Ecological Character Description of the Ord River Floodplain Ramsar Site

A Report to the
Department of Environment and Conservation

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Australian Government

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Jennifer Hale

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Introductory Notes
This Ecological Character Description (ECD Publication) has been prepared in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (National Framework) (Department of the Environment, Water, Heritage and the Arts, 2008).

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prohibits actions that are likely to have a significant impact on the ecological character of a Ramsar wetland unless the Commonwealth Environment Minister has approved the taking of the action, or some other provision in the EPBC Act allows the action to be taken. The information in this ECD Publication does not indicate any commitment to a particular course of action, policy position or decision. Further, it does not provide assessment of any particular action within the meaning of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

This ECD Publication is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention.

Note: There may be differences in the type of information contained in this ECD publication, to those of other Ramsar wetlands.

Table of Contents

Glossary 1

Abbreviations 4

Executive Summary 5

1. Introduction 10

1.1 Site details 10

1.2 Statement of purpose 10

1.3 Relevant treaties, legislation and regulations 14

1.4 Method 16

2. General Description of the Ord River Floodplain Ramsar Site 17

2.1 Location 17

2.2 Land tenure 19

2.3 Climate 20

2.4 Ramsar criteria 23
- 2.4.1 Criteria under which the site was designated (1990) 23
- 2.4.2 Current situation and additional criteria met 24

2.5 Wetland types 26

3. Critical Components, Processes, Benefits and Services 28

3.1 General Description 28

3.2 Critical Components and Processes 29
- 3.2.1 Identifying critical components and processes 29
- 3.2.2 Geomorphology 31
- 3.2.3 Hydrology 35
- 3.2.4 Water quality 41
- 3.2.5 Phytoplankton 45
- 3.2.6 Vegetation 46
- 3.2.7 Invertebrates 51
- 3.2.8 Fish 52
- 3.2.9 Waterbirds 56
- 3.2.10 Crocodiles 61

3.3 Benefits and services 63
- 3.3.1 Overview of benefits and services 63
- 3.3.2 Cultural and economic services and benefits 64
- 3.3.3 Identifying critical ecosystem services and benefits 65
- 3.3.4 Supports diverse physical habitat types 66
- 3.3.5 Supports threatened species 67
- 3.3.6 Supports critical life stages 68
- 3.3.7 Supports abundant and diverse waterbirds 71
- 3.3.8 Supports diverse fish populations 71

4. How the Ord River Floodplain System Works: Interactions between components, processes & services 72

4.1 Primary determinants of ecological character 72

4.2 Abiotic components 73

4.3 Habitat 77

5. Limits of Acceptable Change ... 80
5.1 Process for setting LAC ... 80
5.2 LAC for the Ord River Floodplain Ramsar site ... 84
6. Threats to the Ecological Character of the Ord River Floodplain Ramsar site ... 87
6.1 Water resource development and management ... 88
6.2 Agriculture ... 88
6.3 Commercial and recreational fishing ... 90
6.4 Introduced species ... 90
6.5 Recreation ... 91
6.6 Tidal power ... 91
6.7 Fire ... 92
6.8 Climate change ... 92
7. Current Ecological Character and Changes to Ecological Character since the time of listing ... 93
8. Knowledge Gaps ... 95
9. Monitoring Needs ... 97
9.1 Existing monitoring programs ... 97
9.2 Monitoring of Ecological Character ... 98
10. Communication and Education Messages ... 101
References ... 102
Appendix A: Method ... 110
A.1 Approach ... 110
A.2 Consultant Team ... 111
Appendix B: Fish Species ... 113
Appendix C: Waterbirds and mangrove birds recorded in the Ord River Floodplain Ramsar Site ... 116
Appendix D: Native flora recorded within the Ord River Floodplain Ramsar site ... 121

Glossary

Definitions of words associated with ecological character descriptions (DEW 2008).

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

	Convention 2005, Resolution IX.1 Annex A). The phrase "at a given point in time" refers to Resolution VI.1 paragraph 2.1, which states that "It is essential that the ecological character of a site be described by the Contracting Party concerned **at the time of designation for the Ramsar List**, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).
Ecological communities	any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2005).
Ecosystems	the complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services). (Millennium Ecosystem Assessment 2005).
Ecosystem components	include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002)
Ecosystem services	are the benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food & water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational), and supporting (e.g nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also “Benefits”.
Ecologically Sustainable Development	development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ANZECC and ARMCANZ 2000).
Geomorphology	the study of water-shaped landforms (Gordon *et al*. 1999)
Indicator species	species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2005).
Indigenous species	a species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Introduced (non-native) species	a species that does not originate or occur naturally in a particular country (Ramsar Convention 2005).
Limits of Acceptable Change	the variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed’ (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ("the Ramsar List")	the list of wetlands which have been designated by the Ramsar Contracting Partiy in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties [http://www.ramsar.org/about/about_glossary.htm].
Monitoring	the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management (Ramsar Convention 2002, Resolution VIII.6).
Ramsar	city in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title, "Ramsar Convention on Wetlands" [http://www.ramsar.org/about/about_glossary.htm].

Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values. http://www.ramsar.org/about/about_glossary.htm
Ramsar Convention	*Convention on Wetlands of International Importance especially as Waterfowl Habitat*. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names "Convention on Wetlands (Ramsar, Iran, 1971)" or "Ramsar Convention" are more commonly used [http://www.ramsar.org/index_very_key_docs.htm].
Ramsar Information Sheet (RIS)	the form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and conservation measures taken and needed (http://www.ramsar.org/about/about_glossary.htm).
Ramsar List	the List of Wetlands of International Importance [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Sites	wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Sites Database	repository of ecological, biological, socio-economic, and political data and maps with boundaries on all Ramsar sites, maintained by Wetlands International in Wageningen, the Netherlands, under contract to the Convention [http://www.ramsar.org/about/about_glossary.htm].
Wetlands	are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Finlayson *et al*. 2001; Ramsar Convention 2002).
Wetland Ecological Risk Assessment	a quantitative or qualitative evaluation of the actual or potential adverse effects of stressors on a wetland ecosystem
Wetland types	as defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/ris/key_ris.htm#type].
Wise use of wetlands	is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches[1], within the context of sustainable development[2]" (Ramsar Convention 2005 Resolution IX.1 Annex A). 1. Including *inter alia* the Convention on Biological Diversity's "Ecosystem Approach" (CBD COP5 Decision V/6) and that applied by HELCOM and OSPAR (Declaration of the First Joint Ministerial Meeting of the Helsinki and OSPAR Commissions, Bremen, 25-26 June 2003). 2. The phrase "in the context of sustainable development" is intended to recognize that whilst some wetland development is inevitable and that many developments have important benefits to society, developments can be facilitated in sustainable ways by approaches elaborated under the Convention, and it is not appropriate to imply that 'development' is an objective for every wetland.

Abbreviations

CALM	Department of Conservation and Land Management (former Western Australian government department)
CAMBA	China Australia Migratory Bird Agreement
CMS	Bonn Convention on Migratory Species
DEC	Department of Environment and Conservation (Western Australia)
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth)
DoW	Department of Water (Western Australia)
ECD	Ecological Character Description
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999 (Commonwealth)
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
ORIA	Ord River Irrigation Area
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement

Executive Summary

The Ord River Floodplain Ramsar site is located in the north east of Western Australia, approximately 8km east of the town of Wyndham within the Victoria-Bonaparte bioregion. The site covers over 140,000 hectares and lies within the Shire of Wyndham – East Kimberley.

The Ord River Floodplain site contains a wide range of wetland types and includes inland and marine components. The Ramsar site comprises (Figure E1):

Parry Lagoons – this includes both the permanent (or near permanent) waterholes, such as Marglu Billabong, as well as the broader area of floodplain within the Parry Lagoons Nature Reserve that are subject to periodic inundation.

Ord Estuary – as the Ord River within the Ramsar site is under tidal influence, the area from the boundary near Adolphus Island to the Rocks has been grouped as "Ord Estuary". In some instances (e.g. for water quality measurements) this has been divided into two areas: open or outer estuary which is the area from Panton Island downstream to the boundary near Adolphus Island, and the upper estuary; upstream of Panton Island, which has a greater freshwater influence.

