Coorong and Lakes Alexandrina and Albert ECD update: Critical Components, Processes and Services Justification and Review.

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Report submitted to: Adam Watt, DEWNR

Prepared by: R. Butcher and P. Cottingham, Water's Edge Consulting.

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Coorong and Lakes Alexandrina and Albert ECD update

Introduction to project

The outcomes of this project are to review and update elements of the Ecological Character Description (ECD) for the Coorong, Lakes Alexandrina and Albert wetland of International Importance in accordance with the National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands- *Module 2 of the National Guidelines for Ramsar Wetlands or any subsequent updates* (DEWHA 2008). This will include:

- Confirmation of Critical CPS, including providing a detailed justification for nominating a CPS as critical (Report 1);
- An update on Chapter 7 of the ECD, which is an assessment of potential change in ecological character since the time of listing based on draft LAC (separate report due February 2016). A review and update of LAC if recommended in Chapter 7 (Report 2)
- A review and update of Chapters 3, 4, and 5 in light of outcomes of Reports 1 and 2 with directions on changes to other Chapters in the ECD (Report 3); and
- A review of technical compliance against the DSEWPaC (now DoE) checklist – building on the review prepared by Butcher (2011) (Report 4).

Output: Four technical review reports and completed drafts of Chapters 3, 4 5 and 7 of the ECD for submission to DEWNR and DoE.

1 Definition of ecosystem components, processes, services and benefits

In the context of this report and the Coorong ECD the following definitions are adopted.

Ecosystem components include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Ramsar Convention 2005, Resolution IX.1 Annex A).

Ecosystem processes are changes or reactions that occur naturally within wetland ecosystems. They may be physical, chemical or biological. Examples include processes such as carbon cycling, denitrification, acidification, sedimentation, migration, breeding, reproduction, etc. (from Ramsar Convention, Resolution V1.1).

Ecosystem functions are activities or actions which occur naturally in wetlands as a product of the interactions between the ecosystem structure and processes. Ecological functions, as defined by Ramsar, include flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stabilization and erosion controls; storm protection; and stabilization of local climatic conditions, particularly rainfall and temperature (from Ramsar Convention, Resolution V1.1).

Ecosystem services and benefits have been classified in a number of ways since being first introduced by Daily (1997), and then more widely accepted with the advent of the Millennium Ecosystem Assessment (MEA) in 2005 (Millennium Ecosystem Assessment 2005, Costanza 2008, TEEB 2010). There is considerable debate over the definitions of ecosystem ''functions'', ''goods'', ''benefits'', and ''services'' (Barnaud and Antona 2014). Some authors have argued for making a distinction between the final ecosystem services that contribute to the well-being of a specific human beneficiary, and the intermediate ecosystem functions that represent the capacity of an ecosystem to give rise to ecosystem services (Butcher 2014, see Fisher et al. 2008, Lamarque et al. 2011, Potschin and Haines-Young 2011).

Fisher et al. (2008) redefined the MEA "ecosystem services" as including: benefits, intermediate and final ecosystem services. They also redefined the MEA "benefits people obtain from ecosystems" as the aspects of ecosystems utilised (passively or actively) to produce human wellbeing. This redefinition is illustrated in Figure 2 and was derived to avoid problems of double counting in environmental-economic accounts of ecosystem services. Fisher et al. (2008) define intermediate and final ecosystem services as follows:

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

Ecosystem services are defined by DEWHA (2008) as benefits that people receive or obtain from an ecosystem (Ramsar Convention 2005, Resolution IX.1 Annex A). The components of ecosystem services include (Millennium Ecosystem Assessment 2005):

- provisioning services — such as food, fuel and fresh water
- regulating services — the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation
- cultural services — the benefits people obtain through spiritual enrichment, recreation, education and aesthetics

- supporting services — the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit in the long term.

Benefits are defined in DEWHA (2008) as the economic, social and cultural benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). These benefits often rely on the underlying ecological components and processes in the wetland.

Whilst DEWHA (2008) provides a list of ecosystem services, some are better described as processes, which has led to come confusion in describing services. Also in the guidelines for preparing ECD Biodiversity is treated as a supporting service, whereas the literature in this field treats biodiversity as an emergent property which is the source of many ecosystem goods, such as food and genetic resources. The MEA system separates biodiversity from being an ecosystem services as well – as illustrated in Figure 1.

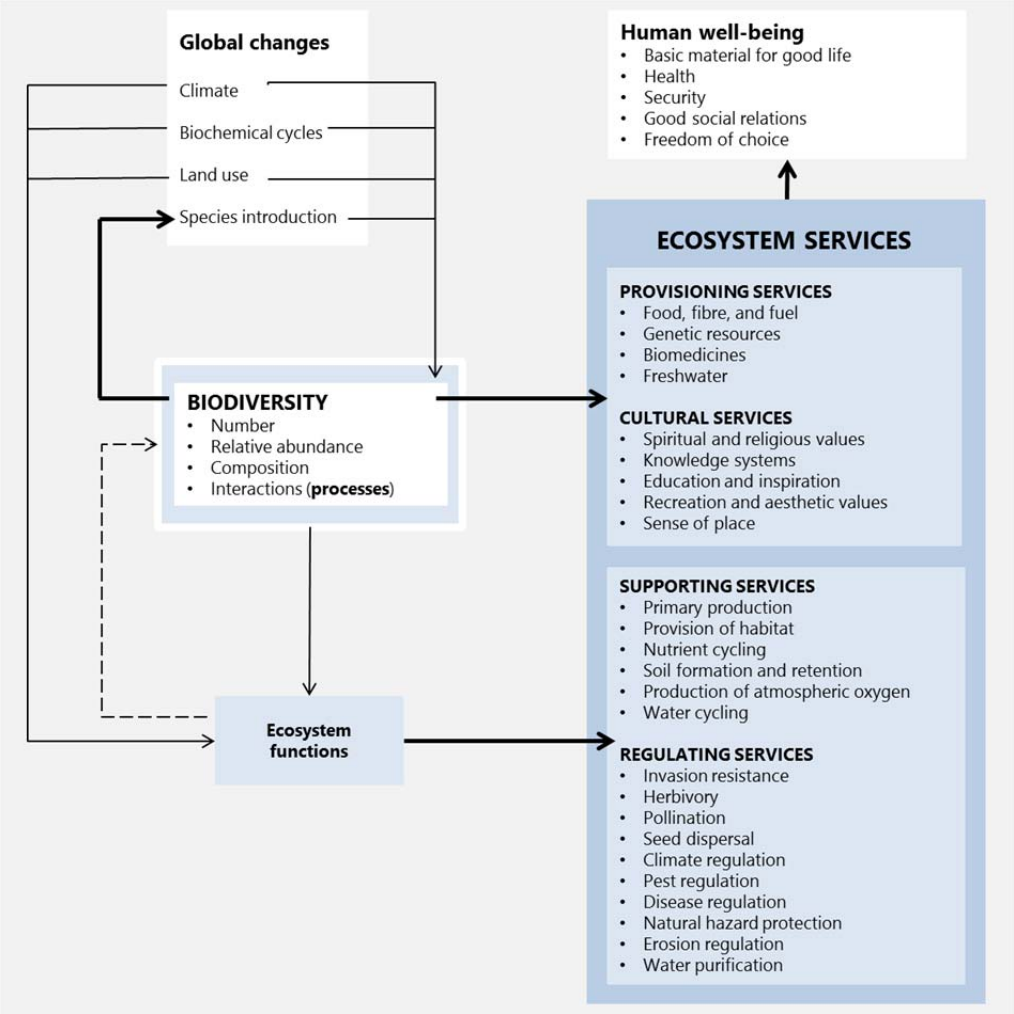

Figure 1. Millennium Ecosystem Assessment's overview of ecosystem services (from DEWHA 2009).

How ecosystem services and benefits are defined and described is an area of the National Framework that could benefit from being updated. As an example of the differences in classifications used are presented in Appendix C.

The relationship between the different elements as defined and applied in this report is illustrated in Figure 2. Components are the abiotic and biotic 'things' that are in a wetland. Processes are how the components interact,

and the functions are what those interactions produce or the wetland does, and the end products are that things humans benefit from either passively or actively.

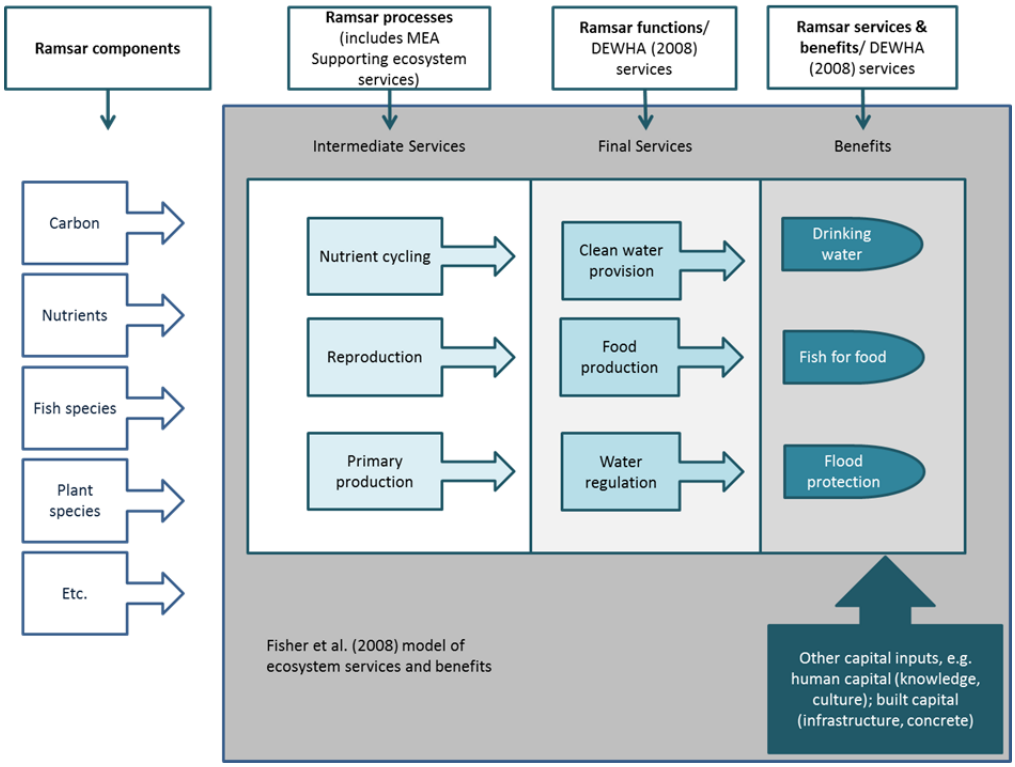

Figure 2: Model of ecosystem services and benefits (all in shaded blue box) with the Ramsar definition of processes and functions added (modified from Fisher et al. 2008 by Butcher et al. 2016).

