence of declines in native fish populations (MDBC 2004c)." (DWLBC, 2005)
24(b) around the site:	Activities around the site include agriculture and urban developments while up-stream water diversions are having a significna t detrimental im; act on the site.
25. Conservation measures taken:	The Coorong is reserved as a National Park. A management plan is in place and this is to be revised in late 2005.
26. Conservation measures proposed but not yet implemented:	SA DEH to provide advice.
27. Current scientific research and facilities:	SA DEH to provide advice.
	SA DEH to provide advice. SA DEH to provide advice.
facilities:	·
facilities: 28. Current conservation education:	SA DEH to provide advice. The wetlands and adjoining areas are used for outdoor recreation and research purposes. It is estimated that the area under the park reserve receives in excess of 200,000 visitor days per year and activities include: boating, fishing, camping, walking and wildlife observation. Access to important wetland sites -
facilities: 28. Current conservation education: 29. Current recreation and tourism:	SA DEH to provide advice. The wetlands and adjoining areas are used for outdoor recreation and research purposes. It is estimated that the area under the park reserve receives in excess of 200,000 visitor days per year and activities include: boating, fishing, camping, walking and wildlife observation. Access to important wetland sites -

Attachment 1:

Ecological communities and species that qualify against criterion 2

Decision rules applied:

- 1. Wetland-dependent/related ecological communities or species listed under the EPBC Act 1999 as critically endangered, endangered and vulnerable, and/or,
- 2. Wetland-dependent/related species listed as critically endangered, endangered or vulnerable under the IUCN Red Lists but not rare or other lesser IUCN categories.

Note: communities and species that qualify under this criterion automatically qualify under criterion 3 also. See Table 2.

Ecological communities

Swamps of the Fleurieu Peninsula

The listing of the swamps of the Fleurieu Peninsula as a critically endangered ecological community under the EPBC Act is notable in this context as this area and the Ramsar site partially overlap. This same area (in part) provides habitat for the Mount Lofty Ranges Southern Emu-Wren for further details.

Plant taxa

Common name	Scientific name	Ramsar criteria	Status - National	Status - IUCN	Status - SA
Family Asteraceae					
Silver Daisy-bush	Olearia pannosa ssp. pannosa	2,3	V		V
George's Groundsel	Senecio georgianus var. georgianus	2,3	V		E
Family Mimosaceae					
Yellow Swainson-pea	Swainsona pyrophila	2,3	V		R
Family Orchidaceae	Family Orchidaceae				
Sandhill Greenhood	Pterostylis arenicola	2,3	V		V
Metallic Sun-orchid	Thelymitra epipactoides	2,3	E		E
Family Proteaceae	Family Proteaceae				
Scarlet Grevillea	Grevillea treueriana	2,3	V		V

Animal taxa

Common name	Scientific name	Ramsar criteria	Status - National	Status - IUCN	Status - SA
Amphibians					
Southern Bell Frog	Litoria raniformis	2,3,4	V	E	V

Fish						
Hardyheads or Silversides - Family Atherinidae						
Murray hardyhead	Craterocephalus fluviatilis	2,3,4,7,8	V	E	С	
Yarra pygmy perch	Nannoperca obscura	2,3,4,7,8	V	V	P,C	
Murray cod	Maccullochella peelii peelii	2,3,7,8	V		_	

Pipefishes & seahorses - Family Syngnathidae							
Big-bellied seahorse	Hippocampus abdominalis	2,3,7		٧			
Grunters - Family Terapor	Grunters - Family Terapontidae						
Silver perch	Bidyanus bidyanus	2,3,4,7,8		V	P,C		

Birds								
Herons, Egrets, Bitterns – F	Herons, Egrets, Bitterns - Family <i>Ardeidae</i>							
Australasian Bittern	Botaurus poiciloptilus	2,3		E	V			
Parrots - Family Psittacida	ne							
Orange-bellied Parrot	Neophema chrysogaster	2,3,4	E	CE	E			
Fairy-wrens - Family Malu	ıridae							
Mount Lofty Ranges Southern Emu-wren &	Stipiturus malachurus intermedius	2,3,4	E	E	Е			

Key:

Conservation status:

National: E - Endangered, V - Vulnerable under the EPBC Act 1999.

IUCN: CE = Critically endangered, Endangered, V - Vulnerable in the IUCN Red list

State: P - protected under the Fisheries Act 1982, C - provisional State conservation concern under the draft

Threatened Species Schedule NPWSA. (refer:

http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

JAMBA = Japan-Australia Migratory Bird Agreement, CAMBA = China-Australia Migratory Bird Agreement

Notes:

& = This species is found in association with the swamps of the Fleurieu Peninsula, a critically endangered ecological community under the EPBC Act (see above).

Frog data comes from the Wetlands Baseline Survey, 2004. Southern Bell Frogs recorded at Tolderol survey site only.

Attachment 2:

Ecological communities and species that qualify against criterion 3

Decision rules applied:

- 1. Wetland-dependent/related ecological communities and species that qualify under criterion 2 also automatically qualify under this criterion. These communities and species are not shown below see Table 1.
- 2. Wetland-dependent/related plant species that are:
- (a) listed as vulnerable or endangered (but not rare) under SA legislation, and/or
- (b) listed as threatened, vulnerable or endangered regionally for the Southern Lofty botanical region
- (SL) or Murray botanical region(MU) of SA.
- 3. Native fish species that are listed at the State level as P protected under the *Fisheries Act 1982* or C provisional State conservation concern under the *draft Threatened Species Schedule NPWSA*.

Ecological communities

Vegetation association of Gahnia spp.

"The Department for Environment and Heritage has compiled a provisional list of threatened ecosystems. The vegetation association of *Gahnia filum* is identified as a vulnerable ecosystem within the agricultural district of South Australia. This ecosystem is described as a sedgeland located in

drainage lines and depressions, the distribution of intact remnants within the agricultural district is largely contained in a number of small areas within NPWSA Reserves. This is an ecosystem that historically has suffered severe degradation from drainage, increased salinity (can tolerate a certain level) and grazing. There is little regeneration evident across the agricultural districts (DEH 2001). The Coorong and Lower Lakes Habitat Database has been queried to display records of *Gahnia filum* to be included within the Core Habitat Zone. Approximately 471 hectares are identified with distribution along the northern shoreline of the Finniss River and the Western shoreline of Lake Alexandrina (50ha), scattered remnants occur throughout the Lower Lakes. Within the Coorong National Park, good remnants remain south of Parnka Point comprising of approximately 421 hectares." (Seaman, draft report 2005)

Plant taxa

Common name	Scientific name	Ramsar criteria	Status – SA	Status regionally
See Table 1 also				
Family Goodeniaceae				
Dune Fanflower	Scaevola calendulacea	3	V	