False Mouths of the Ord – the area of extensive intertidal creeks and flats in the north of the site.

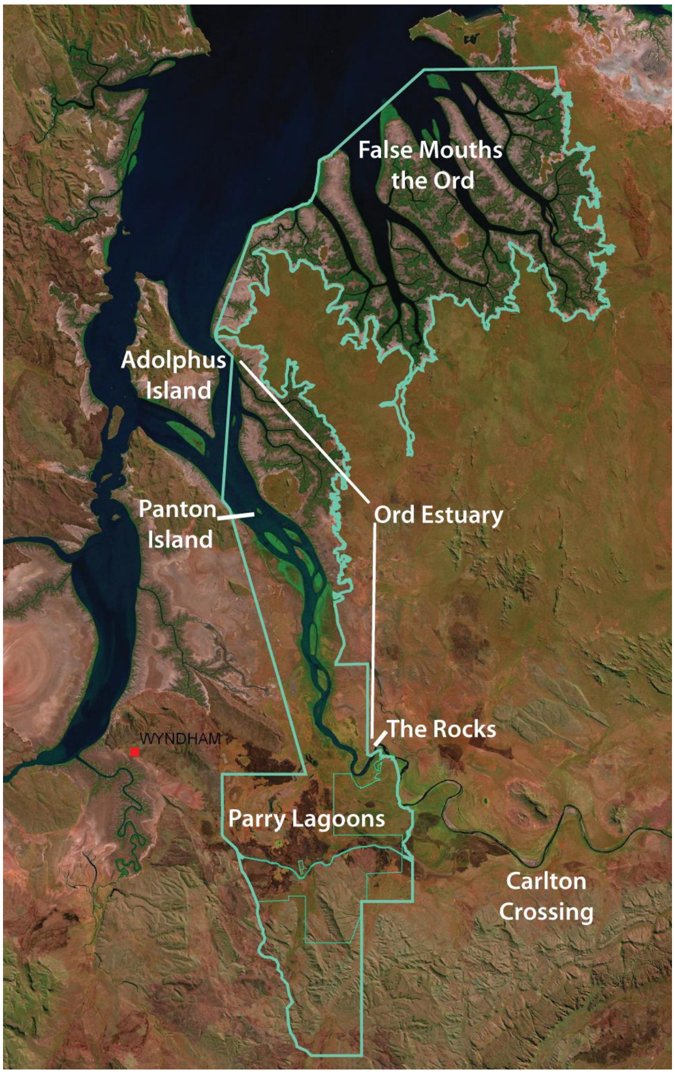


Figure E1: Map of the Ramsar site (boundary shown in green) with landmarks.

The Ord River Floodplain Ramsar site meets the following seven criteria for listing as a wetland of international importance:

Criterion 1: The site represents the best example of wetlands associated with the floodplain, and estuary of a tropical river system in The Kimberley region of Western Australia.

Criterion 2: The site supports a number of threatened species including the Freshwater Sawfish (*Pristis microdon*), the Green Sawfish (*Pristis zijsron*) and the Australian Painted Snipe (*Rostratula australis*), which are listed as vulnerable under the EPBC Act. The site is also one of only two known habitats in Western Australia of the nationally endangered Northern River Shark (*Glypis sp. C*).

Criterion 3: The site contains an extensive and diverse mangrove community containing 14 of the 18 species of mangrove known to occur in Western Australia, potentially the most diverse in Western Australia.

Criterion 4: The site supports an array of species and communities during critical life stages including: migratory birds; breeding of waterbirds, fish, crabs, prawns and crocodiles.

Criterion 5: Despite the fact that much of the area is difficult to survey, there is sufficient evidence to support the criterion of "regularly supports 20,000 waterbirds. Surveys conducted at Parry Lagoons in the 1980s regularly recorded > 20,000 birds in this portion of the Ramsar site alone.

Criterion 6: According to the 4th edition of Waterbird Population Estimates, the site regularly supports 1% of the population of Plumed Whistling Duck and Little Curlew.

Criterion 8: The Ord River Floodplain Ramsar site is important as a nursery and/or breeding and/or feeding ground for at least 50 species of fish and a migratory route for 15 species that are known to be diadromous.

A summary of the ecological character of the Ord River Floodplain Ramsar site is provided in Table E1.

Table E1: Summary of the ecological character of the Ord River Floodplain Ramsar site at the time of listing

Category	Summary Description
Benefits and services	
Provisioning services	Wetland products - Commercial fisheries for a number of species of fish, as well as prawns and crabs Genetic resources - plausible, but as yet no documented uses
Regulating services	Erosion control – mangroves Climate regulation – plausible, but data deficient Biological control of pests – support of predators of agricultural pests
Cultural services	Recreation and tourism – site is important for recreational fishing; tourism; bird watching and crocodile watching Spiritual and inspirational - spiritually significant for the Miriuwung, Gajerrong and contain a number of specific culturally significant sites; site has inspirational, aesthetic and existence values at regional, state and national levels The site contains a number of non-indigenous historical sites Scientific and educational – focus of scientific research (e.g. CSIRO investigation)
Supporting services	As evidenced by the listing of the Ord River Floodplain site as a wetland of international importance. The system provides a wide range of biodiversity related ecological services critical for the ecological character of the site including: • Supporting diverse habitat types • Supporting critical life stages • Supporting threatened species • Supporting waterbird populations

Category	Summary Description
	• Supporting fish populations
Components and processes	
Climate	Semi-arid monsoonal 80% of rainfall in the wet season (December to February) On average evaporation exceeds rainfall in 11 of 12 months
Geomorphology	Estuarine reaches of river Tidal flat creek system (False Mouths of Ord) Seasonally inundated floodplain with permanent waterholes (Parry Lagoons)
Hydrology	Macro-tidal influence Modified flows from dams upstream Low flow during dry season Higher flows in wet season Overbank flows from the Ord River to Parry Lagoons now low frequency Parry Creek major source of water for Parry Lagoons (and floodplains)
Water Quality	Estuary is highly turbid Potentially high nutrient levels from upstream agriculture Estuary is a net exporter of nutrients Salinity in estuary varies seasonally (30 – 35 ppt in dry season; < 4 ppt in wet) Parry Lagoons predominantly fresh Levels of agrichemicals above ANZECC guidelines detected
Phytoplankton	Estuary dominated by diatoms Plankton is predominantly epi-benthic
Vegetation	Extensive mangroves in intertidal areas – 15 species Saltmarsh at higher elevations Parry Lagoons characterised by extensive sedge / grass lands (intermittent inundation); aquatic vegetation in permanent waterholes; wooded swamp surrounding
Invertebrates	Commercially significant taxa include mud crabs and white banana prawns Data deficient for other communities and populations
Fish	> 50 species (estuarine, marine and freshwater) Migratory route for approximately 17 species Supports threatened taxa listed under the EPBC Act (Freshwater Sawfish, Green Sawfish and Northern River Shark)
Birds	Regularly supports > 20,000 waterbirds Breeding recorded for 16 species Regularly supports > 1 % of the population of Plumed Whistling Duck and Little Curlew Supports the EPBC listed species the Australian Painted Snipe
Crocodiles	Supports Saltwater and Freshwater Crocodiles

The attributes that are central to maintaining the ecological character of a Ramsar site have been described as "primary determinants". In the context of the Ord River Floodplain Ramsar site primary determinants have been defined as the characteristics of the wetland that are crucial to the maintenance of the components and processes for which the site has been listed. This includes the abiotic components of water quality and hydrology as well as habitat to maintain key species and communities (Figure E2).