Note: Until there has been an update in direction for the description of ecosystem services provided by DoE, the list of services as presented in the national guidelines (DEWHA 2008) are used in this report and the ECD.

2 Assessing what's critical

2.1 Criteria and guidance for identifying critical CPS

DEWHA (2008) provides criteria for confirming CPS that are critical to the ecological character of a Ramsar site. To be considered critical to the ecological character of the site CPS must (referred to as critical criteria):

1. Be important determinants of the site's unique character,
2. Be important for supporting the Ramsar or DIWA criteria under which the site was listed,
3. Be of a nature for which change is reasonably likely to occur over short or medium time scales (< 100 years)
4. Be of a nature that will cause significant negative consequences if change occurs.

The critical criteria have been used as the basis for justifying the selection of critical CPS in the Coorong ECD. Firstly, all the CPS identified for the site have been compared with the critical criteria. Then, further supporting evidence is provided to justify the selection of CPS as critical. In this process, and in prior work considering the

inclusion of ecosystem services and benefits, it is our opinion the four critical criteria above are not well suited for identifying critical services and benefits. In particular benefits are not easily able to meet all four critical CPS criteria as they are derived outcomes of the character of the site, not determinants of the sites character (i.e. can't meet critical criterion 1). The annex to Resolution VI.1 (Ramsar Convention 2014) notes that there is a need to increase the value of the information collected for describing and assessing the ecological character of listed sites, and it urges that emphasis should be given to:

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

Wetland cultural services in particular are considered problematic when applying the critical CPS criteria. Cultural heritage represents a legacy of past generations whose knowledge, when included in modern management schemes, constitutes an invaluable contribution to wise use of wetlands (Tolentino 2013). Ramsar sites which have considerable cultural heritage cannot be dissociated from the natural environment to which they are attached and associated management should take into account not only tangible or material heritage, but intangible heritage (i.e. all forms of traditional knowledge, practices and uses and popular culture or folklore) as well (Tolentino 2013). The mandates of the Ramsar Convention, the Convention on Biological Diversity (CBD) and the UNESCOs Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention) all regard the use of cultural values in conservation sites as a tool for their management as a positive factor that can help ensure the wise use of those sites (Tolentino 2013). It is clear from all of these Conventions (especially the World Heritage Convention which is the only instance of a treaty which truly unites natural and cultural together), to which Australia is a signatory, that the separation of natural and cultural elements of Ramsar sites is an inherently false dichotomy (Blake 2013).

In the absence of accepted criteria for the listing of Ramsar sites explicitly on cultural values and other ecosystem services and benefits, the principles and criteria identified in Resolution IX.21 become relevant. These provide for the inclusion of internationally important cultural values in Ramsar listing and therefore enable cultural values to be considered under the critical criteria in the Australian ECD Framework. They key points of Resolution IX.21 are:

> Para 12 'Agree to the application of the existing criteria for identifying Wetlands of International Importance, a wetland may also be considered of international importance which, 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.'
>
> Para 15 'Identifies the following cultural characteristics as relevant to the designation of Ramsar sites:
>
> i. the site provides a model of wetland wise use, demonstrating the application of traditional knowledge and methods of management and use that maintain the ecological character of the wetland
> ii. the site has exceptional cultural traditions or records of former civilizations that have influenced the ecological character of the wetland
> iii. the ecological character of the wetland depends on its interaction with local communities or indigenous peoples
> iv. 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.'

These principles/criteria all include an element of *influencing the ecological values/ecological character* of the site and as such have been used to include assessment of cultural ecosystem services and benefits against critical criterion 1 (see scoring system presented in Table 1).

Finally, DoE provided the following clarification and guidance on the selection of critical CPS (January 2016, J. Cullen, pers. comm.), stating:

> "The Guidance criteria for selecting critical CPS does not allow for values that do not support the Ramsar criteria for which the site was listed. As such socio economic values are excluded from being critical, and cultural values are excluded except where they meet the cultural value international significance criteria. The use of 'As a minimum . . ' in the ECD Framework allows consideration of other values, but these can only be considered for values that we would notify a change of ecological character for their merit alone.
>
> That is, if they changed but nothing else at the site changed, we would notify. This would not be the case for the non-ecological based services. (It should be noted that these values will in most cases still be supported by the selection of environmental CPS)."

2.2 Scoring system adopted

A simple scoring system, or relative strength of relationship between the CPS and the criteria, has been applied in identifying which CPS are considered critical at the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site. The relative importance as a determinant of the sites character (critical criterion 1) and strength of relationship to the Ramsar listing criteria (critical criterion 2) varies among the CPS that occur at the site. Similarly not all CPS have the same likelihood (critical criterion 3) or severity/consequence (critical criterion 4) of change.

A key to the scoring system used to identify the CPS considered critical is presented in Table 1. To be considered a critical CPS, individual CPS must receive at least one '+' for each of the four critical criteria. The scoring system is based loosely on a risk assessment approach and uses variations of the IUCN (2012) threat scope and severity classification. This system has been adopted as it allows for a more transparent means of judging what CPS are critical, and replication of this approach to be used at other Ramsar sites (e.g. nomination of the Glenelg Estuary and Long Swamp system for Ramsar listing, Butcher et al. 2016).

2.3 Assessment of components, processes and services for the Coorong and Lakes Alexandrina and Albert Ramsar Site

Using the critical criteria and the scoring system described in Table 1 and guidance received from DoE, the CPS as listed in the draft ECD (Butcher et al. 2013) were re-assessed with the results presented in Table 2. Where a CPS met the required number of criteria a brief justification based on published literature and expert opinion is provided (see Appendix A).

In undertaking the assessment a number of the critical CPS identified in earlier iterations of the ECD (Butcher et al. 2013) have had a change in status. To provide some context regarding these key changes, a short discussion is provided below to clarify how they have been assessed, classified and incorporated within the Ecological Character Description of the site. These include:

- *Ruppia* as a priority wetland species,
- provision of pollution control,
- maintenance and regulation of hydrological cycles and regimes,

- provision of food for human consumption, and
- special ecological, physical or geomorphic features – Murray mouth.

A brief discussion outlining the changes is outlined below. Section 2.3.6 details the justification for assessing cultural heritage and spiritual and inspirational cultural services as being critical are presented in Appendix B.

2.3.1 Ruppia as a priority wetland species

Ruppia was initially assessed under the ecosystem service of supporting priority wetland species. This species is considered a priority wetland species as it has a central role in the food web of the Coorong and has undergone significant reductions since listing (e.g. Paton et al. 2015 and references therein). Submergent halophytic vegetation is identified as a critical component and the Coorong food web, of which *Ruppia* is often the dominant species, was also identified as a critical service. In discussion with DoE it was decided that it was appropriate to include consideration of *Ruppia* at the component and service level as part of the submergent halophytic vegetation, rather than have three critical CPS covering essentially the same element of the character of the site. Key aspects of Ruppia growth, reproduction and extent are included in the assessment of the condition of the Coorong food web. The critical service of supporting priority wetland species now only relates to the support of migratory species listed under international treaties.

2.3.2 Provision of food for human consumption

The guidance received from DoE (January 2016, J. Cullen, pers. comm.) precludes the inclusion of provisioning services as they are considered socio-economic services. The only provisioning service previously considered to be critical at the site was the provision of food for human consumption. This service is largely focused on the commercial and recreational fishing undertaken within the system, but also includes indigenous use of fish stocks. A decline in this service is likely to picked up by declines in other critical CPS such as fish diversity, or a change in ecological connectivity.

2.3.3 Maintenance and regulation of hydrological cycles and regimes

Maintenance and regulation of hydrological cycles and regimes has had its status as a critical service changed a number of times in the development of the draft ECD. The description of this service in the national guidelines (DEWHA 2008) relates to the capacity of wetlands to regulate hydrological processes and cycles, including retaining and retarding flows, maintaining groundwater–surface water balances through recharge and discharge processes, and providing habitats and refugia for wetland-dependent species (DEWHA 2008). As such this is considered a critical service to the site, but its Limit of Acceptable Change (LAC) will be a Cascade LAC where the elements of the service are captured in the LAC for other critical CPS.

2.3.4 Provision of pollution control

The second regulating service of concern is pollution control and detoxification. This service includes the role a wetland plays in slowing flow, trapping and assimilating sediments, nutrients and other contaminants, and 'buffering' the amount of contaminant transfer that may occur (DEWHA 2008). During the period of over allocation in the Murray-Darling Basin and low inflows to the Ramsar site in the mid-2000s, the resultant exposure of acid sulphate soils and release of acidity highlighted the importance of the buffering capacity of the waters of the Lower Lakes. However, this service can be captured by the critical component of hydrology, and would not likely undergo significant change without corresponding changes to hydrology. Also it does not link directly to

the listing criteria in that it does not influence other critical CPS related to the listing criteria. This service whilst extremely important does not fit the current guidance for being a critical CPS.

2.3.5 Special ecological, physical or geomorphic features – Murray mouth

Initially the Murray mouth was identified as a special geomorphic feature of the Ramsar site (Butcher et al. 2013) however further discussions with DoE and DEWNR resulted in this aspect of the site being captured as part of the critical service of ecological connectivity. As the mouth is geomorphically part of the whole terminal wetland system it was agreed not to artificially separate it from the rest of the system.

2.3.6 Cultural services for the Coorong and Lakes Alexandrina and Albert Ramsar site

As indicated by the guidance provided by DoE (see section 2.1) only cultural values which meet one of the criteria specified in Resolution IX.21 can be deemed as being a critical CPS, and must influence CPS for which the site is listed. The inclusion of ecosystem services and benefits within the definition of ecological character inherently includes consideration of human or cultural values. The Millennium Ecosystem Assessment (MA) cultural services acknowledge that human cultures, knowledge systems, heritage values, social interactions and associated amenity services always have been influenced and shaped by the nature of the ecosystems and ecosystem conditions in which culture is based (Tengberg et al. 2012). Within any given socioecological context, some significant contribution from ecological structures and/or functions, however indirect, is required if cultural benefits are to be attributed as an ecosystem service (Daniel et al. 2012).

Two cultural services are considered critical CPS – Cultural heritage, and Spiritual and Inspirational.