Animal taxa

Common name	Scientific name	Ramsar criteria	Status - National	Status - IUCN	Status – SA
See Table 1 also.					
Fish					
Glassfishes - Family Amba	assidae				
Chanda perch (Olive perchlet, Agassiz's glassfish)	Ambassis agassizii	3,4,7,8			P,C
Freshwater eels - Family A	Anguillidae				
Short-finned eel	Anguilla australis	3,4,7			С
Hardyheads or Silversides	- Family Atherinidae				
Fly-specked hardyhead	Craterocephalus stercusmuscarum fulvus	3,4,7,8			С
Gudgeons - Family Eleotr	ididae				
Purple-spotted gudgeon	Mogurnda adspersa	3,4,7,8			P,C
Dwarf flathead gudgeon	Philypnodon sp.	3,4,7,8			С
Western carp gudgeon	Hypseleotris klunzingeri	3,4,7,8			С
Murray Darling carp gudgeon	Hypseleotris sp.	3,4,7,8			С
Freshwater blackfishes - F	amily Gadopsidae				
River blackfish	Gadopsis marmoratus	3,4,7,8			P,C
Galaxids or Native minno	ws – Family Galaxidae				
Climbing galaxias	Galaxias brevipinnis	3,4,7,8			С
Mountain galaxias	Galaxias olidus	3,4,7,8			С
Pouched lampreys - Fam	ily Geotriidae				
Pouched lamprey	Geotria australis	3,4,7,8	_		С
Gobies - Family Gobiidae	;				
Bridled goby	Acentrogobius	3#4,7,8			

	bifrenatus		
Tamar goby	Afurcagobius tamarensis	3#,4,7,8	
Western blue spot (Swan River) goby	Pseudogobius olorum	3#,4,7,8	
Lagoon goby	Tasmanogobius lasti	3#,4,7,8	
Shorthead lampreys - Fa	mily Mordaciidae	·	
Shortheaded lamprey	Mordacia mordax	3,4,7,8	С
Freshwater basses and c	ods - Family Percichthyidae	·	
Southern pygmy perch	Nannoperca australis	3,4,7,8	P,C
Estuary perch	Macquaria colonorum	3,4,7,8	С
Eel-tailed catfishes - Fam	nily Plotosidae	·	
Freshwater eel-tailed catfish	Tandanus tandanus	3,4,7,8	Р
Congollis - Family Pseud	aphritidae	•	<u>.</u>
Congolli (Tupong)	Pseudaphritis urvillii	3,4,7,8	С
Birds			
Rails, Crakes, Swampher	ns, Coot - Family Rallidae		
Lewin's Rail	Rallus pectoralis	3	V
Curlows Sandnings Snir	nes Godwits Phalarones – Far	nily Coolongoida	 <u> </u>

Birds				
Rails, Crakes, Swamphen	s, Coot - Family Rallidae			
Lewin's Rail	Rallus pectoralis	3		V
Curlews, Sandpipers, Snip	es, Godwits, Phalaropes - Fa	amily Scolopacio	lae	
Latham's Snipe	Gallinago hardwickii	3,4	J/CAMBA CMS	V
Eastern curlew	Numenius madagascariensis	3,4,5.3	J/CAMBA CMS	V
Lapwings, Plovers, Dottere	els – Family Charadriidae			
Hooded Plover	Charadrius rubricollis	3,4,5.3,6	CMS	V
Gulls, Terns etc - Family L	aridae			
Little Tern	Sterna albifrons	3,4	J/CAMBA	V

Key:

Conservation status: E = Endangered, V = Vulnerable, T = Threatened

State: P – protected under the *Fisheries Act 1982*, C – provisional State conservation concern under the *draft Threatened Species Schedule NPWSA*. (refer:

http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

JAMBA = Japan-Australia Migratory Bird Agreement, CAMBA = China-Australia Migratory Bird Agreement, CMS = Convention on Migratory Species

Notes:

* = see above re this species and Department for Environment and Heritage compilation of a provisional list of threatened ecosystems.

= Gobies considered significant as this is the only location where they are found in the Murray-Darling Basin.

For this criterion, "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"

- for freshwater species the appropriate biogeographic unit is the Murray-Darling Basin (Hammer M. P. and Walker K. F. (2004).
- $\ \, \ \, \ \,$ for marine species the appropriate biogeographic unit is the Flindersian bioregion.

Attachment 3:

Species that qualify against criterion 4

Decision rules applied:

- 1. Supports native fish species at critical stages in their lifecycle or offers refuge.
 - All diadromous species qualify;
 - Estuarine species that spawn or have large populations qualify;
 - Species for which critical life stages are supported; such as, any freshwater taxa that spawn/recruit in the wetland qualify.
- 2. Supports birds species at critical stages in their lifecycle or offers refuge.
 - All JAMBA or CAMBA-listed migratory birds are included, since it is assumed the habitat provided by the site will be important pre- and post-migration. Convention on Migratory Species (CMS) listing on its own is ignored unless the species is within Annex I (Endangered species) of CMS.
 - Species that are migratory but not JAMBA or CAMBA listed can also be considered if they use the site at important stages of migration, and they also qualify against either criterion 5 or 6.
 - Species for which the site is considered important as a refuge during times of drought and which also qualify against either criterion 5 or 6.
 - Species that breed at the site on a regular basis (3 years in 5 on average) and which also qualify against either criterion 5 or 6.

Significant fish

Common name	Scientific name	Ramsar criteria	Status - national	IUCN status	Status- SA
Hardyheads or Silversides - Fa	mily Atherinidae				
Small-mouthed hardyhead	Atherinosoma microstoma	4,7,8			
Herrings -Family Clupeidae					
Sandy sprat	Hyperlophus vittatus	4,7,8			
Bony bream	Nematalosa erebi	4,7,8			
Blue sprat	Spratelloides robustus	4,7,8			
Gudgeons - Family Eleotridida	е				
Flathead gudgeon	Philypnodon grandiceps	4,7,8			
Midgley's carp gudgeon	Hypseleotris sp.	4,7,8			
Hybrid carp gudgeon (e.g. Lakes carp gudgeon)	Hypseleotris spp.	4,7,8			
Galaxids or Native minnows -	Family Galaxidae				
Common galaxias	Galaxias maculatus	4,7,8			
Halfbeaks - Family Hemiramhi	dae				
River garfish	Hyporhamphus regularis	4,7,8			
Rainbowfishes - Family Meland	otaeniidae				
Murray (Crimson-spotted) rainbowfish	Melanotaenia fluviatilis	4,7,8			
Grey mullets - Family Mugilida	e				
Yellow-eye mullet	Aldrichetta forsteri	4,7,8			
Jumping mullet	Liza argentea	4,7,8			
Freshwater basses and cods -	Family Percichthyidae				
Golden perch	Macquaria ambigua ambigua	4,7,8			

Righteye flounders - Family Rhor	nbosoleinae			
Greenback flounder	Rhombosolea tapirina	4,7,8		
Smelts - Family Retropinnidae				
Australian smelt	Retropinna semoni	4,7,8		
Drums - Family Sciaenidae				
Mulloway	Argyrosomus hololepidotus	4,7,8		
Scorpion fishes - Family Tetrarog	idae			
South Australian Cobbler	Gymnapistes marmoratus	4,7,8		
Breams - Family Sparidae				
Black bream	Acanthopagrus butcheri	4,7,8		
Grunters - Family Terapontidae				
Striped perch	Helotes sexlineatus	4,7,8		
Pufferfishes- Family Tetraodontid	ae			
Smooth toadfish	Tetractenos glaber	4,7,8		

Significant birds

Common name	Scientific name	Ramsar criteria	Status - national	Status IUCN @	J/CAMBA or CMS	Status- SA
Pelicans - Family Pelecani	dae					
Australian Pelican	Pelecanus conspicillatus	4, 5.1, 5.2, 5.3				
Darters - Family Anhingida	e					
Australian Darter	Anhinga melanogaster	4?				
Cormorants - Family Phala	crocoracidae					
Little Pied Cormorant	Phalacrocorax melanoleucos	4				
Pied Cormorant	Phalacrocorax varius	4				
Little Black Cormorant	Phalacrocorax sulcirostris	4, 5.1, 5.2				
Great Black Cormorant	Phalacrocorax carbo	4, 5.1, 5.2				
Geese, Swans and Ducks -	- Family Anatidae					
Australasian Shoveler	Anas rhynchotis	4			CMS	R
Australian Shelduck	Tadorna tadornoides	4, 5.1, 5.2, 5.3			CMS	
Rails, Crakes, Swamphens,	, Coot - Family Rallidae	е				
Dusky Moorhen	Gallinula tenebrosa	4				
Purple Swamphen	Porphyrio porphyrio	4, 5.3				
Herons, Egrets, Bitterns – Fa	amily Ardeidae					
Little Egret	Ardea garzetta	4				
Cattle Egret	Ardea ibis	4				
Great Egret	Ardea alba	4			J/CAMBA	