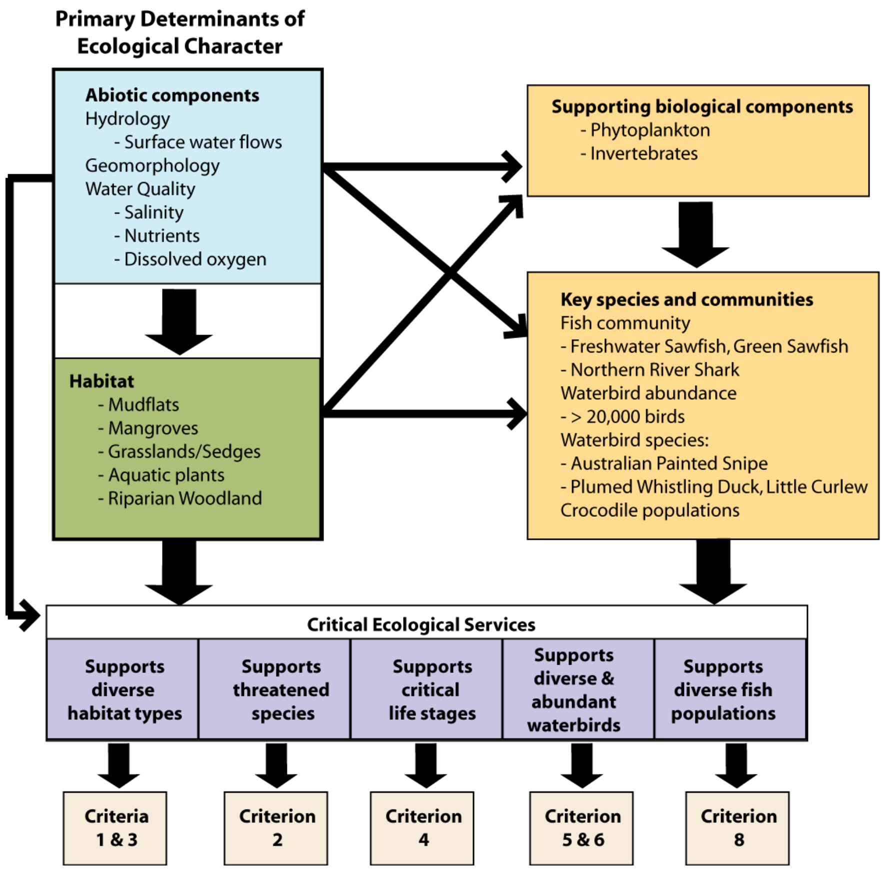


Figure E2: Primary determinants of ecological character at the Ord River Floodplain Ramsar site.

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

The major threatening activities, the threatening processes they induce and the potential impacts to the Ord River Floodplain Ramsar site have been identified as (Figure E3):

- Water resource development;
- Agricultural activities in the catchment;
- Commercial and recreational fishing;
- Introduced species;
- Recreation;
- Tidal power;
- Fire; and
- Climate change

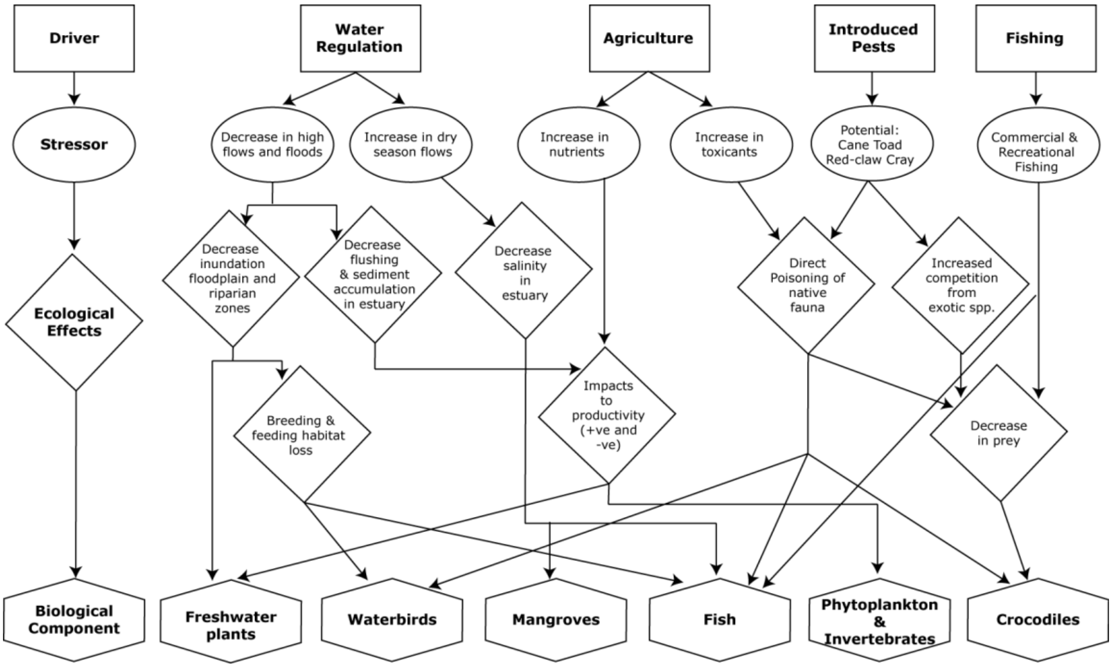


Figure E3: Stressor model of the Ord River Ramsar site showing major threatening activities.

The Ord River Floodplain Ramsar site was first listed under the Ramsar Convention as a wetland of international importance in 1990. At this point in time, the site had already been subject to significant hydrological alteration, as a result of water regulation and development as a part of the Ord River Irrigation Scheme, Phase 1. Since 1990, there has been further water related development on the Ord River, most significantly the increasing of the Ord River Dam wall by 6 metres and the commissioning of a hydroelectric power station. However, there has been little change in landuse activities, population or other activities that could impact on the ecological character of the Ramsar site. A lack of monitoring data spanning the period from the time of listing to current prevents any quantitative assessment of changes in ecological character of the site since 1990.

There are a number of key knowledge gaps that limit the description of ecological character and the setting of limits of acceptable change for the Ord River Floodplain Ramsar site. These include:

- An understanding of the hydrology of Parry Lagoons (and associated floodplain) and particularly the role of Parry Creek in inundation of the floodplain;
- Connectivity (and barriers to connectivity) between the floodplain and estuarine areas of the Ramsar site;
- Hydrology of the False Mouths of the Ord and other tidal creek areas;
- Long-term water quality;
- Composition and extent of vegetation communities;
- Community composition and abundance of fish within the site;
- Waterbird usage, abundance and composition (current data is limited to a small number of surveys at Parry Lagoons); and
- Threatened species – the site is thought to support two species listed under threatened species legislation (Freshwater Sawfish, Green Sawfish, Northern River Shark and Australian Painted Snipe); however, records for these species are based on isolated surveys.

To address these knowledge gaps and inform against the limits of acceptable change the monitoring needs for the Ord River Floodplain Ramsar site have been documented and prioritised.

1. Introduction

1.1 Site details

The Ord River Floodplain is located in the East Kimberley region in north Western Australia. It was originally nominated as a "Wetland of International Importance" under the Ramsar Convention in 1990. Site details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for the Ord River Floodplain Ramsar site taken from the Ramsar Information Sheet (2003).

Site Name	Ord River Floodplain, Western Australia
Location in coordinates	Latitude: 14°51' S to 15° 46' S Longitude: 128° 12' E to 128° 33' E
General location of the site	The Ord River Floodplain system is in the Shire of Wyndham-East Kimberley (local authority), Western Australia. Biogeographic region: Victoria Bonaparte. The original areas nominated comprised: the floodplain and associated wetlands of the lower Ord River and of Parry Creek as well as the intertidal wetlands associated with the East Arm of Cambridge Gulf and the "False Mouths of the Ord". The site was extended in 2001 to include additional areas, which were recent additions to the conservation reserve system.
Area	141,453 hectares
Date of Ramsar site designation	Originally nominated in February 1990 and designated on 7/6/1990 Site was extended in 2001
Ramsar/DIWA Criteria met by wetland	Ramsar criteria 1, 2, 3 and 5.
Management authority for the site	The Nature Reserves are vested with the Western Australian Conservation Commission and managed by the Department of Environment and Conservation, marine areas are non-reserved.
Date the ECD applies	1990, but includes the 2001 extension to the site
Status of Description	This represents the first ECD for the site
Date of Compilation	July 2008
Name(s) of compiler(s)	Jennifer Hale on behalf of DEC all enquires to Michael Coote, DEC, 17 Dick Perry Ave, Technology Park, Kensington, WA 6983, Australia, (Tel: +61-8-9334-0479; Fax: +61-8-9334-0199; email: Michael.Coote@dec.wa.gov.au).
References to the Ramsar Information Sheet (RIS)	Ord River Floodplain Ramsar site RIS compiled by the Western Australian Department of Conservation and Land Management (CALM) in 1990; updated by Roger Jaensch, Wetlands International - Oceania, on behalf of CALM in 1998, and by CALM staff in 2000 and 2003. Electronic version: www.naturebase.net/pdf/national_parks/wetlands/fact_sheets/ord_river_floodplain1.doc Updated by Jennifer Hale on behalf of DEC 2008
References to Management Plan(s)	CALM 1998 Draft Lower Ord Ramsar Site Management report. A management plan is due to be completed by 2009

1.2 Statement of purpose

The act of designating a wetland as a Ramsar site carries with it certain obligations, including managing the site to retain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Thus, understanding and describing the 'ecological character' of a Ramsar site is a fundamental management tool for signatories and local site managers which should form the baseline or benchmark for management planning and action, including site monitoring to detect negative impacts.