Cultural heritage as per DEWHA (2008) is when *the wetland provides culturally important landscape features or species. For example the wetland may contain historical structures or sites that use wetland derived products, tools for hunting wetland-dependent biota. There may also be sites of spiritual significance such as burial sites*. P46

With regard to Cultural heritage, the fourth criterion of Resolution IX.21 is met as the Coorong and Lakes Alexandrina and Albert Wetland include a registered Aboriginal heritage site – under the Aboriginal Heritage Act 1988 (SA). The 'Meeting of the Waters'[6626-4727] site was registered in 2009 via a negotiated agreement with the South Australian Government. The 'Meeting of the Waters' is internationally significant through its uniqueness as a registered Aboriginal site (including the waters) at the mouth of one of the world's most important river systems, located in a Ramsar listed wetland. The resolution, and the complexity of the case, has made the 'Meeting of the Waters' famous in international legal, historical, archaeological, anthropological and Indigenous contexts. The Meeting of the Waters is a fundamental aspect of the Ngarrindjeri world where all things are connected, whether they are living, from the past and/or for future generations. The Meeting of the Waters makes manifest core concepts of Ngarrindjeri culture that bind land, body, spirit, and story in an integrated, inter-functional world (from DEWNR 2013).

The cultural service of Spiritual and inspirational as per DEWHA (2008) is *the wetland may provide a source of inspiration for religion and art. The wetland may represent a place of significant nonmaterial culture such as though folklore, music, customs and traditional knowledge, and may also include species of cultural and religious significance, including family and totem species*. P46

Although it is often difficult to measure cultural heritage values, in the case of totem species (ngartjis) they can be concretely linked to specific ecosystem features (Daniel et al. 2012). These relationships offer the opportunity to

define appropriate indicators for cultural heritage services and fit clearly into the MEA ecosystem service framework (Daniel et al. 2012) adopted by the Ramsar Convention. Additional information on the ngartjis of the Ngarrindjeri has yet to be sourced (by Water's Edge Consulting); however species of cultural significance include Murray cod (relevant to Ramsar listing criterion 2), black swan and pelicans as species but also for their large breeding events (relevant to listing criterion 4 and 5). Native fish and waterbird diversity in general (relevant to listing criterion 3, 7 and 8) are also culturally significant, as are certain aquatic plant species and cockles. Further detail on these elements will be included in the ECD.

A Western science perspective of how the critical CPS are linked to some of the values associated with the cultural services of Heritage and identity and Spiritual and Inspiration are illustrated in Figure 3. No lines are used in the illustration as the concept of Yarluwar-Ruwe is inclusive and doesn't distinguish country in parts.

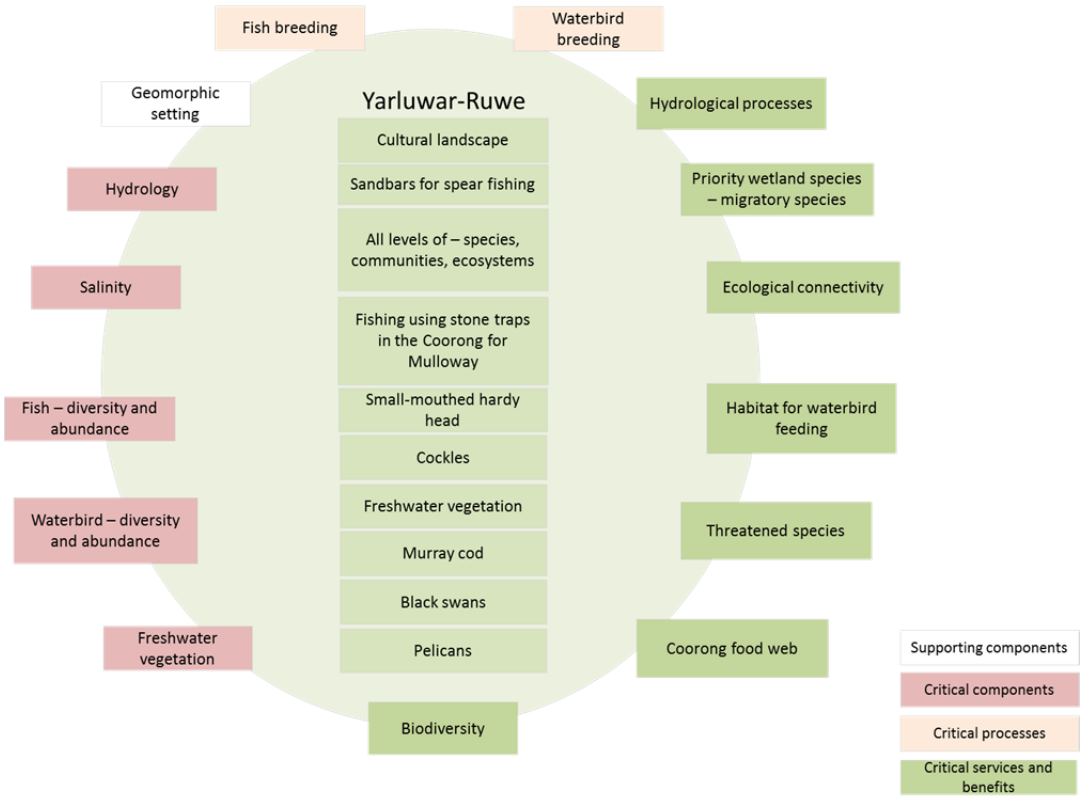

Figure 3. Western science perspective of Yarluwar-Ruwe which incorporates critical CPS (as per concepts used in the preparation of ECD). This illustration is not representative of Ngarrindjeri views.

It is possible that both critical cultural services will have cascading LAC linked to other critical CPS which are the main drivers of the ecological character of the site are relate directly to ngartjis and Ruwar. The most likely candidates for a cascading LAC include hydrology, salinity and ecological connectivity.

Table 1. Key to scoring assigned to CPS in Table 3.

Criteria	Score			
	-	+	++	+++
Criterion 1 - CPS is an important determinant of the site's unique character	Not something the site is recognised for in the scientific literature or by the community. No significant cultural values, whether material or non-material, linked to its origin, conservation and/or ecological functioning.	CPS is thought to be important based on inferred data from other sites, but may be lacking evidence from the site, and has a reasonable expectation by community that the CPS would be present at the site. For cultural values, either material or non-material, the CPS must be significantly linked to it's the sites origin, conservation and/or ecological functioning (i.e. relates to other critical CPS) as specified by Resolution 1X.21 (see Appendix A). Notably this will include cultural landscapes.	Site specific evidence of the significance of the CPS in determining the sites character, and ahigh expectation by community that CPS would be present at the site.	Considered an ecological driver or controlling variable. Strong support in literature with clear relationship between CPS and character of the site.
Criterion 2 – important for supporting the Ramsar or DIWA criteria under which the site was listed	No relationship between CPS and listing criteria.	Indirect relationship between CPS and listing criteria. For example may be a service or benefit which influences other critical CPS directly related to the listing criteria. Can include cultural values specifically related to the listing criteria (i.e. ngartjis of indigenous groups), however socio-economic ecosystem services are excluded (see section 2.1) as not being relevant to the Ramsar listing criteria (this excludes most provisioning services).		Strong, direct relationship between CPS and listing criteria.
Criterion 3 – of a nature for which change is reasonably likely to occur over short or medium time scales (<100 years)	Unlikely: occurs only in exceptional circumstances.	Possible: Could occur but not expected.	Likely: Will probably occur in most circumstances.	Almost certain: Is expected to occur in most circumstances.
Criterion 4 – of a nature	Change likely to cause	Change likely to cause relatively slow but significant	Change likely to cause	Change likely to cause very

that will cause significant negative consequences if change occurs	minor fluctuations and or negligible declines/deterioration in other CPS. No known impact on ecological character.	declines/deterioration in other critical CPS (for species/ populations <20% loss over 10 years or three generations; whichever is the longer). Affects minority of the CPS (<50%) and a possible change in ecological character.	rapid declines/ deterioration in other critical CPS (for species/ populations 20–30% over 10 years or three generations; whichever is the longer). Affects the majority of the CPS (50-90%), likely change in ecological character but may be short lived.	rapid declines/deterioration in critical CPS (for species/ populations >30% over 10 years or three generations; whichever is the longer). Affects the vast majority of CPS (>90%), and definite sustained change in ecological character.

Table 2. Assessment of components, processes, services and benefits at the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site against critical CPS criteria as per Table 1 above. Those CPS that meet all the required number of criteria are shaded – these are the critical CPS.

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
Climate	Component	+++ Driver of ecological character of the site.	-	+++ Climate change is likely to have impacts	++ Possibly a stronger impact but temporal aspect currently not known. Level of resilience in the system is also poorly understood.
Geomorphic setting	Component	+++ Driver of ecological character of the site	+++ Meets Ramsar criterion 1.	-	++ (if no remediation) Closure of Murray mouth
Soils	Component	-	- No organic peatlands/ fens of significance	-	++ (if no remediation) ASS have potential to impact site significantly
Sedimentation	Process	-	-	++	++ Infilling of terminal lakes will occur if flows insufficient to flush sediments out of system – barrages cause deposition in Lake Alexandrina.
Hydrology – surface water	Component	+++ Driver of ecological character of the site.	+++ Meets Ramsar criterion 1. The Ramsar Convention suggests that consideration under this Criterion is to give priority to those wetlands whose ecological character plays a substantial role in the natural functioning of a major river basin or coastal system (Ramsar Convention 2009)	+++ Reduced inflows are likely to occur again due to over allocation in the upper sections of the Murray Darling Basin, particularly in light of climate change and the demands this will place on water resources.	+++ Changes to diversity of critical components, altered processes, and reduced resilience.
Hydrology – groundwater	Component	+	-	++	+ Knowledge gap
Water quality - salinity	Component	+++ Driver of ecological character	+++ Contributes to meeting criterion 1 and is a strong	+++ Reduced inflows are likely to occur again due to over allocation in	+++ Significant impacts on diversity, abundance of flora and