Rufous Night Heron	Nyctocorax caledonicus	4, 5.3		
Ibises, Spoonbills - Family	Threskiornidae	·		
Glossy Ibis	Plegadis falcinellus	4	CAMBA	R
Straw-necked Ibis	Threskiornis spincollis	4, 5.1		
Royal Spoonbill	Platalea regia	4, 5.3		
Yellow-billed Spoonbill	Platalea flavipes	4, 5.3		
Curlews, Sandpipers, Snipe	es, Godwits, Phalaropes	- Family Scolopacidae		
Sharp-tailed sandpiper	Calidris acuminata	4,5.3,6	J/CAMBA CMS	
Curlew Sandpiper	Calidris ferruginea	4,5.3,6	J/CAMBA CMS	
Common sandpiper	Tringa hypoleucos	4	J/CAMBA CMS	
Marsh Sandpiper	Tringa stagnatilis	4	CAMBA CMS	
Terek Sandpiper	Xenus cinereus (Tringa terek)	4	J/CAMBA CMS	
Pectoral Sandpiper	Calidris melanotos	4	JAMBA CMS	
Red-necked Stint	Calidris ruficollis	4,5.3,6	J/CAMBA CMS	
Sanderling	Crocethia alba	4,6	J/CAMBA CMS	
Common Greenshank	Tringa nebularia	4,5.3,6	J/CAMBA CMS	
Red-necked Pharalope	Phalaropus lobatus	4	J/CAMBA CMS	
Bar-tailed godwit	Limosa lapponica	4	J/CAMBA CMS	
Black-tailed godwit	Limosa limosa	4, 5.3	J/CAMBA CMS	
Great Knot	Calidris tenuirostris	4	J/CAMBA CMS	
Red Knot	Calidris canutus	4	J/CAMBA CMS	
Grey-tailed Tattler	Tringa brevipes	4	J/CAMBA CMS	
Wandering Tattler	Tringa incana	4	JAMBA CMS	
Ruddy turnstone	Arenaria interpres	4	J/CAMBA CMS	
Ruff	Philomachus pugnax	4	J/CAMBA CMS	
Oystercatchers - Family H	aematopodidae			
Pied Oystercatcher	Haematopus	4,5.3,6		

	longirostris		
Lapwings, Plovers, Dotterels	- Family Charadriid	ae	
Pacific Golden Plover	Pluvialis fulva	4,5.3,6	CMS
Grey Plover	Pluvialis squatarola	4	J/CAMBA CMS
Pacific Golden Plover	Pluvialis fulva	4	J/CAMBA CMS
Lesser Sand Plover	Charadrius mongolus	4	CMS
Oriental Plover	Charadrius veredus	4	CMS
Double-banded Plover	Charadrius bicinctus	4	CMS
Gulls, Terns etc - Family Lar	idae		
Crested Tern	Sterna bergii	4,5.1,5.2	JAMBA
Caspian Tern	Hydropogne tschegrava (Hydroprogne caspia)	4,5.3,6	CAMBA
Pacific Gull	Larus pacificus	4?	
Old World Warblers - Family	y Sylviidae		
Great (Oriental) Reed- Warbler	Acrocephalus arundinaceus		
Little Grassbird	Megalurus gramineus	4	
Golden-headed Cisticola	Cisticola exilis	4?	

The order used follows that of *Field Guide to the Birds of Australia*, 6th Edition by Simpson and Day, 1999 **Key:**

Conservation status:

National: E - Endangered, V - Vulnerable under the EPBC Act 1999.

IUCN: CE = Critically endangered, Endangered, V - Vulnerable in the IUCN Red list

State: P – protected under the *Fisheries Act 1982*, C – provisional State conservation concern under the *draft Threatened Species Schedule NPWSA*. (refer:

http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

JAMBA = Japan-Australia Migratory Bird Agreement, CAMBA = China-Australia Migratory Bird Agreement

Attachment 4:

Species that qualify against criterion 5

Decision rules applied:

Ramsar criterion 5 specifies that the site qualifies for Ramsar listing if it "...regularly supports 20,000 of more waterbirds.". At the time of listing (1985) the site regularly supported in excess of 200,000 waterbirds and so qualifying against this criterion was unquestioned. However, within the context of describing the ecological character of site this simple recognition of total number of waterbirds was considered too superficial and more specific sub-criteria were developed to help better understand the composition and ecological roles of the waterbird community of the Coorong and Lower Lakes Ramsar site. These sub-criteria are detailed below along with advice on how they have been applied.

Note: waterbird species that qualify against either criteria 4 or 6 and considered to automatically qualify against this criterion also and so are not shown in the table below.

<u>Sub-Criterion 5.1:</u> The species is a prominent component of the overall waterbird community in the Coorong and Lower Lakes Ramsar site.

A species can be listed under this sub-category if it represents a numerical contribution equivalent to at least 5% of the aquatic bird community.

- 1. Since the waterbird communities of the Coorong and Lower Lakes Ramsar site typically contain greater than 20,000 birds during the summer months (but possibly less than this number in winter), in applying this sub-criterion, species were included that regularly (at least 3 in 5 years on average) accounted for at least 1,000 individuals (5% of 20,000), irrespective of season, OR,
- 2. Where data were limited to only a portion of the Coorong or Lower Lakes site, all species that regularly (at least 3 in 5 years on average) accounted for 5% of the counts in that location were included.

<u>Sub-Criterion 5.2</u>: The species is a prominent component in ONE of the distinctive waterbird communities in the Coorong and Lower Lakes Ramsar site.

One of the most important features of the overall waterbird community of the Coorong and Lower Lakes Ramsar site is that it consists of a series of distinct communities determined primarily by the various water regimes (fresh, estuarine, hypermarine) and ecological factors (mix of open water, protected riparian areas etc).

For the purpose of documenting the ecological character of this Ramsar site, six wetland components have been identified from a geographic/ecological perspective; namely, the South Lagoon, North Lagoon, Murray Mouth and estuary; Lake Albert, Lake Alexandrina and the tributaries of all waters that enter Lake Alexandrina. Several of the waterbird communities found in these components regularly consist of more than 20,000 birds and so would in their own right qualify under Ramsar criterion 5. Therefore, this sub-criterion allows for the recognition of those species that represent on a regular basis (at least 3 out of 5 years on average), either in a numerical or through biomass contribution, the equivalent of at least 5% of the waterbird community in the relevant system component (namely, South Lagoon, North Lagoon, Murray Mouth and estuary; Lake Albert, Lake Alexandrina and the tributaries of all waters that enter Lake Alexandrina). The decision rules applied here were the same as above.

<u>Sub-Criterion 5.3:</u> The species occupies a unique or prominent foraging niche or represents a key trophic position in the aquatic bird communities of the Coorong and Lower Lakes Ramsar site.

This sub-criterion acknowledges the importance of the diversity and range of ecological roles within the waterbird communities of the Coorong and Lower Lakes Ramsar site. Applying similar logic to that used to apply Ramsar criterion 7 for this project (see Significant Fish Table), species that forage in different ways on the same resources (e.g. Red-necked Avocet versus Banded Stilt; pelicans versus terns versus cormorants versus grebes versus Greenshanks versus herons all feed on fish but use different strategies to hunt them) or on different resources (e.g. the various Terns; Fairy, Whiskered, Caspian, Crested) or in different parts of the water column should have at least one representative species listed to capture the full ecological character and breadth of the waterbird communities.