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

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

And

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

In order to detect change it is necessary to establish a benchmark for management and planning purposes. Ecological character descriptions (ECD) form the foundation on which a site management plan and associated monitoring and evaluation activities are based. The legal framework for ensuring the ecological character of all Australian Ramsar sites is maintained is the Environment Protection and Biodiversity Act, 1999 (the EPBC Act) (see Figure 1). As mentioned above a Ramsar Information Sheet is prepared at the time of designation. However whilst there is some link between the data used for listing a site (based on the various criteria) the information in an RIS does not provide sufficient detail on the interactions between ecological components, processes and functions to constitute a comprehensive description of ecological character. In response to the short fall, the Australian and state/territory governments have developed a *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEWHA 2008).

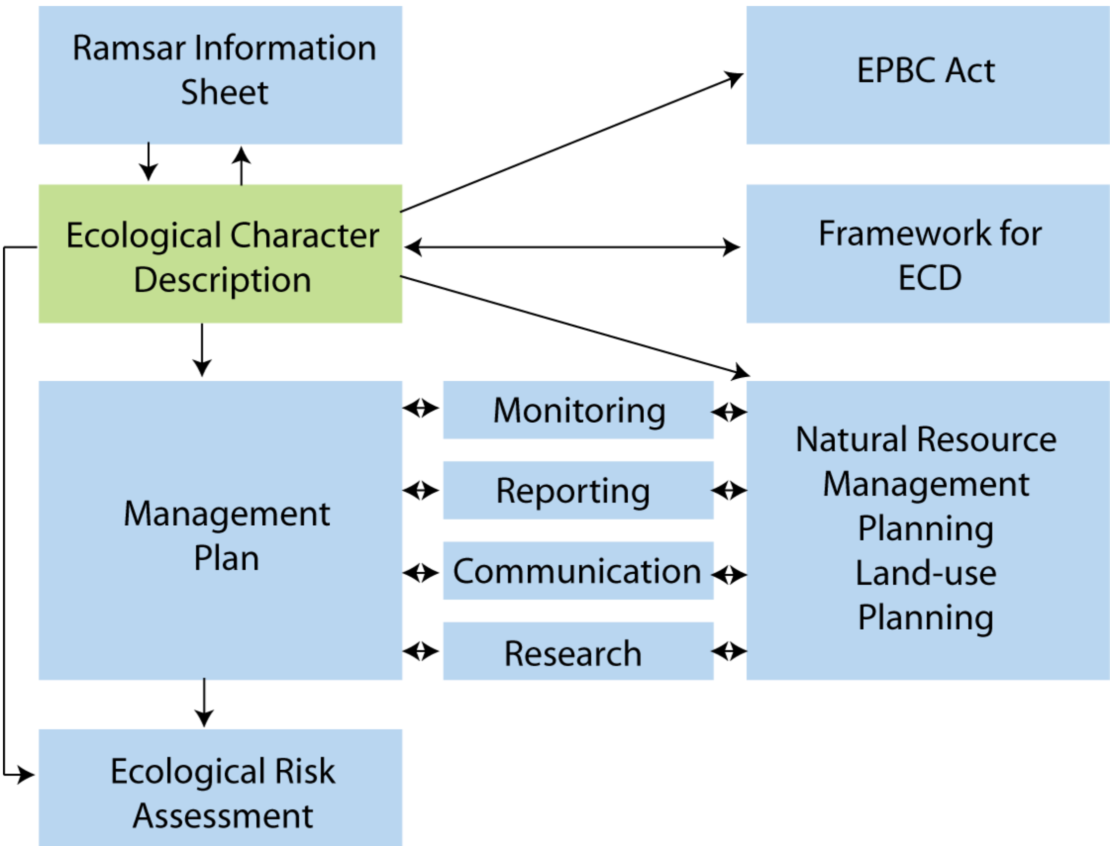


Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA, 2008).

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

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

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Commonwealth):
   a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and
   b) To formulate and implement planning that promotes:
      i) Conservation of the wetland; and
      ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.
2. To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.
3. To supplement the description of the ecological character contained in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.
4. To assist the administration of the EPBC Act, particularly:
   a) To determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or
   b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.
5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.
6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

A draft Ramsar Management Report for the Ord River Floodplain was developed in 1998 (CALM 1998). Although never finalised it is currently being revised with a new management plan expected to be released in 2009. The ECD will be an important source document in guiding the development of the revised management plan for the site. The progress taken to get to the point of providing a description of the ecological character of the Ord River Floodplain system is illustrated in Figure 2.

1975 Ramsar Convention on Wetlands in force in Australia

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

1990 Australia designates the Ord River Floodplain

Australia designates the Ord River Floodplain as a Wetland of International Importance

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

1998 Draft Ord River Floodplain Ramsar Site Managment Plan

Draft plan for the managment of the Ramsar site is developed by CALM

1999 Commonwealth Environment Protection and Biodiversity Conservation Act, enacted

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

2001 Ord River Floodplain Ramsar Site expanded

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

2007 Or River Floodplain Ecological Water Requirements

Hydrological reccomendations to protect and maintain the ecological components of the freshwater wetlands in the Ramsar site.

2008 ECD for the Ord River Floodplain Ramsar Site

This is a fundamental step in the development of a new management plan for the Ramsar site.
The ECD describes the character of the site for the time of listing (1990) and changes in ecological character since this time.

2009 Management Plan for the Ord River Floodplain Ramsar Site

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

Figure 2: Ramsar listing and management pathway for the Ord River Floodplain.

In addition to the Ramsar driven process of site management, a number of other planning programs and initiatives also impact on the management of the Ramsar site. The most significant of these has been the development of Ecological Water Requirements for the Ord River Floodplain (Braimbridge and Malseed 2007), which provides hydrological recommendations for maintaining the ecology of the lower Ord River (including parts of the Ramsar site).

The objectives of the Ecological Character Description for the Ord River Floodplain are to provide a description of ecological character that:

1. Describes the critical components, processes and benefits/services of the wetlands with the Ord River Floodplain Ramsar site at the time of Ramsar listing and the relationships between them;
2. Develops a conceptual model for the Ord River Floodplain that describes the 'ecological character' in terms of components, processes and benefits/services and the relationships between them;
3. Quantifies the limits of acceptable change for the critical components, processes and benefits/services of the wetland;
4. Provides a monitoring program that will facilitate the detection and ability to report any significant changes in the ecological character of the Ord River Floodplain; and
5. Identifies actual or likely threats/risks to the ecological components, processes or services of the Ord River Floodplain Ramsar site.