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
		of the site.	determinant of criterion 3. Wetland types range from freshwater through to hypersaline systems. Salinity strongly influences biodiversity values.	the upper sections of the Murray Darling Basin, particularly in light of climate change and the demands this will place on water resources..	fauna and food web impacts.
Water quality - pH	Component	-	-	++	++ (if no remediation) Change could occur if another period of reduced inflows leads to acidification of surface waters. Potential for toxic metals and direct toxic impacts to biota and soils microorganisms.
Water quality – turbidity	Component	-	-	+	+ Possible decline in submergent macrophytes.
Water quality – nutrients	Component	-	-	++	+
Vegetation - freshwater/saline aquatic species	Component	++ Driver of habitat structure and key attribute of different wetland types.	+++ Meets Ramsar criterion 1 and 3.	++ Salinity and inappropriate water regimes are ongoing issues for maintaining vegetation extent and diversity of aquatic species and associations.	++ Provides critical habitat and spawning sites for fish. Provides critical habitat for waterbird feeding and nesting.
Fish – diversity	Component	+++ Highest level of fish diversity in the Murray Darling Basin.	+++ Meets Ramsar criterion 2, 3, 4, 7, and 8.	++ Fish diversity likely to respond to environmental drivers over years-decades, as highlighted during 2002-2009 period of significantly reduced inflows due to over allocation in the Murray-Darling Basin and subsequent wetter years (2010-2012).	++ Integral component of food webs and important for supporting piscivore waterbirds, as well as recreational and commercial fisheries (services and benefits).
Fish breeding	Process	++ Only estuary in the biogeographic region and as such is critical for	+++ Meets Ramsar criterion 4, 7 and 8	+ Possible change but limited data for some species	++ Freshwater flow has a major influence on fish breeding, in particular those that migrate from the sea inland, but also through

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
		diadromous species.			habitat impacts. Salinity is also an indirect influence through habitat (i.e. vegetation change) on fish nursery and spawning sites.
Waterbird diversity	Component	++ One of the most diverse and abundant wetlands in the MDB.	+++ Meets Ramsar criterion 2 and 3.	++ Susceptible to onsite changes – rate of decline greater at the Coorong that elsewhere according to O'Connor et al. (2013).	++ Shorebird declines noted for several key species. Ongoing declines in flyway populations likely to be reflected in diversity at the site. Coorong is iconic for waterbirds - loss of waterbirds is central to the character of the site
Waterbird abundance	Component	++ Very characteristic of the site – large numbers of shorebirds in particular.	+++ Meets Ramsar criterion 5 and 6.	+++ Susceptible to onsite and off-site changes to habitat and reduced populations.	++ Shorebird declines noted for several key species. Ongoing declines in flyway populations likely to be reflected in reduced abundances at the site. Flyway declines in waterbirds are a global issue (Global Flyway Network 2012), with habitat losses in key staging areas being identified as contributing to ongoing declines (e.g. (Minton et al. 2012)
Waterbird breeding	Process	+++ 23 wetland types supported.	+++ Meets Ramsar criteria 2, 3, 4, 5 and 6.	++ Disturbance of beach breeding species is a significant impact on recruitment (e.g. TSSC 2014 – hooded plover, Fairy terns – TSSC 2011)	++ Loss of habitat identified as key off site impact on populations, potential for loss of habitat on site (i.e. nesting habitat, feeding habitat) would increase rate of decline.
Algae and phytoplankton	Component	-	-	+	+ Possible impact on *Ruppia* and or submergent vegetation through shading.

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
Invertebrates	Component	++	-	++	++ Possible food web impacts, may be short lived if another species fills a niche
Amphibians	Component	-	+ (C2)	+	+++ Could lead to loss of species at the site – bell frog
Reptiles	Component	-	+ (C3)	+	- Limited contribution to biodiversity of the site – not a key determinant of the site so limited impacts.
Mammals	Component	-	+ (C3)	+	- Limited contribution to biodiversity of the site – not a key determinant of the site so limited impacts.
Water supply	Benefit	-	+ (C1)	+	++ In recognition that losing the water supply would affect CPS associated with the lakes as well as affecting stock watering, irrigation and human consumption benefits.
Stock watering	Benefit	-	-	-	+
Irrigation	Benefit	-	-	+	+
Industrial use	Benefit	-	-	-	-
Provision of aquatic foods for human consumption	Benefit	- Estuarine ecosystems are known for being highly productive systems, the Coorong and Lower Lakes support large commercial and recreational fisheries.	-	+ Change is possible – particularly in association with water resource use and climate change.	+ Fisheries are regulated so sustainable wise use is possible to allow this benefit to continue.
Genetic resources	Service	-	-	+	-
Maintenance and	Service	+++ Driver of	+Meets Ramsar criterion 1.	+ Reduced inflows are likely to occur	+++ Highly regulated system but

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
regulation of hydrological cycles and regimes		ecological character of the site.	The Ramsar Convention suggests that consideration under this Criterion is to give priority to those wetlands whose ecological character plays a substantial role in the natural functioning of a major river basin or coastal system (Ramsar Convention 2009)	again due to over allocation in the upper sections of the Murray Darling Basin, particularly in light of climate change and the demands this will place on water resources.	assumes further changes could affect CPS at the site, based on experience in the Millennium drought. Evidence from the period of reduced inflows due to water resource management in the Murray-Darling Basin, emphasises the critical nature of surface water inflows to maintaining the ecological character of the site. Reduced inflows and lake levels led to a change in character.
Coastal shoreline stabilisation and storm protection	Service	-	-	+	+
Natural hazard reduction	Benefit	-	-	+	+
Pollution control and detoxification through trapping, storage and/or treatment of contaminants	Benefit	- Not recognised as a key aspect of the sites character until the Millennium drought, but the buffering capacity of the lakes mitigated a lot of the impacts from exposed ASS.	- Reliant on hydrology and climate, but not directly related to the listing criteria.	+ Capacity to provide service is linked to water levels and water quality, as such it may change in response to water resource management in the Murray-Darling Basin..	++ Impacts likely to be exacerbated by associated reduced water – would only occur in extreme periods of reduced inflows. Resilience of the system may have been lessened during the Millennium drought. Severity of impact associated with further periods of reduced inflows is a knowledge gap.
Cultural heritage and identity	Service/benefit	+ Linked to historic and contemporary use of the site. The	+ Indirectly contributes to meeting all Ramsar criteria. Many creation stories relate	++ High risk of impact on Ngarrindjeri culture and identity due to the nature of the Ruwe-Ruwar relationship – may	+ Because of nature of Ruwar would expect significant consequences.

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
		Ramsar site provides a highly significant cultural landscape as detailed in the Meeting of Waters National Heritage listing.	to the significance of the cultural landscape and the geomorphic and hydrological processes in particular (C1).	be positive or negative.	
Spiritual and inspirational	Benefit	+ Linked to creation and contemporary use of the site.	+ Indirectly contributes to meeting all Ramsar criteria. Ngarrindjeri ngartjis are an important spiritual element of the Ramsar site which relate to listing criteria 2, 3, 4 and 5 in particular.	+ Likelihood of inspirational aspect changing are low Loss of, or damage to, spiritual elements such as ngartjis is possible, as is interference with spiritually significant hydrological and geomorphological phenomena such as those referred to in Creation stories.	+Because of nature of Ruwar would expect significant consequences.
Science and education	Benefit	-	-	+	-
Aesthetic amenity	Benefit	-	+ (C1, 5)	+	+ Assume that aesthetic amenity, recreation and tourism are interlinked.
Recreation	Benefit	-	-	+	+ Recreation is dependent on fish diversity and breeding, particularly for target fishing species.
Tourism	Benefit	-	-	+	+ Linked to aesthetic amenity.
Hydrological processes	Service	+++ Driver of ecological character of the site.	+++ Indirectly contributes to meeting all Ramsar criteria, as well as directly meeting Ramsar criterion 1.	++ Reduced inflows due to upstream water resource management are likely to occur again, particularly in light of climate change.	+++ Evidence from the period of significant reduced inflows to the site (2002-2009) emphasises the critical nature of surface water inflows. Reduced inflows and lake levels led to a change in character.
Special ecological,	Service	++ Murray mouth	- The specific feature of the	++ Dredging is required to maintain	+++ Evidence from the period

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
physical or geomorphic features		strongly influences the ecological character in the Coorong providing connectivity between the marine and estuarine environment.	Murray Mouth is considered geomorphically part of the Coorong and not a separate feature in its own right. Functionally the Murray Mouth is a key element of ecological connectivity and as such is captured as part of that critical service.	the mouth as open. Climate change may affect this critical CPS.	2002-2009 and the early 2000s emphasises the critical nature of the Murray mouth remaining open.
Provides physical habitat (for waterbird feeding)	Service	+++ 23 wetland types supported.	+++ Meets Ramsar criteria 2, 3, 4, 5 and 6.	++ Reduced inflows due to upstream water resource management are likely to occur again, particularly in light of climate change. This will change spatial and temporal availability of key feeding areas within the site.	++ Loss of habitat has been identified as a key off site impact on waterbird populations, with the potential for loss of habitat on site (i.e. feeding habitat) would increase rate of decline in waterbird populations long term.
Threatened wetland species, habitats and ecosystems	Service	++ Two ecological communities and 9 nationally listed species.	+++ Primarily contributes to meeting Ramsar criterion 2, but also 3, 4, 5 and 6.	+ to ++ The vulnerability of each species varies, however it is possible that due to both onsite and offsite conditions some species may suffer further declines in less than 100 years.	++ Some species likely to go extinct if not managed – i.e. OBP, but most of the recovery actions are not relevant to the site.
Priority wetland species and ecosystems	Service	+++ Supports 57 species listed on migratory agreements, and 56 which use the site for moulting.	+++ Primarily contributes to meeting Ramsar criteria 5 and 6, but also 2, 3, and 4.	++ Susceptible to onsite and off-site changes to habitat leading to reductions in populations	+++ Flyway declines in waterbirds are a global issue (Global Flyway Network 2012), with habitat losses in key staging areas being identified as contributing to ongoing declines (e.g. (Minton et al. 2012, Hansen et al. 2015)
Biodiversity	Service	+++ Emergent property of the sites ecological character (see Figure 1).	+++ Contributes to meeting Ramsar criteria 1, 2, 3, 4, 5, 6, 7 and 8. Primary criterion of relevance is criterion 3.	++ Susceptible to change at multiple levels of biodiversity – loss at habitat, species, community and populations.	+++ Range of impacts is significant and could occur at all structural and functional levels of biodiversity. Resilience and ecosystem function has strong

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
					relationships with biodiversity (TEEB 2010).
Nutrient cycling	Service	-	+	-	+
Primary production	Service	-	+ (C3, 5)	+	+
Ecological connectivity	Service	++ The site is the only part of the MDB where diadromous fish can move between freshwater estuarine and marine environments. This is an important part of the high level of native fish biodiversity associated with the site.	+ Meets Ramsar criteria 4 and 7 and possibly 8. Ecological connectivity at the site is integral to maintaining native fish diversity and the site is an important part of the mosaic of sites likely to be utilised by waterbirds at the MDB and continental scales.	+ Breeding of diadromous fish species is likely to be driven by environmental factors that operate at yearly and decadal scales (e.g. closure of the Murray mouth).	+ Loss of ecological connectivity would put at risk diadromous fish species at the site and within the MDB.
Food webs – Coorong food web	Service	++ High primary and secondary production supports the biodiversity for which the site is acknowledged, including that of fish and waterbirds. Submergent halophytes are critical elements in the Coorong in particular. Guidance from the Ramsar Convention indicates that "keystone"	++ Meets Ramsar criteria 2, 3, 4, 5 and 6. The food web of the Coorong is unusually short with only a few key species, yet it is extremely productive and supports significant numbers of other critical components and processes.	++ While the food web can withstand (resist) pressures such as fluctuations in production and habitat availability for organisms at each trophic level, largescale changes can occur over years and decades (e.g. decline of *Ruppia megacarpa*). The limited number of species involved in the Coorong food web makes it susceptible to disturbance. Salinity and inappropriate water regimes are ongoing issues for maintaining the Coorong food web.	++ The relatively simple food web structure means that changes to any one level can have large effects on the diversity and abundance of organisms supported by the site.