Common name	Scientific name	Ramsar criteria	Status - national	Status IUCN @	J/CAMBA or CMS	Status- SA				
Note: waterbird species that qualify against either criteria 4 or 6 and considered to automatically qualify against this criterion also and so are not shown in the table below.										
Geese, Swans and Ducks -	Family Anatidae									
Black swan	ack swan Cygnus atratus 5.1, 5.3 CMS									
Musk Duck	Biziura lobata	5.3			CMS	R				

Grey Teal	Anas gracilis	5.1, 5.2, 5.3	CMS	
Chestnut Teal	Anas castanea	5.1, 5.2, 5.3	CMS	
Rails, Crakes, Swamphens,	Coot - Family Rallidae	•		
Spotless Crake	Porzana tabuensis	5.3		
Herons, Egrets, Bitterns - Fa	mily <i>Ardeidae</i>		 ·	
White faced Heron	Ardea navaehollandiae	5.3		
Ibises, Spoonbills - Family T	hreskiornidae		 ·	
Australian White Ibis	Threskiornis molucca	5.3?		
Oystercatchers - Family Ha	ematopodidae		 ·	
Sooty Oystercatcher	Haematopus fuliginosa	5.3		
Lapwings, Plovers, Dotterels	s - Family Charadriida	е	 ·	
Masked Lapwing	Vanellus miles	5.3	CMS	
Red-kneed Dotterel	Erthrogonys cinctus	5.3	CMS	
Stilts, Avocets - Family Rec	urvirostridae		<u> </u>	
Black-winged Stilt	Himantopus himantopus	5.3	CMS	
Gulls, Terns etc - Family Lai	idae	<u> </u>	,	
Whiskered Tern	Chlidonias hybridus	5.1,5.2,5.3		
Silver Gull	Larus navaehollandiae	5.1,5.2,5.3		

Key:

Conservation status:

National: E - Endangered, V - Vulnerable under the EPBC Act 1999.

IUCN: CE = Critically endangered, Endangered, V - Vulnerable in the IUCN Red list

State: P – protected under the *Fisheries Act 1982*, C – provisional State conservation concern under the *draft Threatened Species Schedule NPWSA*. (refer:

http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

JAMBA = Japan-Australia Migratory Bird Agreement, CAMBA = China-Australia Migratory Bird Agreement

Attachment 5:

Waterbirds that qualify against criterion 6

Decision rules applied:

1% levels taken from Waterbird Polulation Estimates (Third edition, 2002) by Wetlands International which maintains these figures as reference of applying this Ramsar criterion.

1. Species that regularly (see below) exceed the 1% population level. Where possible the assessment has been based on surveys conducted around the time the site was Ramsar listed (1985). For some species more recent data has been used.

Common name	Scientific name	Ramsar criteria	Status - national	Status IUCN	J/CAMBA or CMS	Status- SA
Grebes - Family Podiciped	didae					
Great Crested Grebe	Podiceps cristatus	5.3, 6				R
Hoary-headed Grebe	Podiceps poliocephalus	5.1, 5.2, 5.3, 6				
Geese, Swans and Ducks	- Family Anatidae					
Cape Barren Goose	Cereopsis novaehollandiae	6			CMS	R
Curlews, Sandpipers, Snipe	es, Godwits, Phalarope	s - Family Scol	opacidae			
Sharp-tailed sandpiper	Calidris acuminata	4,5.3,6			J/CAMBA CMS	
Curlew Sandpiper	Calidris ferruginea	4,5.3,6			J/CAMBA CMS	
Red-necked Stint	Calidris ruficollis	4,5.3,6			J/CAMBA CMS	
Sanderling	Crocethia alba	4,6			J/CAMBA CMS	
Common Greenshank	Tringa nebularia	4,5.3,6			J/CAMBA CMS	
Oystercatchers - Family H	aematopodidae					
Pied Oystercatcher	Haematopus Iongirostris	4,5.3,6				
Lapwings, Plovers, Dottere	ls - Family Charadriida	е				
Hooded Plover	Charadrius rubricollis	3,4,5.3,6			CMS	V
Red-capped Plover	Charadrius ruficapillus	5.3,6			CMS	
Pacific Golden Plover	Pluvialis fulva	4,5.3,6			CMS	
Stilts, Avocets - Family Red	curvirostridae					
Banded Stilt	Cladorhynchus leucocephalus	5.3,6			CMS	
Red-necked Avocet	Recurvirostra novaehollandiae	5.3,6			CMS	
Gulls, Terns etc - Family La	nridae					
Fairy Tern	Sterna nereis	3,4,5.1, 5.2, 5.3,6				V
Caspian Tern	Hydropogne tschegrava (Hydroprogne caspia)	4,5.3,6			САМВА	

Key:

Conservation status:

National: E - Endangered, V - Vulnerable under the EPBC Act 1999.

IUCN: CE = Critically endangered, Endangered, V - Vulnerable in the IUCN Red list

JAMBA = Japan-Australia Migratory Bird Agreement, CAMBA = China-Australia Migratory Bird Agreement

Notes:

Those hose species that regularly use (see below) the site in numbers representing 1% or more of the estimated flyway or sub-species population.

- "Regularly is defined in the Ramsar guidance as follows:
- (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)." See Ramsar Wise Use 'toolkit' Handbook 7 (page 39 for further clarification).

The data used to establish the 1% flyway population level are as given by Wetlands International (http://www.wetlands.org/IWC/WPEnote.htm)

Attachment 6:

Species that qualify against criteria 7 and 8

Criterion 7: This criterion allows for the recognition of species that are representative of wetland benefits and/or values, and thereby contribute to global biodiversity. The guidelines associated with this criterion are less than definitive and in general focus on the issues of biodiversity and biodisparity within the overall fish community found within the Ramsar site. In the absence of more specific guidance the following decision rules have applied here:

Decision rules:

- any species that qualified against criteria 2, 3 or 4 automatically qualify here also.
- species that contribute significantly to diversity within the fish community; such as through morphological body forms (large top order predators, omnivores through to small microphagic carnivores) or representative of a wide array of diverse families and classes etc. qualified.
- species with a wide diversity of ecological roles, such as in the interface of fresh and marine environments (overlap between fresh, estuarine and marine life history strategies) qualified.
- ❖ Endemic species qualify; genetically distinct subpopulations for Yarra and Southern pygmy perch occur n the Ramsar site. Other species likely to display similar patterns once research is undertaken include Estuary perch, Smelt, gudgeon and River blackfish.

Note: native fish species that qualify against criteria 2, 3, or 4 automatically qualify against this criterion also and so are not shown in the table below. See the relevant tables for these species.

Criterion 8

Decision rules:

Supports fish through providing important sources of food, spawning ground, nursery and/or migration path. Rules applied here:

- any species that qualified against criterion 4 automatically qualifies here also;
- any species that spawn in the Ramsar area qualify;
- any species that use the area as a nursery qualify;
- any species that use the area as part of a migration pathway qualify.

Species omitted:

Species were omitted if the Ramsar site is not considered an 'important' location, that is, they don't breed there or are unlikely to be resident species.

Common name	Scientific name	Ramsar criteria	Status - national	IUCN status	Status- SA					
Note: native fish species that qualify against criteria 2, 3, or 4 automatically qualify against this criterion also and so are not shown in the table below. See the relevant tables for these species.										
Leptoscopids- Family Leptoscop	oidae									
Sand fish	Crapatalus arenarius lasti	Crapatalus arenarius lasti 7								
Goblin shark - Family Mitsukurin	idae									
Goblin shark	Mitsukurina owstoni	7								
Pufferfishes - Family Tetraodontic	Pufferfishes- Family Tetraodontidae									
Prickly toadfish	Contusus brevicaudus	7								
Richardson's toadfish	Tetractenos hamiltoni	7								

<u>Key:</u> Conservation status:

IUCN: E - Endangered in the IUCN Red list, V- Vulnerable in the IUCN Red list

National: V - vulnerable under the EPBC Act 1999.