1.3 Relevant treaties, legislation and regulations

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

International

Ramsar convention

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

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds, which are relevant to the –Ord River Floodplain Ramsar site. The bilateral agreements are:

JAMBA – The agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986;

ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006; and

The Bonn Convention on Migratory Species (CMS) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

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

The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles (EPBC Act 1999 s335), which are set out in Schedule 6 of the Environment Protection and Biodiversity Conservation Regulations 2000. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention. Some matters protected under the EPBC Act are not protected under local or state/territory legislation, and as such, many migratory birds are not specifically protected under State legislation (though they are in Western Australia). Species listed under international treaties JAMBA, CAMBA and CMS have been included in the List of Migratory species under the Act. Threatened species and communities listed under the EPBC Act may also occur, or have habitat in the Ramsar site; some species listed under State legislation as threatened are not listed under the EPBC Act as threatened, usually because they are not threatened at the national (often equivalent to whole-of-population) level. The Regulations also cover matters relevant to the preparation of management plans, environmental assessment of actions that may affect the site, and the community consultation process.

Australian Heritage Council Act 2003
The Australian Heritage Council Act establishes the Australian Heritage Council, who advise the Australian Government on heritage list nominations under the EPBC Act, and also gives the Australian Heritage Council responsibility to maintain the Register of the National Estate. The Ord River Floodplain including Parry Creek, the Ord River Estuary and the False Mouths of the Ord have been placed on the Register for National Estate. Under the EPBC Act the Minister must consider information in the Register of the National Estate in making decisions under the Act.

Western Australia state policy and legislation
Wildlife Conservation Act 1950
This Act provides for the protection of wildlife and all fauna in Western Australia is protected under section 14 of the Wildlife Conservation Act 1950. The Act establishes licensing frameworks for the taking and possession of protected fauna and also establishes offences and penalties for interactions with fauna.

Conservation and Land Management Act 1984
This Act is administered by the State Department of Environment and Conservation (DEC) and applies to public lands. It sets the framework for the creation and management of marine and terrestrial parks, reserves and management areas in Western Australia, and deals with the protection of flora and fauna within reserve systems.

Aboriginal Heritage Act 1972
There are several important Aboriginal heritage sites around Ord River Floodplain, which are protected under this act including ceremonial, mythological and burial sites, associated with the river.

Fisheries Resource Management Act 1995
The Fisheries Resource Management Act 1995 establishes a regulatory framework for managing commercial fishing in WA and has a primary objective: 'to conserve, develop and share the fish resources of the State for the benefit of present and future generations'. The Act provides stipulations for specific fishing equipment and also covers aquaculture industries. It is administered by Fisheries Western Australia.

Environmental Protection Act 1986
The Environmental Protection (Clearing of Native Vegetation) Regulations 2004 under the Act prohibit clearing of native vegetation, unless a clearing permit is granted by the Department of Environment and Conservation or the clearing is for an exempt purpose. The exemptions allow low impact day-to-day activities involving clearing to be undertaken in accordance with the regulations. People who wish to clear native vegetation are required to obtain a permit if an exemption does not apply. Ramsar wetlands and the area within 50 metres of their boundary are identified as environmentally sensitive areas. The clearing exemptions of the Act do not apply in environmentally sensitive areas

Rights in Water and Irrigation Act 1914
The Rights in Water Irrigation Act 1914 and the Rights in Water and Irrigation Amendment Bill 1999 provides for the management of water resources in the state. There are provisions for sustainable use and development to meet the needs of current and future users as well as for the protection of ecosystems and the environment in which water resources are situated. Amendments to the Act, which came into operation on 10 January 2001, establish a licence trading system of water rights in Western Australia.

1.4 Method

The method used to develop the ecological character description for the Ord River Floodplain Ramsar site is based on the twelve-step approach provided in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) illustrated in Figure 3. A more detailed description of each of the steps and outputs required is provided in the source document.

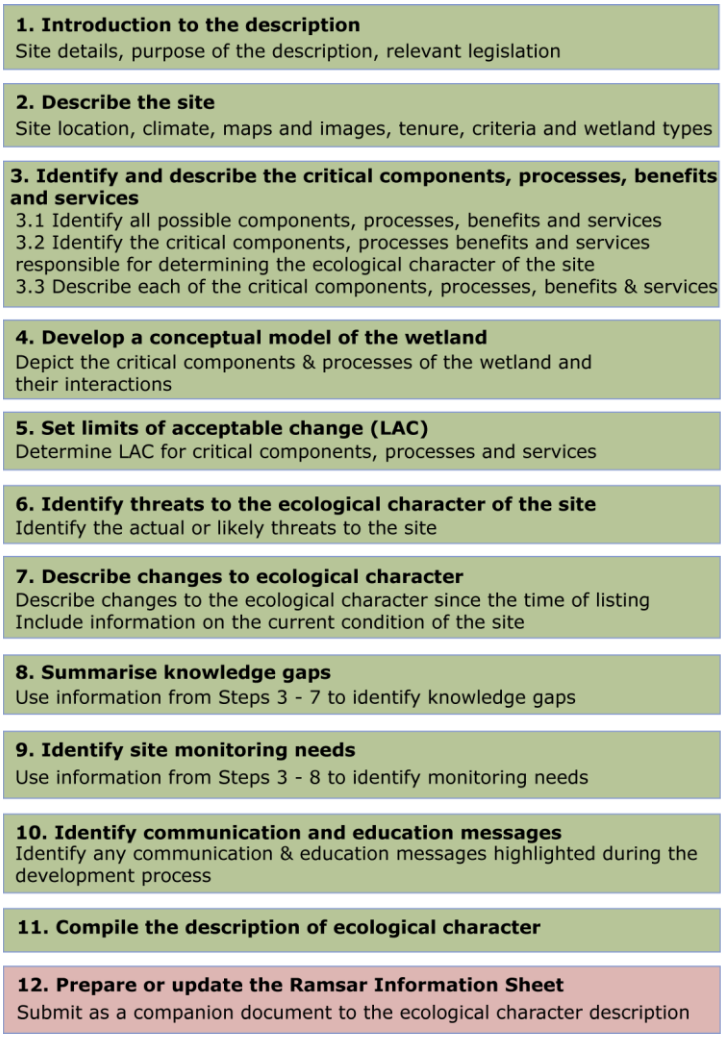


Figure 3: Twelve step process for developing an ECD (adapted from DEWHA 2008).

This ECD was developed primarily through a desktop assessment and is based on existing data and information. Although a series of visits to the site were undertaken, no new data was collected. A technical expert group and a stakeholder advisory group were formed to provide input and comment on the ECD. Details of members of each of these and more details of the method are provided in Appendix A.

2. General Description of the Ord River Floodplain Ramsar Site

2.1 Location

The Ord River Floodplain Ramsar site is located in the north east of Western Australia, approximately 8km east of the town of Wyndham within the Victoria-Bonaparte bioregion. The site covers over 140,000 hectares and lies within the Shire of Wyndham – East Kimberley.

The Victoria-Bonaparte bioregion covers > 70,000 km^2 and spans the Western Australian and Northern Territory borders with over 70% of the bioregion within the Northern Territory. Although the wetlands of the bioregion have not been inventoried, there are a number of nationally and internationally important wetlands present. These include the Lower Ord Floodplain, the Legune wetlands in the Northern Territory and the artificial wetlands created by the damming of the Ord River: Lakes Argyle and Kununurra.

The Ord River catchment also spans the border of the two jurisdictions, although it lies predominantly within Western Australia. The catchment covers over 64,000 km^2 and the 650 km long Ord River, which has its source near Halls Creek, drains into Cambridge Gulf through the Ramsar site. The major tributaries of the Ord River are the Panton, Elvire, Nicholson, Negri, Wilson / Bow and Dunham Rivers. Lower Ord River tributaries include Valentine Creek, Spring Creek, Goose Hill Creek, Parry Creek and Reedy Creek.

The Ord River is the central water supply for large scale irrigated agriculture in the area. The Ord was first dammed in 1963, with the construction of the Lake Kununurra Diversion Dam, located approximately 70 km upstream of the extent of tidal influence. A second, larger structure, the Ord River Dam was completed in 1973 a further 55km upstream. The water held upstream of the Ord River Dam forms Lake Argyle and the waterbody between the two dams is Lake Kununurra; both of which are listed as “Wetlands of International Importance” under the Ramsar Convention. In 1995 the spillway from Lake Argyle was raised by 6m to improve reliability of water for hydroelectric power generation.