CPS	Type (according to DEWHA 2008)	Criterion 1 – important determinant of the sites character	Criterion 2 – supports listing criteria (C1-9)	Criterion 3 – change is likely <100 years	Criterion 4 – change will cause significant negative consequences
		species play vital ecological roles, and wetlands with significant populations of such species may merit special consideration as sites of international importance (Ramsar Convention 2009)			

2.3.7 Critical CPS – final proposed list

The assessment identified six components, eight services and two benefits. Only two processes were identified as critical and this is a reflection of the inclusion of some processes as services in the DEWHA (2008) guidelines (see Section 3 for further discussion). The critical CPS essential to the ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar site include:

Components:

- Hydrology – surface water
- Water quality – salinity
- Vegetation -freshwater/saline aquatic species diversity and extent
- Fish – diversity
- Waterbird diversity
- Waterbird abundance

Processes

- Fish breeding
- Waterbird breeding

Services and benefits

- Maintenance and regulation of hydrological cycles and regimes
- Cultural heritage and identity
- Spiritual and inspirational
- Hydrological processes
- Provides physical habitat (for waterbird feeding)
- Threatened wetland species, habitats and ecosystems
- Priority wetland species and ecosystems
- Biodiversity
- Ecological connectivity
- Food webs (including *Ruppia*)

3 Moving forward: Illustrating relationship between components, processes and services and benefits

The linkages between components, processes, benefits and services and the criteria under which the site was listed will be presented as a series of conceptual models in the final ECD. This will include a simple conceptual model for Coorong, and Lakes Alexandrina and Albert Wetland Ramsar site that shows the components, processes and services that are critical to the ecological character of the site, but also those which are important in supporting the critical components, processes and services the site provides.

A series of stressor models and critical path models have been developed for the Ramsar site, with further conceptual diagrams being refined by DEWNR early in 2016. It is proposed to undertake a risk assessment workshop in 2016 with the aim of identifying impact pathways and illustrating the linkages between threats, stressors and critical CPS. An example of a pictorial representation of an impact pathway model is provided in Figure 4 and Figure 5.

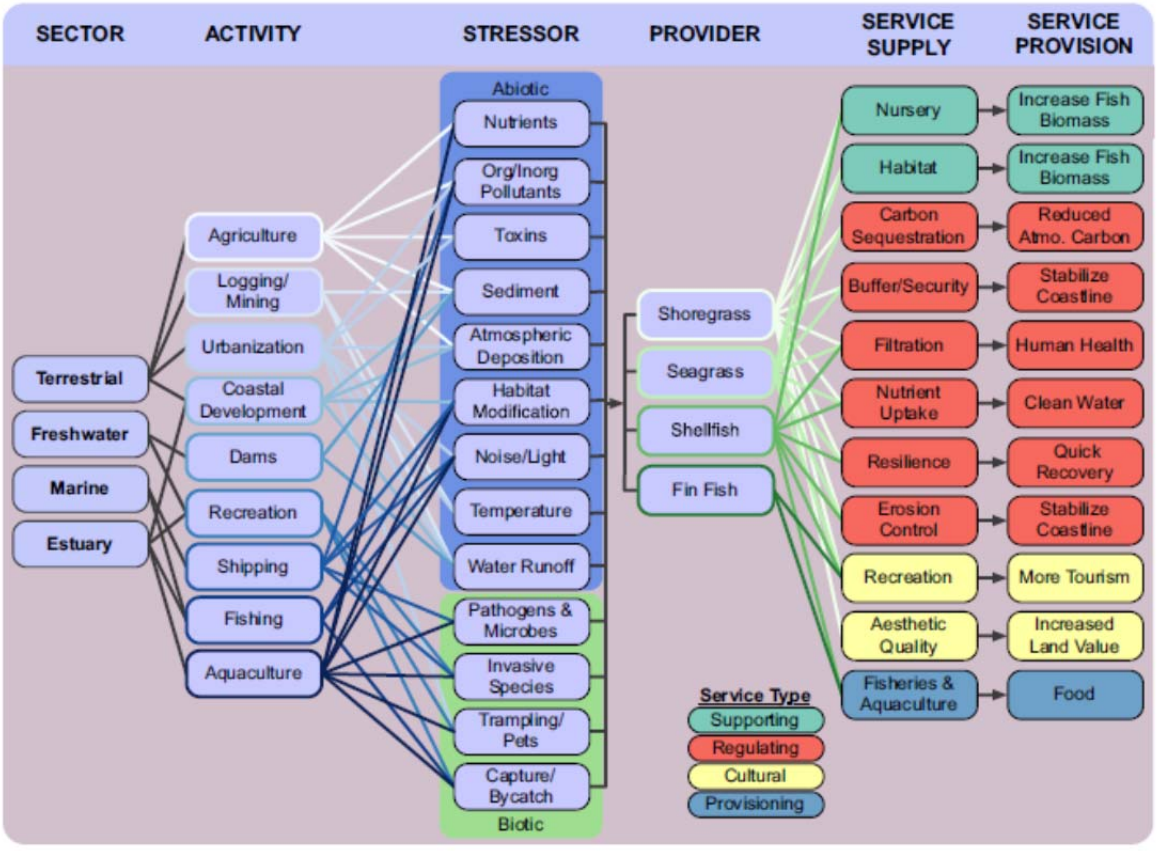

Figure 4. Diagram of impact-pathway relationships that commonly occur at the intersection of terrestrial, freshwater and marine sectors in estuarine ecosystems. Anthropogenic activities in each ecosystem produce stressors (blue—abiotic stressors; green—biotic stressors) that impact all ecosystem service providers, altering the supply and provision of services (represents only one example of possible ecosystem benefits). Not included in these pathways are external natural and societal drivers of change (i.e., natural climate cycles, climate change, grass roots scale management, etc.), as well as many

additional activities, impacts and service providers (which include microbes, birds, and other species that comprise estuarine ecosystems (Mach et al. 2015).

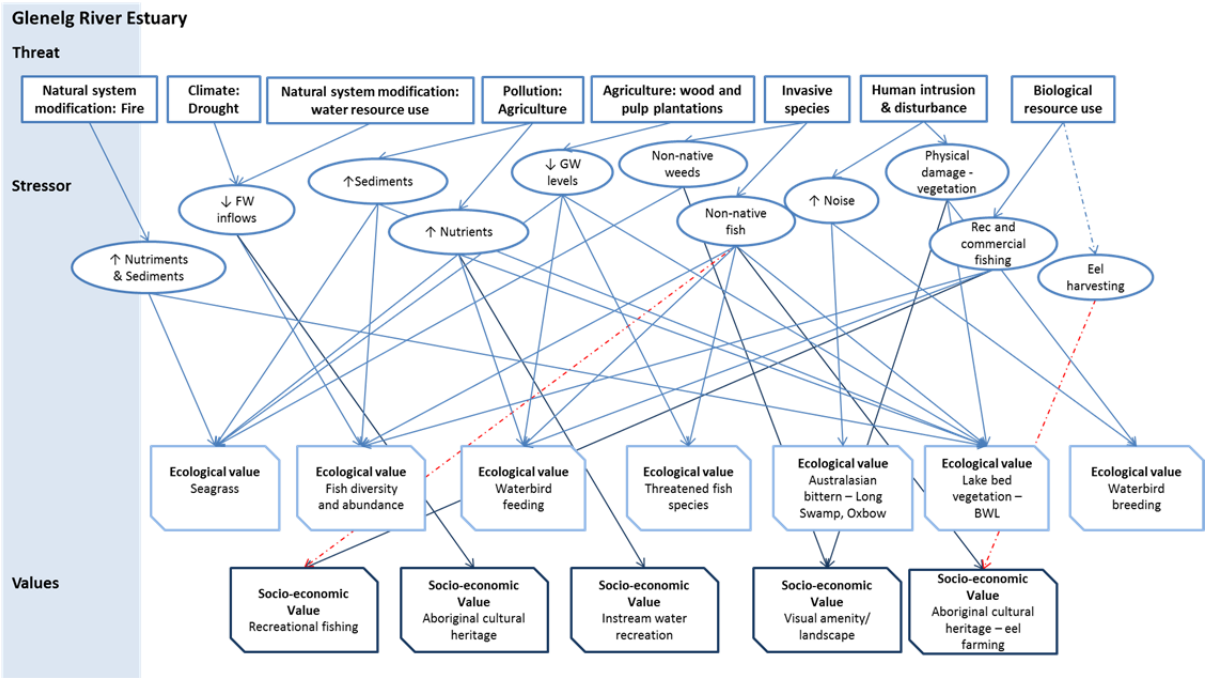

Figure 5. Impact pathway stressor model for Glenelg River Estuary section of the Glenelg River Estuary ad Long Swamp Wetland complex (Cottingham and Butcher 2015).

Actual models for the site have not been included as they are draft and will be refined once agreement on the final set of critical CPS is reached.

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Appendix A: Justification of critical CPS

A brief justification for each of the critical CPS is presented in Table 3 including citations for relevant papers which support statements made. Further detail is presented in the draft update of the ECD.

Table 3. Justification for each of the critical CPS.