State: P - protected under the Fisheries Act 1982, C - provisional State conservation concern under the draft

Threatened Species Schedule NPWSA. (refer:

http://www.environment.sa.gov.au/biodiversity/latest_news.html#review_of_status)

Appendix D. Obligate freshwater fish - Summary of spawning, larval and juvenile characteristics (SKM, 2003)

Extracts from MDBC report Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)

[note: as a review-style project the SKM report presents information from previous studies in parts of the Murray-Darling Basin. Care should be exercised in applying it to the Coorong and Lower Lakes Ramsar site]

Summary of spawning characteristics

		Pre-spawni	Pre-spawning behaviour					viour		Post-spawning behaviour	
Scientific Name	Common Name	Migration				0.1	•				
		Migrate	Direction	Season	Induction	Other	Season	Induction	Site	Migration	Parental care
Ambassis agassizii	Olive Perchlet	Not recorded					Spring-summer	Rise in water level	Macrophytes	Not recorded	Not recorded
Craterocephalus stercusmuscarum		Not recorded					Prolonged over spring-summer	Water temperature >23°C	Rock, weedy areas, crevices or rocky beds	Not recorded	Unlikely due to prolonged spawning
Craterocephalus fluviatilis	Murray Hardyhead	Not recorded					Spring-summer	-	Macrophytes	Not recorded	Unlikely
Nematalosa erebi	Bony Herring	No					Spring-summer	Increasing flows?	Shallow backwaters during floods	Not recorded	No
Mogurnda adspersa	Southern Purple- spotted Gudgeon	No					Spring-summer	Increasing day length & water temperature >18°	Hard substrates	No	Males guard & fan eggs
Philypnodon sp.1	Dwarf Flathead Gudgeon	Not recorded					-	Variation in temp.	Hard surfaces	No	Males guard & fan eggs
Hypseleotris spp.	Carp Gudgeon	Not recorded				Males territorial & develop lump on head during spawning	Spring-summer	Low flows	Shallow backwaters, macrophytes, woody debris	No	Males guard & fan eggs
Gadopsis marmoratus	River Blackfish	No					Late spring- summer	Increasing water temperature >16°	In hollow snags or spaces between boulders	No	Males guard eggs/larvae
Galaxias olidus	Mountain Galaxias	Possible	Short upstream movement				Winter-summer	-	Riffle cobbles	Downstream	No
Melanotaenia fluviatilis	Murray-Darling Rainbowfish	No					Spring-summer	Warming of flooded backwaters & during low flow periods	Macrophytes	No	No

		Pre-spawnir	ng behaviour				Spawning beha	viour		Post-spawning behaviour		
Scientific Name	Common Name	Migration										
Nannoperca australis	Southern Pygmy Perch	No				Males territorial during breeding	Late winter- spring	Temp <15°	Scattered over bed & macrophytes in still waters	No	No	
Nannoperca obscura	Yarra Pygmy Perch	Not recorded					Spring	-	-	Not recorded	-	
Maccullochella peelii peelii	Murray Cod	Yes - some individuals (facultativ e migration)	Upstream	Late winter- spring	Increasing flows, change in temperature		Spring-summer	Increasing water temperatures, flow & day length			Males guard & fan eggs	
Macquaria ambigua	Golden Perch	Facultative migration	Upstream	Spring- summer	Increasing flows		Spring-summer	Increasing flow & water temperatures >23°	Water column near surface	Gradual downstream dispersal	No	
Tandanus tandanus	Freshwater Catfish	No					Spring-summer	> 24° for nest building	Nest in shallows on sand/gravel substrate	No	Both sexes guard & fan eggs	
Bidyanus bidyanus	Silver Perch	Yes	Long upstream migration	Spring- summer	Increasing flows and behind flood peak	Move through fishways during daylight-	Spring-summer	Increasing flow?	Water column near surface	Return	No	
Retropinna semoni	Australian Smelt	Movement not associated with spawning					Spring	Increase in temperature	Macrophytes	No	No	
Philypnodon grandiceps	Flathead Gudgeon	Not recorded					Spring-summer	-	Hard substrates	No	Males guard & fan eggs	

- Data deficient

Summary of larval and juvenile characteristics

					Water quality	y tolerance			
Scientific Name	Common Name	Movement	Habitat	Tempe	rature	Salinity	Dissolved oxygen	Other	
				Low	High		oxygon		
Ambassis agassizii	Olive Perchlet	Large scale movement not recorded	-	-	-	-	-		
Craterocephalus fluviatilis	Murray Hardyhead	Large scale movement not recorded	Slow flowing littoral zones of lakes and weir pools	=	-	<48,000 mg/l	-		
Craterocephalus stercusmuscarum	Fly-specked Hardyhead	Large scale movement not recorded	-	<23.5°C	36°C	-	-		
Nematalosa erebi	Bony Herring	Larvae drift with flood waters	Floodplains, creeks and weir pools	-	-	-	-	Winter kills occur in low temperatures	
Mogurnda adspersa	Southern Purple- spotted Gudgeon	Large scale movement not recorded	-	=	-	-	-		
Philypnodon sp.1	Dwarf Flathead Gudgeon	-	-	-	-	-	-		
Hypseleotris spp.	Carp Gudgeon	Dispersal migration	Shallow ponded habitats	-	-	-	-		
Gadopsis marmoratus	River Blackfish	No	Silt/detrital substrate	-	-	<6000 mg/l	-		
Galaxias olidus	Mountain Galaxias	Downstream dispersal of juveniles	Form loose shoals in pools	-	-	-	-	Forms loose shoals	
Melanotaenia fluviatilis	Murray-Darling Rainbowfish	No	Shaded backwaters and still littoral habitats	18°C	28°C	<12,000 mg/l	-		
Nannoperca australis	Southern Pygmy Perch	Large scale movement not recorded	Shallow still waters amongst macrophytes	=	-	-	-		
Nannoperca obscura	Yarra Pygmy Perch	Large scale movement not recorded	Shallow still waters amongst macrophytes	-	-	Brackish waters	-		
Maccullochella peelii peelii	Murray Cod	Proportion of larvae drift downstream at night close to bed	Benthic habitats in main channel, not recorded from floodplain habitats	-	-	<10,000- 14,000 mg/l	-		
Macquaria ambigua	Golden Perch	Eggs & larvae swept downstream; juveniles may move back upstream during increased flows	Range of habitats including amongst LWD, slow flowing water, deep water, main channel, anabranches and floodplain habitats	4°C	37°C	<8270 mg/l	Prefer high DO	Larvae rarely sampled but require large numbers of zooplankton for survival	
Tandanus tandanus	Freshwater Catfish	Large scale movement not recorded	-	-	-	-	-	Form loose schools	
Bidyanus bidyanus	Silver Perch	Larvae swept downstream but juveniles actively move upstream or downstream during increased flows in spring and summer	Backwaters and floodplain areas rich in zooplankton	2°C	37°C	<24,600 mg/l	-		
Retropinna semoni	Australian Smelt	Upstream dispersal movement in spring and summer during increased flow	Backwaters and still littoral habitats in main channel and billabongs	-	-	<2800 mg/l	-		
Philypnodon grandiceps	Flathead Gudgeon	Observed in drift (facultative)	Slow flowing backwaters, pools and littoral zones	=	-	-	-		

⁻ Data deficient

Appendix E. Diadromous fish - Summary of spawning, larval and juvenile characteristics (SKM, 2003)

Extracts from MDBC report Habitat requirements of native fish of the Murray-Darling Basin (SKM, 2003)

[note: as a review-style project the SKM report presents information from previous studies in parts of the Murray-Darling Basin. Care should be exercised in applying it to the Coorong and Lower Lakes Ramsar site]