The Ord River Floodplain Ramsar site is located downstream of the dams in the lower reaches of the Ord River and includes a portion of the estuarine reaches of the Ord River where it discharges into Cambridge Gulf. Specifically, the Ramsar site encompasses the East Arm of the Ord River Estuary, and the area along the eastern shore “the False Mouths of the Ord (Figure 4).

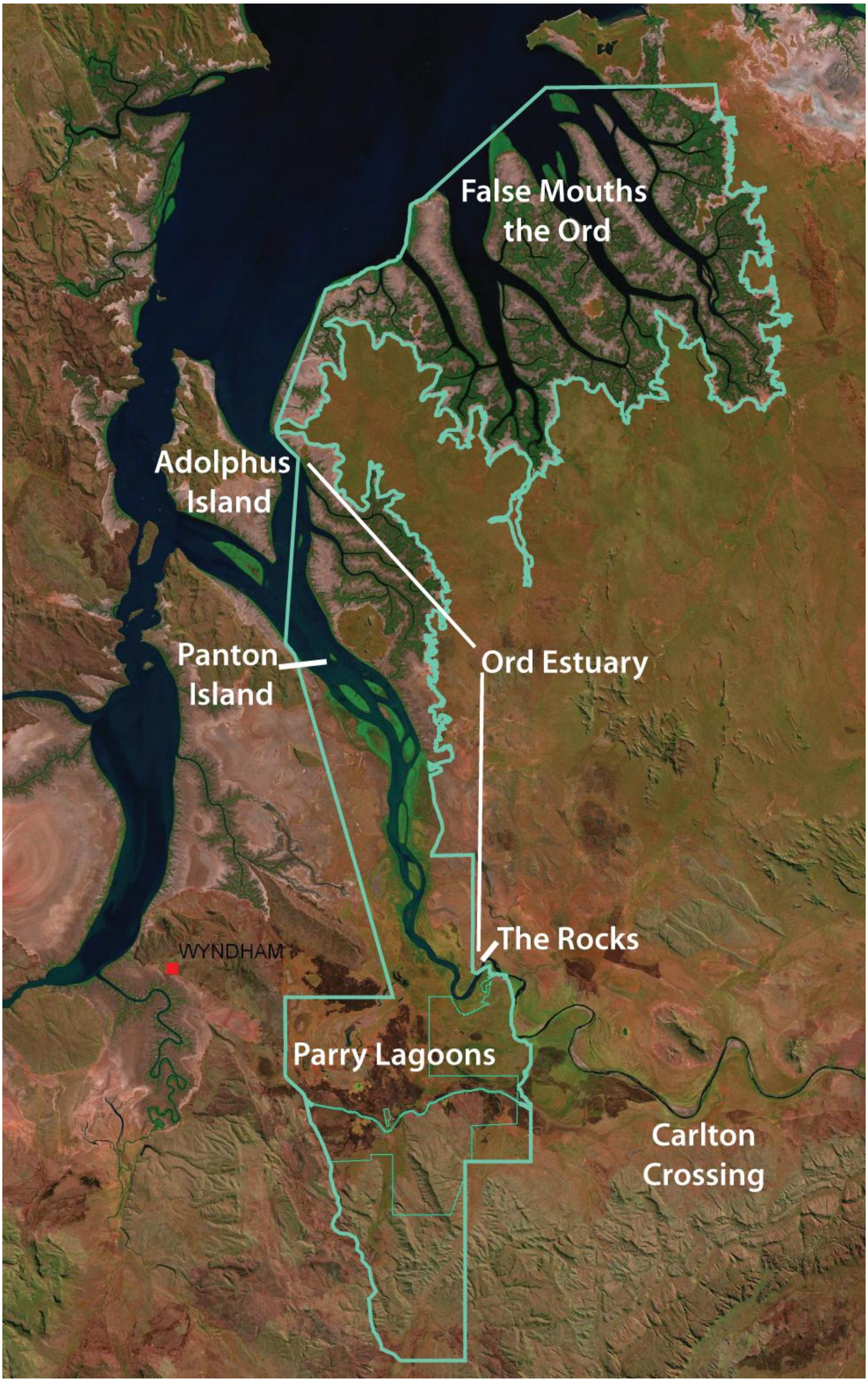


Figure 4: Map of the Ramsar site (boundary shown in green) with landmarks (data from DEC, Perth).

Land use within the Ramsar site is exclusively nature conservation, with a series of nature reserves and marine environments forming the boundary of the Ramsar site. The immediately adjacent land is predominantly termed "production natural environments" and used for grazing on non-irrigated pasture. The Ord River Irrigation Area (ORIA) 1 is some distance from the site in an area to the south of Kununurra. However, a portion of the proposed ORIA 2 development would see the area adjacent to the Ramsar site near Parry Lagoons developed for irrigation (Figure 5).

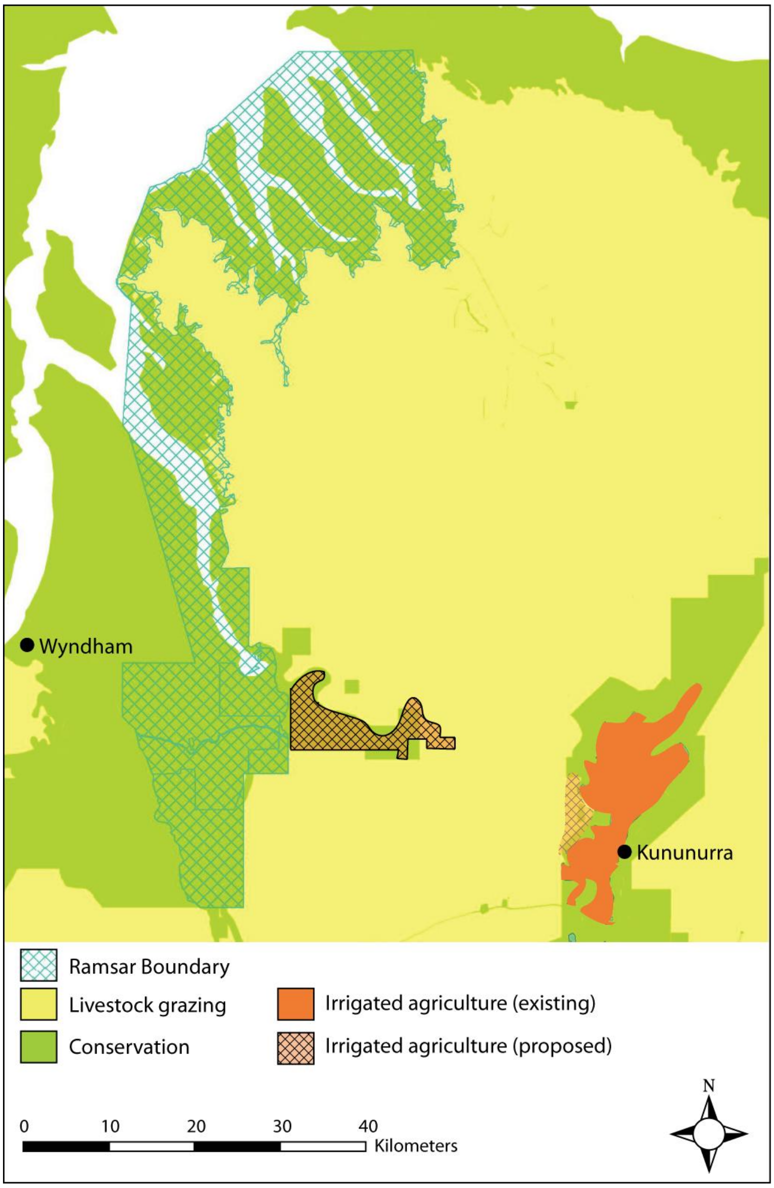


Figure 5: Primary landuse within and surrounding the Ord River Floodplain Ramsar site (data provided by DEC 2008).