CPS	Justification
Climate	Not critical
Geomorphic setting	Not critical
Soils	Not critical
Sedimentation	Not critical
Hydrology – surface water	• Wetlands are crucial in maintaining the water cycle which, in turn, underpins all ecosystem services and therefore sustainable development" p5 ten Brink et al. (2013). • Historical data from 1977 to 1997 highlights that water levels in any given year have been managed, either by design or necessity, to a range of maximum heights (Heneker 2010). • Zampatti et al. (2011) state that freshwater inflows and connectivity between the freshwater and marine environments of the Ramsar sites are fundamental drivers of fish assemblage composition. • Fundamental determinant of wetland biological chemical and physical attributes (Mitsch and Gosselink 2007, see conceptual model in DEWHA 2008 – Figure 2).
Hydrology – groundwater	Not critical
Water quality - salinity	• Data from 1979 to 2009 clearly show three major shifts in salinity levels in the freshwater lakes associated with water levels (Heneker 2010). Salinities greater than 1000 EC in Lake Alexandrina lead to increasing salinities in Lake Albert. This corresponds to lake levels between 0.25 and 0.85 metres AHD with normal interchange between the lakes. Once water levels fall from 0.25 to 0.0 metres ADH the interchange between lakes is reduced. Salinities increased at different rates in each lake. • At the peak of the drought salinities reached 6,200 EC in Lake Alexandrina. High salinity water from Lake Alexandrina was pumped into Lake Albert to maintain lake levels and prevent exposure of acid sulfate soils. With further concentration by evaporation, salinities in Lake Albert reached 19,000 EC in 2010 (MDBA 2011). • During the 1997-2009 drought high salinities in the South Lagoon led to the loss of the key primary producer *Ruppia tuberosa*, chironomids and Small-mouthed Hardyheads (*Atherinosoma microstoma*) (DEH 2010; Paton and Bailey 2012). • Brine shrimps that had not been previously recorded in the Coorong thrived in the South Lagoon and southern reaches of the North Lagoon during this period but disappeared in July 2011 after 12 months of freshwater flows through the barrages (Paton and Bailey 2012). • Salinities increase along the length of the Coorong from the Murray Mouth to the south lagoon where a lack of mixing and inflows results in concentration by evaporation to salinities several times seawater concentrations (Webster 2005).

CPS	Justification
Water quality - pH	Not critical
Water quality – turbidity	Not critical
Water quality – nutrients	Not critical
Vegetation -freshwater/saline aquatic species	• Seven major vegetation associations • Submergent freshwater and halophytic species and associations believed to be central in food webs and as habitat for many species. • No wetland dependent threatened species found at the site. • Ganf (2000) identified four issues influencing the productivity, distribution and community composition of macrophytes within the Ramsar site: salinity, turbidity, water regime and wind and wave action. • 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 (Gehrig et al. 2012; Lester et al. 2013). • Important to several listed fish species including the Yarra pygmy perch (*Nannoperca obscura*), Southern pygmy perch (*Nannoperca australis*) and Murray hardyhead (*Craterocephalus fluviatilis*) (Wedderburn and Hammer 2003).
Fish – diversity	• Over 50 native fish species have been recorded at the site in the past decade (e.g. Zampatti et al. 2011, Bice et al. 2012). • A review of the species listed by Phillips and Muller (2006), Bice (2010), Zampatti et al. (2010, 2011), Bice et al. (2012)and Watt (2013) indicate a total of 47 species occur regularly at the site (carp gudgeons counted as a single species complex). • During the period 2002-2009 the number of species supported by the site was variably reported as ranging from 26 (Noell et al. 2009) up to 47 in the estuarine component alone (Zampatti et al. 2011). • There are three listed species under the EPBC Act with an additional three species listed by the IUCN. A further 11 are protected in South Australian under the Fisheries Management Act 2007.
Fish breeding	• Possible impacts include impediment to migration of diadromous species without attractant flows, particularly when there are physical barriers (e.g. barrages); lack of stimulus for spawning; indirect impact on spawning and recruitment success as a result of modified water temperature and salinity; alteration of nursery habitat with changes in food, temperature, turbidity and salinity; reduction in primary production and trophic structure of ecosystem; and changes in fish assemblages (Drinkwater & Frank (1994) Gillanders & Kingsford (2002) cited in Watt 2013). • There are numerous estuarine resident species commonly monitored in the Ramsar site (Ye et al. 2012), including small-mouthed hardyhead, Tamar River goby, greenback flounder, and black bream, , that utilise the CLLMM site as a spawning ground, nursery and as adult habitat (Watt 2013). • The Ramsar site represents a significant migratory pathway, and potentially a nursery, for several diadromous fish species, including common galaxias, congolli and lamprey species, which require move between freshwater (Lakes Alexandrina) and marine environments (Coorong/Murray Mouth) in order to complete their life cycle (Bice 2010, Watt 2013). • The Coorong has been highlighted as an important nursery ground and habitat for the marine migrant sandy sprat (*Hyperlophus vittatus*) (Rogers and Ward 2007).
Waterbird breeding	• Thirty eight species of wetland bird have been recorded breeding within the Coorong, and Lakes Alexandrina and Albert Ramsar site, 15-27 of which breed either regularly or annually within the site. The species recorded breeding at the site utilise a range of different habitats within the system with breeding success related to a number of key factors.

CPS	Justification
	• Key references include Paton and Rogers (2009) O'Connor et al. (2012), O'Connor et al. (2013b)and Ecological Associates (2010) among others.
Waterbird diversity	• A total of 307 species of wetland dependent bird recorded within the Ramsar site, 118 of which are core species and the rest are seabirds or vagrants which do not utilise the site as core habitat (O'Connor et al. 2013b) • Waterbird diversity explicitly contributes to the site meeting Ramsar Criterion 3 and is a fundamental element of the ecological character of the site. • 47 species listed under international migratory agreements with an additional 54 species listed as marine under the EPBC Act. • Average of approximately 170,000 shorebirds annually (based on aerial surveys 2007-2011) • Eight species are regularly recorded in numbers greater than one percent of the population. • Nesting of 38 species have been recorded at the site, 15 of which regularly breed in the site.
Waterbird abundance	• Data indicate that the site regularly supports 20000 or more waterbirds. O'Connor et al. (2012) reviewed available data for fourteen species of waterbird clearly illustrating the site meets this criterion. • Large aggregations are considered highly characteristic of the Coorong and Lakes Ramsar site. • The site is one of Australia's most significant inland wetland systems in terms of the numbers of waterbirds that it supports (Kingsford et al. 2012; O'Connor et al. 2012).
Algae and phytoplankton	Not critical
Invertebrates	Not critical
Amphibians	Not critical
Reptiles	Not critical
Mammals	Not critical
Water supply	Not critical
Stock watering	Not critical
Irrigation	Not critical
Industrial use	Not critical
Provision of aquatic foods for human consumption	Not critical
Genetic resources	Not critical
Maintenance and regulation of hydrological cycles and regimes	• Historical data from 1977 to 1997 highlights that water levels in any given year have been managed, either by design or necessity, to a range of maximum heights (Heneker 2010). • Zampatti et al. (2011) state that freshwater inflows and connectivity between the freshwater and marine environments of the Ramsar sites are fundamental drivers of fish assemblage composition. • The Lakes are predominantly operated as a storage system for water supply, so this service is considered critical. • This service contributes to habitat diversity with the site having over 20 Ramsar wetland types mapped (Seaman 2003).
Coastal shoreline stabilisation and storm protection	Not critical

CPS	Justification
Natural hazard reduction	Not critical
Pollution control and detoxification through trapping, storage and/or treatment of contaminants	Not critical
Cultural heritage and identity	• From Ngarrindjeri perspective the lands and waters are a living body – the Coorong, and Lakes Alexandrina and Albert Wetland are part of the Ngarrindjeri living body. At the centre of Ngarrindjeri knowledge and identity is an understanding of the interconnectedness of all things – this is termed Ngarrindjeri Ruwe/Ruwar (from DEWNR 2013). • The cultural 'archaeological' places of the Yarluwar-Ruwe, such as middens and hearths, provide evidence of the lives of Ngarrindjeri people over thousands of years, lending independent support to many of their stories and beliefs.
Spiritual and inspirational	• Ngarrindjeri respect the gifts of Creation that Ngurunderi passed down to their Spiritual Ancestors, Elders and current generation. Ngarrindjeri believe that Ngurunderi taught them their Miwi, which is their inner spiritual connection to their lands, waters, each other and all living things, and which is passed down through our mothers since Creation (Ngarrindjeri Nation 2007). • The Kaldowinyeri story of Krowi Thukabi (the giant short-necked turtle) explains the creation of the Murray Mouth and connects Ngarrindjeri culturally and spiritually to this part of Yarluwar-Ruwe. • Krowi Thukabi the giant turtle travelled across the country from the Darling before Ngurunderi's travels. As Thukabi travelled looking for a place to lay her eggs she made many wetlands and backwaters. When she got to the sea she made the mouth of the river by pushing herself into the sea. (Bell 2014:99). • Other stories, such as the Creation Story of the Muntjingga (Seven Sisters) explains the connection between the lives of these ancestral women, the Lower Lakes and Murray Mouth, the 'Meeting of the Waters', the spirit world and all Ngarrindjeri women, and are linked to the principles of interconnectedness and renewal.
Science and education	Not critical
Aesthetic amenity	Not critical
Recreation	Not critical
Tourism	Not critical
Hydrological processes	• "Wetlands are crucial in maintaining the water cycle which, in turn, underpins all ecosystem services and therefore sustainable development" p5 ten Brink et al. (2013). • Site specific references regarding the importance of hydrological processes underpinning the ecological function and biodiversity values of the site include: Bourman and Harvey (1983), Webster (2005), Haese et al. (2008), Heneker (2010), Lester et al. (2011) and others.
Special ecological, physical or geomorphic features	Not critical
Provides physical habitat (for waterbird feeding)	• This diversity of habitat is brought about by the interactions between geomorphology, hydrology and vegetation. • Water regime and salinity are most significant determinant of wetland vegetation, with different groups of species having different morphological adaptations to patterns of inundation (Roberts & Marston 2011).
Threatened wetland species, habitats	• Notwithstanding the small numbers of individuals or sites that may be involved, or poor quality of quantitative data or