Summary of spawning characteristics

		Pre-spawning behaviour					Spawning behaviour			Post-spawning behaviour	
Scientific Name	Common Name	Migration				Other	Season	Induction	Site	Migration	Parental care
Anguilla australis	Short-finned Eel	Migrate Yes	Direction Downstream to sea	Season Spring and summer	Induction Moon phase, increase in water temperature, increase floodwaters.		Spring-summer	Specific temperature and pressure	Sea	Adults presumably die	No
Galaxias brevipinnis	Climbing Galaxias	No					Autumn-early winter	Increasing flows	Damp substrates adjacent to stream	No	No
Galaxias maculatus	Common Galaxias	Yes	Downstream to estuaries	Summer- autumn	Full or new moon		Autumn-winter	High tides	Bank vegetation on estuary margins	Spent adults die	No
Geotria australis	Pouched Lamprey	Yes	Upstream from sea	Spring- summer		Migrate at night	Spring-summer	-	Headwaters, nest in sandy/muddy backwaters	Spent adults die	No
Mordacia mordax	Short-Headed Lamprey	Yes	Upstream from sea	Spring- summer	Increasing water temperature, decreasing flows		Spring-summer	-	Depressions in soft substrates	Spent adults die	-
Macquaria colonorum	Estuary Perch	Yes	Downstream to estuary	Late winter- summer			Spring-summer	Delayed by cold temp.	Estuarine macrophytes	Presumably return upstream	-
Pseudaphritis urvilli	Tupong	Yes	Downstream to estuaries	Autumn- winter	Increased river flow		Late autumn- early summer	-	Weedy estuaries	Return upstream?	-

⁻ Data deficient

Summary of larval and juvenile characteristics (SKM, 2003)

					Water quality	y tolerance			
Scientific Name	Common Name	Movement	Habitat	Temper	ature	Salinity		Other	
				Low	High		, , ,		
Anguilla australis	Short-finned Eel	Upstream from sea at night during spring and summer	Larvae drift at sea and enter rivers as glass eels	-	-	-	-	Can climb damp walls and travel over damp ground	
Galaxias brevipinnis	Climbing Galaxias	Swept to sea as larvae (coastal populations); swept downstream into lakes as larvae (inland populations); return to freshwater as juveniles (coastal populations)	At sea for a few months before returning to freshwater.	-	-	-	-		
Galaxias maculatus	Common Galaxias	Larvae swept to sea	Submerged vegetation in shallow lake margins and river mouths	-	-	>6000 mg/l	LC50 <1 mg/l	Shoals	
Geotria australis	Pouched Lamprey	Migrate downstream to sea to mature, return to freshwater after 18 months	Ammocetes prefer shaded silty areas in slow water	-	28°C	-	Adapted to low DO	Burrows	
Mordacia mordax	Short-headed Lamprey	Migrate downstream to sea over late winter-spring with high flows	Mud and silt along river edges	-	ı	-	-	Burrows	
Macquaria colonorum	Estuary Perch	Large scale movement not recorded	-	-	-	-	-		
Pseudaphritis urvilli	Tupong	Upstream from estuaries in spring & summer when ~9 months old	Estuaries until 9 months old	-	-	-	-		

⁻ Data deficient

Appendix F: Glossary and abbreviations

From: Upper South East Drainage and Flood Management Program Glossary, or The Murray Mouth Exploring the implications of closure or restricted flow, July 2002

Glossary	
Aeolian	erosion and deposition of sediments by wind-blown movement
Anadromous	fish species that spawn in freshwater environments but use estuaries and/or the sea for larval, juvenile and/or adult phases of their life cycle.
Angiosperm	a flowering plant.
Anoxia	lack of oxygen.
Australian Height Datum	the measure of elevation above mean sea level. The AHD is the official datum used in Australia and is used to measure the water level in the Lower Lakes.
Benthic	species that thrive on the bottom of a water body, ie benthic algae can thrive on the bottom of lakes.
Biomass	the amount of living material in a unit area or volume, usually expressed as mass or weight.
Brackish	water that has a salinity of 2500 – 5000 EC; between that of fresh and estuarine.
Catchment	the area of land drained by a river and its tributaries.
Catadromous	fish species that spawn at sea but use freshwater catchment areas during the juvenile and sub-adult life stages.
Collodial particles	suspended within a liquid - not dissolved.
Cue	a term used for a flow that triggers an ecological event, such as fish spawning.
Crustaceans	belonging to the Crustacea, a phylum of (chiefly aquatic) arthropod animals, including the lobsters, prawns, crabs, barnacles, slaters, etc., commonly having the body covered with a hard exoskeleton or carapace.
Cyanobacteria	aquatic bacteria that can photosynthesize.
Detritus	disintegrated or eroded material that accumulates at the bottom of a water body.
Diurnal	having a 24 hour or daily cycle; ie a diurnal tide occurs each day.
Driver	a process that influences how an ecological system operates.
Density	stratification see stratification.
Depauperate	species-poor.
Ebb tide	receding tide.
Entitlement Flow	the amount of water in the River Murray that NSW and Victoria must allow to flow to South Australia under the Murray-Darling Basin Agreement. South Australia's Entitlement Flow is 1850GL.
Estuarine	water that has a salinity of 12 000 – 60 000 EC; between that of fresh and marine.
Estuarine Migrant	fish species of marine origin that usually reside in estuaries as juveniles and adults but often have a marine larval phase.
Estuarine Resident	fish species of marine origin that reside in estuaries and can complete their entire lifecycle within these systems.
Freshwater Migrant	freshwater fish species that are often recorded in estuaries retreating into catchment rivers when conditions become unfavourable.
Freshwater Straggler	freshwater fish species that sometimes enter estuaries when conditions are favourable.
Endangered s	species that are threatened with extinction.
Euryhaline	species that have a wide tolerance to salinity.
Eutrophic	having water high in nutrients.
Family	a scientific order of taxonomy which contains genera, or genus.

Flocculate	collect into lumps or tufts.		
Freshwater	obligate sp. species that are virtually always found in freshwater environments.		
Hydrograph	a mathematical curve depicting the changes in flow or water level over a given time period.		
Hypermarine	ocean water with very high salinity.		
Hypersaline	water that is extremely saline, and sometimes referred to as twice that of seawater. Greater than 115 000EC.		
Land retirement	the process of changing the way in which land is used in order to rehabilitate it.		
Lever	an option or tool for the management of environmental flows.		
Littoral	the edge or shallow area of a water body.		
Macrofauna	animals large enough to be seen with the naked eye.		
Macroinvertebrate	invertebrates visible to the naked eye, such as insect larvae.		
Macrophytes	water plant that is not algae, and may be either floating or rooted.		
Maintain	to keep the condition of the asset in its current state. This is used if the condition is healthy, but may be appropriate if the condition is declining and there is no way of improving it.		
Marine	water that is highly saline, and salinity of around 60000EC (salinities between estuarine and hypersaline).		
Marine Migrant	marine species that make extensive use of estuaries during juvenile and/or adult life stages.		
Marine Straggler	marine species where only a small proportion of the overall population make use of estuaries.		
Median flow	the flow that occurs in the most number of years.		
Morphospecies	species that are given an informal code or number instead of actual species names, when they cannot be formally identified.		
Neap	tide a tide that occurs when the difference between high and low tide is least; the lowest level of high tide. Neap tides occur twice a month, in the first and third quarters of the moon.		
Nutrients	any substance which has nutritious qualities – that is, which nourishes or promotes growth.		
Pathogen	disease producing organism.		
Prograded	built out; a term that refers to areas of lake edge where elevated water levels have caused erosion of the sediment underneath the clay topsoil, resulting in a 'shelf'.		
Propagules	any vegetative portions of a plant, such as a bud or other offshoot, that aid in dispersal of the species and from which a new individual may develop.		
Restore	move the condition of the asset back to its natural condition.		
Resuspension	when sediment or other matter becomes suspended in water once it has settled to the bottom of a water body.		
Rehabilitate	move the condition of the resource to some better condition, but which is lower than or different to natural. This may be to a reference condition (a specified level of health that is acceptable) or to some predetermined target (ie. a specified salinity).		
Saline intrusion	often referred to as a 'salt wedge', it is the intrusion of dense saline water from the sea below the fresher water in the river.		
Shoal	a sandy elevation on the bottom of a body of water, a sandbank or sandbar.		
Seiche	water oscillations in a water body caused by wind or other resonance. Wind seiche in the Lower Lakes can cause lake edge erosion if water levels are adequate.		
Semi-diurnal	having a 12 hour or half-daily cycle; ie a semi-diurnal tide occurs once every 12 hours.		
Stratification	a natural feature of water bodies characterised by a vertical gradient in density, caused by differential heating of the water surface and/or		

	differences in salinity.
Surcharge	to fill a water body to a pre-determined level to accommodate for extractions and other losses. For example, the Lower Lakes are surcharged to 0.85m prior to the irrigation season, allowing enough storage to cover irrigation extractions, domestic use and evaporative losses.
Taxa	a grouping of organisms given a formal taxonomic name such as species, genus, family, etc.
Tidal prism	the volume of water that passes in and out of an inlet during a tidal cycle.
Turbidity	the murkiness of water caused by suspended sediment.
Turion	an underground bud or shoot from which an aerial stem arises; in this case for <i>Ruppia</i> species, the turions of which are an important food source for wading birds