2.2 Land tenure

The Ramsar site is almost entirely located within conservation reserves (Figure 5) vested with the Western Australian Conservation Commission and managed by the Department of Environment and Conservation. Marine areas are non-reserved. The area was subject to a native title claim by the Miriuwung Gajerrong people, which was ratified in December 2003. As a result of the Ord Final Agreement negotiations, formal processes for Aboriginal consultation and interaction in management and management planning have commenced via the Joint Management Initiative. This involves the Miriuwung Gajerrong people and the

Department of Environment and Conservation co-managing three existing and five newly created reserves within the Kimberley region. The Ramsar site consists of two of these reserves: Ord River Nature Reserve and Parry Lagoons Nature Reserve. In addition, a native title claim for the Balanggarra people still exists over a small portion of the Ramsar site along the western bank of the Ord River. This is currently in mediation with the Native Title Tribunal.

2.3 Climate

The Ord River Floodplain lies in the dry tropics of northern Australia. The climate is semi arid, monsoonal with a prolonged dry season. More than 80% of the rainfall falls in the summer, wet season (December to February). The climate is highly variable both inter-annually (between years) and intra-annually (within a year). The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and relative humidity as these all fundamentally affect wetland hydrology and the water budget.

Rainfall falls almost exclusively in the wet season (November to April) with highest monthly average rainfall in January and February (150 – 200mm). However, there is considerable variability in rainfall as evidenced by the 10^{th} and 90^{th} percentiles, which range from < 70mm per month to > 300 mm per month (Figure 6). The majority of the rainfall occurs during cyclonic events, resulting in large rain events over relatively short periods of time. The highest daily rainfall on record is > 250 mm recorded in March 2006 (Bureau of Meteorology).

Annual average rainfall at Wyndham is in the order of 790 mm per year. However, there is high inter-annual variation with annual rainfalls ranging from < 400mm to > 1400mm in the 40 years of records from this site (Figure 7). This cycle of drought and flood is a dominant feature of the climate (McDonald and McAlpine 1991).

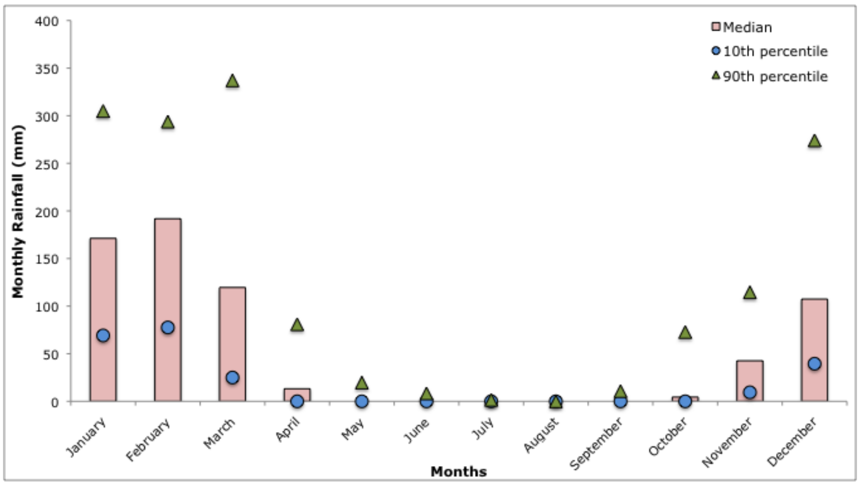


Figure 6: Median (10th and 90th percentile) monthly rainfall at Wyndham (1969 – 2008; Bureau of Meteorology).

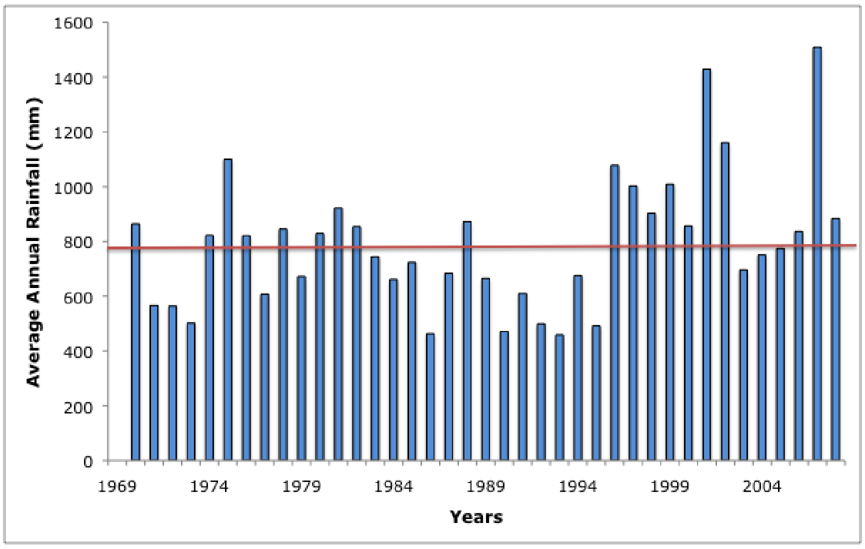


Figure 7: Average annual rainfall at Wyndham (1969 – 2008; Bureau of Meteorology). Note horizontal line shows long term average.

Temperatures range from warm to hot year round, with average wet season maximum temperatures between 36 and 40 °C and average minimum temperatures between 25 and 27 °C. During the dry season average maximum temperatures are slightly cooler (31 – 36 °C). June and July are the coolest months with average maximum temperatures around 30 °C and average minimum temperatures of approximately 17 °C (Figure 8).

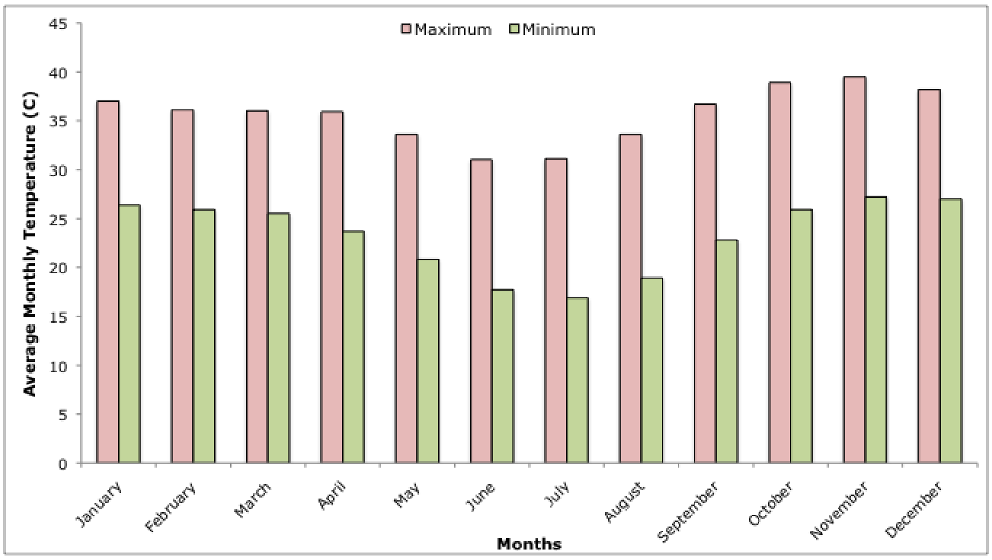


Figure 8: Average monthly maximum and minimum temperatures at Wyndham (1969 – 2008; Bureau of Meteorology).

Relative humidity ranges from 50 – 70% in the wet season to 30 – 40% in the dry months. This, combined with the high temperatures produces evaporation that, on average greatly exceeds rainfall (Figure 9). As a consequence, rainfall alone is insufficient to sustain plant growth for eight months of the year (Beard 1990).