CPS	Justification
and ecosystems	information that may sometimes be available, particular consideration should be given to listing wetlands that support globally threatened communities or species at any stage of their life cycle using Criterion 2 or 3 (Ramsar 2009 – guidance for listing a site under criterion 2). • Key reference for waterbirds is O'Connor et al. (2012) and O'Connor (2015) • Various recovery plans are relevant but not necessarily specific to the site – e.g. Orange bellied parrot. • Data analysis shows the communities and species considered under this service are regularly supported by the site. • Declines in counts of Eastern curlew and curlew sandpiper support their recent listing as nationally threatened under the EPBC Act.
Priority wetland species and ecosystems	• CLLMM meets all five Ramsar criteria that are relevant to birds (Criteria 2-6). In particular, the CLLMM supports 15 threatened species, 15-27 species that regularly breed at the site, 57 species that are listed on migratory bird agreements, 56 species that use the site for moulting, >20,000 waterbirds every year, and >1% of the Flyway population size for 10 waterbird species (from O'Connor et al. 2012).
Biodiversity	• Many different aspects of biodiversity contribute to ecosystem function and provision of services. For example populations size and biomass of fish directly influence production of food for other biota and human consumption (TEEB 2010). • The site supports regionally significant range and number of species comparable to other sites within the Murray-Darling Basin. This includes supporting a large number and variety of waterbirds, including breeding habitat for over 30 species, a rich and diverse flora and the most diverse fish assemblage found in a wetland complex within the bioregion. Diversity at the ecosystem level is also high compared to other Ramsar sites within the Murray Darling Basin. • Variable lake levels and degree of connectivity to fringing wetlands promotes diversity and this service is maintained by hydrology. Connectivity between the lakes and the Coorong and estuary and Murray mouth are directly controlled by barrage operation and connectivity to the sea. Variation in hydrological connectivity affects habitat heterogeneity and in turn diversity.
Nutrient cycling	Not critical
Primary production	Not critical
Ecological connectivity	• Studies of diadromous fish movement through the site noted the importance of hydrological connectivity and passage through barriers to migration such as the Barrages (Bice et al. 2012). • See assessment and cited references in Watt (2013)
Food webs	• A number of studies have reported on the dynamics of the food web in Coorong (e.g. Paton & Rogers 2009; Deegan et al. 2010) which have illustrated a simplified food web structure in areas with elevated salinity levels. Under optimal conditions in the Coorong, the trophic productivity supports a wide diversity of organisms across numerous trophic levels (Deegan et al. 2010; Brookes et al. 2009). Changes to the availability and abundance of key species in each level of the food web can have a significant impact on the ecosystem components and processes in the Coorong. • Phillips and Muller (2006) and Baker-Gabb and Manning (2011) consider small-mouthed hardyhead as a 'keystone' taxa due to its role in trophic dynamics across the site. • *Ruppia* is considered a key primary producer, with declines in *Ruppia tuberosa* likely as it is vulnerable to further losses within the Coorong as it lacks resilience in the form of an adequate propagule bank (Paton and Bailey 2012). This service may be

CPS	Justification
	better combined with the other saline vegetation as a component.

Appendix B: Relationship between indigenous cultural services and other CPS

Justification is based on material prepared by the Ngarrindjeri as contribution to the development of the ECD, in most cases only minor changes to text have been made.

CPS	Justification
Geomorphic setting	• Ngarrindjeri believe Creation ancestors formed the landscape we see today and populated it, and the active use and care of Yarluwar-Ruwe by Ngarrindjeri over thousands of years has continued to influence the ecological character of the site. • Ngarrindjeri Kaldowinyeri stories pay particular attention to the formation, character and use of different landforms, as well as the relationships between the people, animals, plants and other beings that make use of them. The story of Ngurunderi explains the creation and importance of many of the geomorphological characteristics of the Lower Murray and surrounding landscapes. The story of Jekajeri explains both the creation of a specific sandy beach, and also the spiritual importance of that site. It should be noted that this version of the story is not complete, as Ngarrindjeri consider some details to be unsuitable for a wider audience.
Hydrology – surface water	• Many of the freshwater soaks along the Coorong and in the Lower Murray have become saline as a consequence of land degradation and decreased inflow. This is one of the many indicators Ngarrindjeri use to monitor the long-term degradation of Yarluwar-Ruwe. These soaks used to support the water requirements of both the aquatic and terrestrial animals of the Coorong as well as providing the Ngarrindjeri people themselves with drinking water (Phillips and Muller 2006: 228).
Water quality - salinity	• See comments on impacts of changes in salinity through reduced flows from upper south east drainage scheme into Coorong – Food webs. • Salinity is considered to be of great importance by Ngarrindjeri, as it has been the direct or indirect cause of significant unwelcome environmental change across the site.
Vegetation -freshwater/saline aquatic species	• Lignum provides the setting for the Ngarrindjeri creation story of Waatji Pulyeri (Blue wren) • Ngarrindjeri have reported extensive changes to the character of the site due to the effects of colonisation, and have noted that submerged aquatic plants are now restricted in range to sheltered, littoral habitats. • Currency creek region - Ngarrindjeri belief is that Ngurunderi created the characteristic local freshwater springs and giant River Red Gums, *Eucalyptus camaldulensis*. The Wuri (red gums) are considered to be Ngurunderi's trees, and Wuri and Pondi (Murray Cod) are closely connected through Ngarrindjeri Kaldowinyeri stories. • Important plant species used for Ngarrindjeri cultural weaving have also declined around the lakes, and changes in harvesting patterns and distribution patterns present challenges to contemporary Ngarrindjeri weavers. • The distribution and growth habits of reeds (*Cyperus gymnocaulus*) used for weaving (an important cultural activity with implications beyond the physical production of artefacts, as weaving and story-telling are intimately connected) has altered in response to changed water regimes and non-indigenous land uses.
Fish – diversity	• The Ngarrindjeri creation story Pondi explains the diversity and distribution of fish species throughout Yarluwar-Ruwe. Ngurunderi and Nepelli created and named various fresh and salt-water fish species from the body of the ancestral Pondi. The loss of any of these

CPS	Justification
	species would represent the loss of a part of Pondi.
Fish breeding	• Sustaining successful breeding events are critical to the Ngarrindjeri. Instances such as the disruption of breeding grounds for fish such as the jumping mullet (wankeri), due to the poor water quality of the South Lagoon and the changed drainage regimes in the South East, interrupt cultural life. • Reduced flows through the Murray Mouth also hinder or prevent mullowi and other key fish species from entering the Coorong for breeding during summer months.
Waterbird breeding	• Ngarrindjeri recognise the impacts of global warming on their lands and waters and all living things, and in recent years they have observed changes in the local environment that indicate climate change is a reality. Shifts in long-established cultural indicators show that the breeding behaviour of birds is changing, and the fruiting and flowering patterns of certain Ngarrindjeri bush foods is changing. These changes are highly significant, because natural processes such as these are key cultural markers of seasonal activity.
Waterbird diversity	• As Creation ancestors and ngartji, birds are fundamental to Ngarrindjeri understandings of Ruwe/Ruwar. • Waterbird diversity serves as a marker of seasonality, with changing bird populations reflecting the changing of the seasons throughout the year. • In a time when all birds were ancestral men two Tenetjeri (gulls) migrated from mallee country in search of new fishing grounds. As they travelled they made a pathway by treading down the vegetation. This flattened area contains claypans and samphire stretching from Lake Alexandrina westwards towards the Wimmera. When they reached the River Murray and Lake Alexandrina they were happy that they had found ideal fishing grounds. The brothers travelled with other fishing bird ancestors such as gulls, shags, small white gulls, divers, weet-weets, blue coots and pelicans. They travelled around Lake Alexandrina fishing with nets made from reeds. They moved camp as they reached areas where salt water entered the lake from the sea. They fished together to make a living. Eventually they fought with other bird ancestors such as the magpie over fire and other things and transformed into birds. (Based on Harvey 1943, and Hemming, S pers. com.).
Waterbird abundance	• Reductions in the abundance of species such as Kungari (Black Swan) due to climate change, land degradation, drought, and over-extraction of water mean that opportunities for swan egging are reduced, which in turn reduces the ability to express the cultural and social values associated with this culturally significant activity.
Provision of aquatic foods for human consumption	• Environmental changes have reduced the opportunity for Ngarrindjeri people to use traditional fishing methods for catching mulloway. Stone fish traps have been rendered ineffective, because the Coorong is no longer sufficiently tidally influenced to allow them to work as they were intended. • Traditional areas for spear fishing (e.g. sand bars) have been destroyed (Birckhead et al 2011:32). Kuti (cockles) are an important food species for Ngarrindjeri. Harvesting kuti is an integral part of many of the cultural and educational programs run by the Ngarrindjeri community while supporting the transmission of knowledge relating to the wise and sustainable use of the resource.
Maintenance and regulation of hydrological cycles and regimes	• The Ngarrindjeri have observed the draining of wetlands along the rivers, and in the south east, the disconnection of the living body of the River Murray, Lower Lakes and Coorong. This has been carried out through the installation of locks, levee banks and barrages, and water over-allocation from River and lakes, which have collectively contributed to reduced flows. This prevents the mixing of salt and freshwater, crucial to connectivity, flow, reproduction and the sustenance of the life of the waterways, lands, birds, fish and people within the Yarluwar-Ruwe
Cultural heritage and identity	• This Appendix and Appendix A