Abbreviations	
AHD	Australian Height Datum
Asset Plan	Asset Environmental Management Plan for the Lower Lakes, Coorong and Murray Mouth (DLWBC, 2005)
AWSG	Australasian Wader Studies Groups, of Birds Australia
CAMBA	China-Australian Migratory Migratory Bird Agreement
CMS	Convention on Migratory Species
DSE	Victoria's Department of Sustainability and Environment
EPBC ACT	Commonwealth Environment Protection and Biodiversity Act 1999
GL	Gigalitres - one thousand million litres
ha	hectares
JAMBA	Japan-Australian Migratory Migratory Bird Agreement
MDB	Murray-Darling Basin
MDBC	Murray-Darling Basin Commission
ML	Megalitres - one million litres
MLRSEW	Mount Lofty Ranges Southern Emu-Wren
PAR	Photosynthetically active radiation
RES	Regional Ecosystem Services (the project team leading the development of this report)
RIS	Ramsar Information Sheet
SA DEH	South Australian Department of Environment and Heritage
USEDS	Upper South East Drainage Scheme

Appendix G: Salinity conversion details

From: DWLBC, 2005, Lower Lakes, Coorong and Murray Mouth Asset Environmental Management Plan (draft), report prepared for the Murray-Darling Basin Commission, Canberra (Appendix G)

Salinity definitions

Definitions	mg/L, ppm	EC, uS/cm	mS/cm, dS/m	gpg
FRESH - potable water	0 –1500	0 – 2500	0 – 25	0 - 105.63
BRACKISH	1501 – 3000	2501 – 5000	25.01 – 50	105.70 –
				211.26
SEMI SALINE - often referred	3001 – 7000	5001 – 11666	50.01 – 116.66	211.34 –
to as moderately saline				492.96
ESTUARINE	7001 – 34999	11667 – 58332	116.67 –	493.03 -
			583.32	2468.70
MARINE (sea water)	35000	58333	583.33	2464.80
HYPERMARINE- greater than	35001 – 69999	58335 – 116665	583.35 -	2464.90 -
marine			1166.65	4929.50
HYPERSALINE	> 70000	> 116666	> 1166.66	> 4929.60

Units and symbols

Unit	Symbol
grain per (imperial) gallon	gpg
Electrical Conductivity Unit	EC
= micro-Siemen per cm	uS/cm
deci-Siemen per metre	dS/m
= milli-Siemen per cm	mS/cm
parts per million	ppm
= milli-gram per Litre	mg/L

 $mS/cm \times 100 = uS/cm \quad uS/cm \times 0.6 = ppm \quad ppm \div 14.2 = gpg$

Conversions: 1 ppt = approx. 1,667 EC and conversely 1,000 EC = approx. 0.64 ppt.

Appendix H: Water quality data for Lakes Alexandrina and Albert and three of the tributaries

Data and map supplied by the EPA of South Australia, courtesy of Peter Goonan and Peter Christy.

Lake Alexandrina

Year	Salinity (EC)		NTU	
Site 1(see locality ma	Average (no. of sample dates)	Range	Average (no. of sample dates)	Range
1996	610 (n=10)	340-852	77 (n=8)	7-130
1990	010 (11=10)	340-032	77 (11=0)	(400)*
1997	545 (n=12)	303-1070	59 (n=12)	36-73
1998	979 (n=8)	742-970	31.2 (n=8)	18-47
Site 2 (see locality ma		742-770	31.2 (11-0)	10-47
1996	608 (n=10)	291-840	74.4 (n=8)	8-160
1770	000 (11–10)	271 010	7 1.1 (11–0)	(360)*
1997	632 (n=12)	319-1210	48.1 (n=12)	23-82
1998	942 (n=8)	726-1300	32 (n=8)	16-94
Site 3 (see locality ma	· / /	720 1000	32 (11-0)	10 71
1996	562 (n=10)	258-821	81.5 (n=8)	4-210
1770	302 (11–10)	200 021	01.0 (11–0)	(480)*
1997	519 (n=11)	314-659	68 (n=12)	49-90
1998	877 (n=8)	719-936	28.2 (n=8)	14-54
Site 4 (see locality ma	· · · · · · · · · · · · · · · · · · ·	717700	20.2 (0)	
1996	578 (n=10)	232-823	51.6 (n=8)	10-140
				(380)*
1997	530 (n=12)	315-699	60.2 (n=12)	39-91
1998	868 (n=8)	735-929	29.4 (n=8)	12-51
Site 5 (see locality ma			, ,	
1996	568 (n=11)	223-856	91.5 (n=9)	7.5-130
	, ,		, ,	(400)*
1997	537 (n=12)	265-754	49.4 (n=12)	17-90
1998	840 (n=8)	792-927	36.5 (n=8)	16-58
Site: Goolwa barr	age - upstream			
1999	1895 (n=7)	879-4670	29.1 (n=7)	10.2-91.5
2000	1977 (n=10)	521-2410	23.5 (n=10)	7.9-55.4
2001	1205 (n=12)	448-2460	24.9 (n=12)	5.2-52.4
2002	2877 (n=12)	1420-6690	13.9 (n=12)	2.5-43.1
2003	3894 (n=11)	1386-8460	12.5 (n=11)	8.8-20
2004	2332 (n=11)	1526-4160	17.3 (n=11)	11.7-22.8
2005	2299 (n=10)	1611-3541	15.1 (n=10)	7.6-23.1
Site: Poltalloch Pla	ains			
1999	645 (n=7)	527-722	86.3 (n=7)	40-185
2000	748 (n=12)	424-888	53.5 (n=12)	16.8-120
2001	595 (n=12)	384-678	66.3 (n=12)	19.5-137
2002	956 (n=12)	810-1213	59.3 (n=12)	17.2-114
2003	1228 (n=11)	1028-1340	31.8 (n=11)	15.5-62.8
2004	1259 (n=11)	1150-1380	32.9 (n=11)	16.2-51.9
2005	1315 (n=10)	1109-1664	44.6 (n=10)	16.8-102
Site: Milang				
1971	505 (n=12)	397-611	-	-
1972	587 (n=12)	411-846	-	-
1973	960 (n=9)	446-1075	-	-
1974	451 (n=12)	274-707	-	-
1975	553 (n=12)	269-1260	-	-
1976	493 (n=12)	312-737	-	-