CPS	Justification
Spiritual and inspirational	• This Appendix and Appendix A
Science and education	• Traditional knowledge is passed from generation to generation and western science (which is more recent) reflect many of the concepts of Ruwe with the may difference being that nature and culture are not treated separately. This separate is considered artificial, a false dichotomy.
Aesthetic amenity	• Aesthic amenity reflects the cultural landscape as a whole.
Hydrological processes	• The wetland types and the associated vegetation are an integral part of the Ngarrindjeri cultural landscape. Krowi Thukabi, the ancestral short-necked turtle, is believed to have created the Lake Alexandrina and Lake Albert and associated landforms with her flippers as she moved across the landscape to the sea.
Special ecological, physical or geomorphic features	• The Murray Mouth is a highly significant cultural and spiritual place for Ngarrindjeri people, and it is fundamental to their wellbeing. Kaldowinyeri stories such as Thukabi, Ngurunderi, the Muntjingga and the Mulyewongk are associated with the Murray Mouth area, with each story revealing the significance of the relationship between the country and the people, both practically and spiritually. The Murray Mouth area is a part of the Meeting of the Waters, a place where the fresh and salt water mix, and it is the Ngarrindjeri place of creation - a place of birthing for Ngarrindjeri ngartjis. This site is particularly important as it dramatically illustrates the key principles of flow, reproduction, and interconnected benefit that underpin much of Ngarrindjeri philosophy. • Ngarrindjeri families continue this 'mixing of the waters' through marriages that connect the salt and fresh water parts of Ngarrindjeri Ruwe. This follows the traditions established in the Kaldowinyeri story of the Mulyewongk connecting the River, the Lakes and the Murray Mouth. • This is a very significant area for the Ngarrindjeri, as it was here that Ngurunderi created the Kurangk (Coorong), and the area plays a major part in the Kaldowinyeri story of the Muntjingga (Seven Sisters). George Trevorrow highlights the central significance of the 'Meeting of the Waters' area and the Islands in Lake Alexandrina: • Kumarangk [Hindmarsh Island], that area, is the central point for the Ngarrindjeri people… that's why our ngartjis are there. That's the homeland. That's their area….That area is to us, that's our creation area and that's why so many of our stories, of our beliefs and our culture and heritage all revolves from that area outward upon the land of the Ngarrindjeri. It's a rich environment. It supports all the birdlife. You know, you could see that for yourself when you go there but to us Ngarrindjeri people it's a spiritual environment (Trevorrow in Bell 2014:569-70). • It is important to recognise that the importance of this area is both literal and symbolic. As well as being rich in physical resources, it is also rich in spiritual symbolism, with the themes of flow and cycles being echoed in the flows of fresh and salt water, the changing of the seasons, and the reproductive cycles of ngartjis and other plant and animal species.
Provides physical habitat (for waterbird feeding)	• The South Lagoon was a major breeding ground for Ngarrindjeri ngartjis such as wankeri (jumping mullet) and birds such as ngori (pelicans).
Threatened wetland species, habitats and ecosystems	• Murray cod is a ngartji for the Ngarrindjeri. The barrages impede the movement of mullowi and other fish into the lakes. Long term alteration of water flows has also led to habitat change within the Lakes and River for Pondi (Murray Cod) and a dramatic decline in the numbers of this culturally significant fish.
Priority wetland species and ecosystems	• Ngarrindjeri belief is that Ngurunderi created the characteristic local freshwater springs and giant River Red Gums, *Eucalyptus camaldulensis,* characteristic of the Currency Creek region. The Wuri (red gums) are considered to be Ngurunderi's trees, and Wuri and Pondi (Murray Cod) are closely connected through Ngarrindjeri Kaldowinyeri stories.

CPS	Justification
Biodiversity	• Biodiversity is central to the Ngarrindjeri concept of Ruwe-Ruwar. Each element of Ruwe-Ruwar is as important as every other element, and all elements are inter-dependent. The loss or diminution of any species has an impact on both the physical environment, and the cultural experience and interpretation of the environment. This is why Ngarrindjeri consider they have a cultural responsibility to manage Yarluwar-Ruwe.
Nutrient cycling	• Supporting services considered an essential part of Ruwe
Primary production	• Supporting services considered an essential part of Ruwe
Ecological connectivity	• Ecological and cultural connectivity are considered one and the same thing – the concept of Ruwe does not distinguish between the two.
Food webs	• The main areas of swan weeds (Ruppia spp.) were still abundant in the late 1970s and have only been lost in the last 20 years, partly due to changed water regimes leading to increased silting, and partly due to the negative influence of prolonged drought. In the South Lagoon, the swan weeds once grew extremely well, because of the freshwater inflow 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 (Phillips and Muller 2006:228). • Aquatic invertebrates are well known to the Ngarrindjeri, who value them for their place in the food chain. Invertebrates of many kinds are especially valuable during breeding periods as food for Ngartjis, and therefore their abundance and diversity is considered to be a marker of health for the Ruwar/Ruwe.

Appendix C: Comparison of ecosystems services classifications

All ecosystem services are interrelated to some degree and classification of ecosystem services can be undertaken in a number of ways (Costanza 2008), however one single classification is unlikely to be suited to all situations (Costanza 2008; Fisher et al. 2008). The MEA is one of the most widely accepted categorisation (i.e. provisioning, regulating, cultural and supporting services) but was originally develop to simply promote the general acceptance of the concept of ecosystem services (Reid-Piko et al. 2010).

The ecosystem services described for wetlands by the MA, DEWHA (2008) and the Ramsar Convention (2009) are shown in Table 4. The most notable difference between this set of classifications is in the Supporting services category. Two international initiatives The Economics of Ecosystems and Biodiversity (TEEB) (http://www.teebweb.org/) and the Common International Classification of Ecosystem Services (CICES) (http://cices.eu/) which focus on ecosystem services classifications for environmental accounting are becoming widely accepted. The CICES is a hierarchical system which does not include explicit inclusion of supporting services (see Table 5).

Table 4. Example ecosystem service classification based on MEA four categories (from Reid-Piko et al. 2010).

MEA service category	MEA Wetland specific	DEWHA (2008)	Ramsar (2009)
Provisioning services	• Food (Production of fish, wild game, fruits and grains) • Freshwater (Storage and retention of water for domestic, industrial and agricultural use) • Fibre and fuel (Production of logs, fuel wood, peat, fodder) • Biochemical (Extraction of medicines and other materials from biota) • Genetic material (Genetic resistance to plant pathogens, ornamental species and so on)	• Water supply • Drinking water • Domestic farm water supply • Stock watering • Irrigation • Aquaculture • Provision of aquatic foods for human consumption • Wetland products, such as animal and plant material • Biochemical products • Genetic resources • Ornamental species	• Drinking water for humans and or livestock • Water for irrigated agriculture • Water for industry • Food for humans • Food for livestock • Wood, reed, fibre and peat • Medicinal products • Other products and resources, including genetic material

MEA service category	MEA Wetland specific	DEWHA (2008)	Ramsar (2009)
Regulating services	• Climate regulation (Sources of and sink for greenhouse gases, influence local and regional temperature, precipitation and other climatic processes) • Water regulation (hydrological flows) (Groundwater recharge/discharge) • Water purification and waste treatment (Retention, recovery and removal of excess nutrients and other pollutants) • Erosion regulation (Retention of soils and sediments) • Natural hazard regulation (Flood control, storm protection) • Pollination (Habitat for pollinators)	• Maintenance and regulation of hydrological cycles and regimes • Maintenance and regulation of air quality • Maintenance and regulation of climate • Coastal shoreline stabilisation and storm protection • Bank stabilisation and erosion protection • Biological control of pest species and diseases and support of predators of agricultural pests • Pollution control and detoxification through trapping, storage and/or treatment of contaminants • Natural hazard reduction	• Groundwater replenishment • Water purification/waste treatment or dilution • Biological control agents for pests/ disease • Flood control, flood storage • Soil, sediment and nutrient retention • Coastal shoreline and river bank stabilisation and storm protection • Other hydrological services • Local climate regulations/buffering of change • Carbon storage/sequestration
Cultural services	• Spiritual and inspirational (Source of inspiration, many religions attach spiritual and religious values to aspects of wetland ecosystems) • Recreation (Opportunities for recreational activities) • Aesthetic (Many people find beauty or aesthetic value in aspects of wetland ecosystems) • Educational (Opportunities for formal and informal education and training)	• Recreation • Tourism • Science and education • Aesthetic amenity (including unique or representative land and waterscapes) • Cultural heritage and identity • Spiritual and inspirational	• Recreational hunting and fishing • Water sports • Nature study pursuits • Other recreation and tourism • Educational values • Cultural heritage • Contemporary cultural significance • Aesthetic and sense of place values • Spiritual and religious values • Important knowledge systems and importance for research
Supporting services	• Soil formation (Sediment retention and accumulation of organic matter) • Nutrient cycling (Storage, recycling, processing and acquisition of nutrients)	• Hydrological processes • Food webs • Physical habitat • Nutrient cycling • Primary production • Sediment trapping, stabilisation and soil formation	None identified as services: Nutrient cycling and primary production are identified as processes.

MEA service category	MEA Wetland specific	DEWHA (2008)	Ramsar (2009)
		• Biodiversity • Special ecological, physical or geomorphic features • Distinct or unique wetland species • Threatened wetland species, habitats and ecosystems • Priority wetland species and ecosystems • Natural or near-natural wetland ecosystems • Ecological connectivity	

Table 5. CICES v4.3 ecosystem services classification.

Section	Division	Group	Class	Class type
This column lists the three main categories of ecosystem services	***This column divides section categories into main types of output or process.***	***The group level splits division categories by biological, physical or cultural type or process.***	***The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.***	***Class types break the class categories into further individual entities and suggest ways of measuring the associated ecosystem service output.***
Provisioning	Nutrition	Biomass	Cultivated crops	*Crops by amount, type*
			Reared animals and their outputs	*Animals, products by amount, type*
			Wild plants, algae and their outputs	*Plants, algae by amount, type*
			Wild animals and their outputs	*Animals by amount, type*
			Plants and algae from in-situ aquaculture	*Plants, algae by amount, type*
			Animals from in-situ aquaculture	*Animals by amount, type*
		Water	Surface water for drinking	*By amount, type*
			Ground water for drinking	
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*
			Materials from plants, algae and animals for agricultural use	
			Genetic materials from all biota	
		Water	Surface water for non-drinking purposes	*By amount, type and use*
			Ground water for non-drinking purposes	

Section	Division	Group	Class	Class type
	Energy	Biomass-based energy sources	Plant-based resources	*By amount, type, source*
			Animal-based resources	
		Mechanical energy	Animal-based energy	*By amount, type, source*
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*
			Dilution by atmosphere, freshwater and marine ecosystems	
			Mediation of smell/noise/visual impacts	
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk, area protected*
			Buffering and attenuation of mass flows	
		Liquid flows	Hydrological cycle and water flow maintenance	*By depth/volumes*
			Flood protection	*By reduction in risk, area protected*
		Gaseous / air flows	Storm protection	*By reduction in risk, area protected*
			Ventilation and transpiration	*By change in temperature/humidity*
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*By amount and source*
			Maintaining nursery populations and habitats	*By amount and source*
		Pest and disease control	Pest control	*By reduction in incidence, risk, area protected*

Section	Division	Group	Class	Class type
			Disease control	
		Soil formation and composition	Weathering processes	*By amount/concentration and source*
			Decomposition and fixing processes	
		Water conditions	Chemical condition of freshwaters	*By amount/concentration and source*
			Chemical condition of salt waters	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic parameter*
			Micro and regional climate regulation	
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data, plants, animals, ecosystem type*
			Physical use of land-/seascapes in different environmental settings	
		Intellectual and representative interactions	Scientific	*By use/citation, plants, animals, ecosystem type*
			Educational	
			Heritage, cultural	
			Entertainment	
			Aesthetic	
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*By use, plants, animals, ecosystem type*
			Sacred and/or religious	
		Other cultural outputs	Existence	*By plants, animals, feature/ecosystem type or component*
			Bequest	