1977	810 (n=12)	591-1000	-	-
1978	853 (n=14)	544-1160	-	-
1979	647 (n=22)	487-866	-	-
1980	860 (n=22)	656-1122	-	-
1981	1100 (n=47)	372-1447	-	-
1982	724 (n=49)	436-1163	-	-
1983	1102 (n=53)	450-1410	116 (n=50)	14-390
1984	540 (n=52)	363-674	201.3 (n=52)	144-320
1985	660 (n=51)	379-943	122.1(n=52)	72-195
1986	943 (n=53)	502-1340	82.8 (n=53)	32-198
1987	629 (n=49)	509-983	103.5 (n=51)	57-172
1988	805 (n=51)	504-1350	74.8 (n=52)	16-192
1989	622 (n=49)	380-838	77.5 (n=51)	24-138
1990	569 (n=52)	314-984	83.1 (n=53)	14-182
1991	713 (n=49)	394-1440	50.5 (n=46)	5.3-320
1992	727 (n=51)	491-1005	66.6 (n=52)	25-153
1993	448 (n=52)	362-696	59.7 (n=52)	16-172
1994	613 (n=52)	329-920	34.9 (n=52)	15-78
1995	914 (n=52)	565-1190	53.6 (n=51)	4-180
1996	666 (n=53)	320-882	72.2 (n=53)	12-220
1997	501 (n=52)	293-715	51.2 (n=52)	26-110
1998	891 (n=54)	682-1010	38.8 (n=54)	12.9-120
1999	676 (n=22)	527-720	48.8 (n=22)	0.31-97
2000	782 (n=12)	591-855	33.8 (n=12)	8.1-86.3
2001	564 (n=12)	455-690	49.2 (n=12)	29-81.5
2002	903 (n=12)	773-1073	44.5 (n=12)	16.3-80.6
2003	1193 (n=11)	467-1442	47.3 (n=11)	17.2-88.1
2004	1285 (n=11)	1183-1483	37.4 (n=11)	20.2-58
2005	1364 (n=10)	1250-1427	33.5 (n=10)	11.9-52.8

^{*} the very high readings at these sites were in February 1996 as shown in brackets above. For all four sites the January reading was also very high (390 at Site 1, 390 at Site 2, 460 at Site 3, 450 at Site 4 and 350 at Site 5). These numbers have not been included in the calculation of averages.

Lake Albert

Year	Salinity	y (EC)	NTU	J
	Average (no. of sample dates)	Range	Average (no. of sample dates)	Range
Site 1(see locality ma				
1996	1415 (n=10)	1270-1580	36.5 (n=10)	9-66 (320*)
1997	1116 (n=12)	532-1440	50.8 (n=12)	25-74
1998	1315 (n=8)	1220-1440	59.1(n=8)	24-63
Site 2 (see locality ma	ap attached)			
1996	1466 (n=12)	1350-1650	39.5 (n=12)	9-66 (320)*
1997	1080 (n=12)	466-1280	42.8 (n=12)	18-70
1998	1378 (n=8)	904-1740	48 (n=8)	29-70
Site 3 (see locality ma			<u> </u>	
1996	1821 (n=11)	1270-1560	38.8 (n=9)	9-56 (360*)
1997	1146 (n=12)	1070-1230	43.3 (n=12)	20-80
1998	1386 (n=8)	1260-1460	52.2 (n=8)	33-87
Site: 8kms south w	est of Meningie			
1985	2920 (n=2)	2840-3000		
1986	2445 (n=2)	2300-2590	70 (n=1)	-
1987	2025 (n=4)	1650-2280	48 (n=4)	12-72
1988	1195 (n=4)	1890-2090	43 (n=4)	31-63
1989	2017 (n=3)	1900-2130	70.7 (n=3)	29-130
1990	1921 (n=3)	1850-1983	23.7 (n=3)	5.2-38
1991	1702.5 (n=2)	1660-1745	13.9 (n=2)	12.8-15
1992	2365 (n=2)	2250-2480	19 (n=2)	18-20
1993	1939 (n=1)	-	14 (n=1)	-
1994	1773 (n=1)	-	18 (n=1)	-
Site: Meningie			,	
1999	1567 (n=7)	1240-1570	54.2(n=67)	30. 3-77.7 (234.5#)
2000	1503 (n=12)	1294-1609	61.2 (n=12)	27.9-101
2001	1718 (n=12)	1119-1643	50.4 (n=12)	16-125
2002	1601 (n=12)	1365-2143	50.4 (n=12)	27-81.7
2003	1810 (n=11)	1575-2298	35.7 (n=11)	25.7-45.7
2004	2232 (n=10)	1834-2204	55.7 (n=10)	27.5-124
2005	2094 (n=10)	1920-2279	63.2 (n=10)	35.5-127

^{*} the very high readings at these sites were in February 1996 as shown in brackets above. For all three sites the January reading was also very high (210 at Site 1, 175 at Site 2, 110 at Site 3). These numbers have not been included in the mean calculation.

[#] very high reading taken in September 1999 and excluded from calculation of averages.

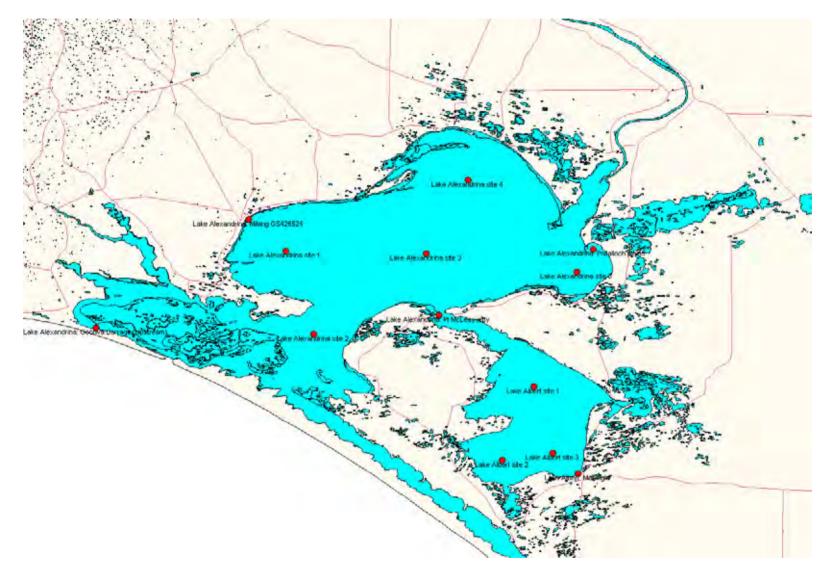
Tributaries

Salinity:

Sites	Average uS/cm (EC)	Range	Sampling dates			
Currency Creek (Near H	liggins)					
Jan '72-Jan '76	2,539	482 - 7,600	n =103			
Feb '85 - Aug '93	2,407	423 – 7,320	n = 40			
Finniss River (4 km East o	of Yundi)					
Apr '70 - Jan '76	1,183	381 – 2,551	n =113			
Jan '00 - Oct '05	1,351	575 – 3,301	n = 67			
Bremer River (near Hartl	Bremer River (near Hartley)					
May '73 - Dec '76	2,552	635 – 5,294	n = 37			
Mar '00 - Oct '05	3,164	997 – 8,380	n = 55			
Bremer River (Wanstead	Bremer River (Wanstead Road)					
May '03 - Oct '05	5,070	981 – 11,410	n = 27			

Turbidity:

Sites	Average NTU	Range	Sampling dates
Currency Creek (Near H	Higgins)		
Jan '72-Jan '76	12.1	2 – 31	n = 36
Feb '85 - Aug '93	17.4	1.2 - 47	n = 32
Finniss River (4 km East o	of Yundi)		
Feb '73 - Jan '76	15.6	5 - 47	n = 38
Jan '00 - Oct '05	7.9	2.2 – 34.1	n = 67
Bremer River (near Hartl	ey)		
Jul '79 – Nov '87	8.9	0.6 - 46	n = 31
Mar '00 - Oct '05	10.4	2.2 – 44.8 (one reading of 110 excluded)	n = 55
Bremer River (Wanstead	d Road)		
May '03 - Oct '05	10.4	0.8 - 65.4 (one reading of 115 excluded)	n = 25



Locality map for water quality recording. Courtesy: Peter Christy (SA EPA)