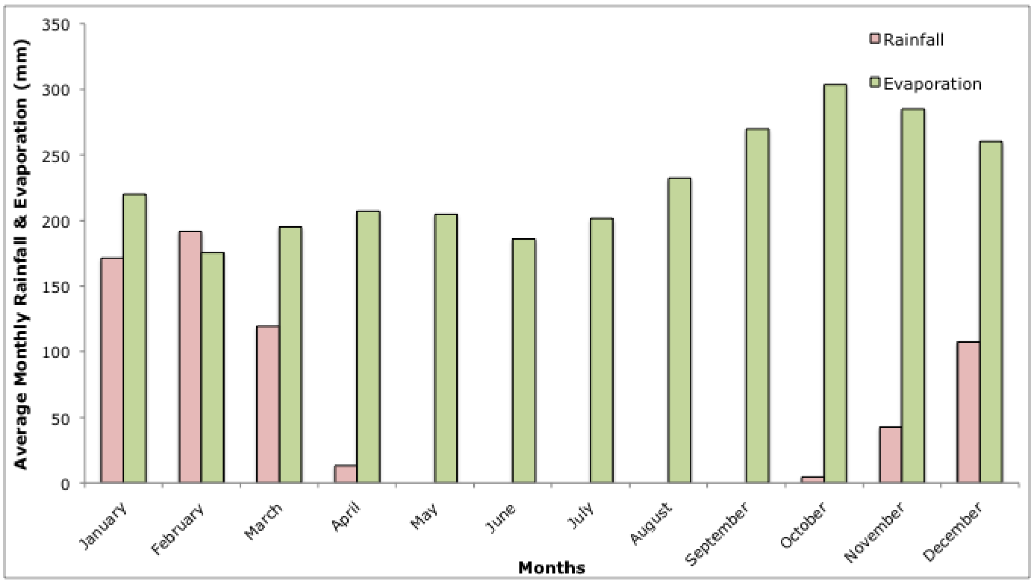


Figure 9: Average monthly rainfall and evaporation at the Kimberley Research Station (1944 – 2008; Bureau of Meteorology).

2.4 Ramsar criteria

2.4.1 Criteria under which the site was designated (1990)

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

Criterion 1a: The site is the best example in Western Australia of an extensive system of wetlands associated with the floodplains and estuary of a tropical river.

Criterion 2a: The site supports a viable population of the globally threatened Saltwater Crocodile (*Crocodylus porosus*) and the nationally vulnerable Freshwater Sawfish (*Pristis microdon*).

Criterion 2b: The site contains the most diverse and structurally complex mangrove system in the Kimberley. In years where rainfall and conditions are sufficient to inundate a large portion of the floodplain within the Parry Lagoons, this area constitutes one of the major breeding sites for waterbirds in the Kimberley region.

Criterion 3b: The site regularly supports large numbers of waterbirds from most waterbird families.

Table 2: Criteria for Identifying Wetlands of International Importance as at listing date, 1990. Criteria for which the Ord River Floodplain has been listed are highlighted in green.

Basis	Number	Description
Criteria for representative or unique wetlands	1a	it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region
	1b	it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region
	1c	it is a particularly good representative example of a wetland, which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position
	1d	it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.
General Criteria based on plants and animals	2a	it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species
	2b	it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna
	2c	it is of special value as the habitat of plants or animals at a critical stage of their biological cycle
	2d	it is of special value for one or more endemic plant or animal species or communities.
Specific criteria based on waterfowl	3a	it regularly supports 20,000 waterfowl
	3b	it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity
	3c	where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl

2.4.2 Current situation and additional criteria met

There have been a number of refinements of the Ramsar criteria since 1990. In 1996, an additional two criteria (criteria 7 and 8) were adopted by the Ramsar Convention in Brisbane and a ninth criterion was added at the 9th Ramsar Conference in Uganda in 2005. In addition, there has been a revision of population estimates for birds (Wetlands International 2006), which influences the application of criterion 6; and additional data has been collected for the site.

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

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

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

The Ramsar Guidelines http://ramsar.org/key_guide_list2006_e.htm#E state (Glossary):
regularly (Criteria 5 & 6) - as in supports regularly - a wetland regularly supports a population of a given size if:
i) the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or
ii) the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).
In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

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

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

Text Box 1: Application of the Ramsar definition of "regularly" to criteria.
An assessment against each of the criteria for the Ord River Floodplain is as follows:

Criterion 1: The site represents the best example of wetlands associated with the floodplain, and estuary of a tropical river system in the Kimberley region of Western Australia. In addition, the False Mouths of the Ord are the most extensive mudflat and tidal waterway complex in WA and the wetland grasslands at Parry Lagoons are the most extensive vegetation community of this type in Western Australia (CALM 1998)[1]. This criterion was met at designation in 1990 and continues to be met at present.

Criterion 2: In the Australian context, it is recommended that this criterion should only be applied with respect to nationally threatened species/communities, listed under the EPBC Act 1999. This does not apply to the Saltwater Crocodile (*Crocodylus porosus*), which is not listed under the EPBC Act or the IUNC Red List. However, the Freshwater Sawfish (*Pristis microdon*) the Green Sawfish (*Pristis zijsron*) and the Australian Painted Snipe (*Rostratula australis*), which have all been recorded from within the site, are listed as vulnerable under the EPBC Act. The site is also one of only two known habitats in Western Australia for the nationally endangered Northern River Shark (*Glypis sp. C*) (see Morgan et al. 2004a, Thorburn and Morgan 2004, Stevens et al. 2005, Thorburn 2006). This criterion was met at designation in 1990 and continues to be met at present.

Criterion 3: The site contains an extensive and diverse mangrove community containing 14 of the 18 species of mangrove known to occur in Western Australia, potentially the most diverse in Western Australia. These mangroves are important habitat for a number of species of birds restricted to mangrove forests in Western Australia. This includes a population of flycatchers, the Black Butcherbird (*Cracticus quoyi*) that breeds in the area, which is the only population of its kind in WA (Johnstone, 1990). This criterion was met at the time of listing and continues to be met at present.

[1] Note that the wetlands of north Western Australia have yet to be inventoried and this criterion should be re-assessed as further information becomes available.

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

- the critical life stage of migration: annual use by large numbers of many species of migratory animals (birds and fish);
- the critical life stage of drought refuge: seasonal influx of large numbers of waterbirds from dried out wetlands in surrounding areas, and periodic massive influx from wider regions during drought; and
- the critical life stage of breeding: 14 species of wetland dependant birds, Saltwater and Freshwater Crocodiles and an unknown number of fish.

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

Criterion 5: Surveys conducted at Parry Lagoons in the 1980s regularly recorded > 20,000 birds in this portion of the Ramsar site alone. Much of the area is difficult to survey, but there is sufficient evidence to support the criterion of "regularly supports 20,000 waterbirds". Therefore, this criterion was met at designation in 1990 and continues to be met at present.

Criterion 6: Surveys from the 1980s indicated that maximum counts for two species exceed the 1% population thresholds (Wetlands International 2006):

- Plumed Whistling Duck – maximum count 15,000 (1% = 10,000); and
- Little Curlew – maximum count 2500 (1% = 1800).

Based on currently available habitat, wetland condition and threats – which are probably unchanged since the 1980s – threshold-meeting numbers of these two species can be expected to still occur in the Ramsar site. In addition, it is likely that several other waterbird species would meet this criterion if comprehensive surveys were conducted at appropriate times of year. Therefore, this criterion was met at designation in 1990 and continues to be met at present.

Criterion 7: This criterion is very difficult to apply. A site can potentially qualify based on the proportion of fish species present that are endemic to the site (must be > 10%) or by having a high degree of biodisparity in the fish community. Over 50 species of fish from 32 families have been recorded or are predicted to occur within the Ord River Floodplain Ramsar site. Although less than 10% of these would be considered endemic to the site, there have been few surveys conducted and more cryptic species are likely to remain undetected. Therefore, given the paucity of data from the site it is unable to be determined if this criterion would be met.

Criterion 8: The Ord River Floodplain Ramsar site is important as a nursery and/or breeding and/or feeding ground for at least 50 species of fish and a migratory route for 15 species that are known to be diadromous. Therefore, this criterion was met at designation in 1990 and continues to be met at present.

Criterion 9: The application of this criterion relies on estimates of the total population of non-bird species. In the case of the Ord River Floodplain this would require population estimates of fish, crustacean, crocodile and / or frog species not only within the site, but nationally and globally. This criterion cannot be assessed based on current information.

2.5 Wetland types

The Ord River Floodplain site contains a wide range of wetland types and includes inland and marine components. Classification of wetlands into discrete types is a difficult exercise and an inexact science. Clear boundaries are difficult to define or delineate and at a landscape scale the diversity in aquatic ecosystems is part of a continuum, rather than a series of discrete units. At this site, where freshwater floodplain grades into estuarine systems, the line between fresh non-tidal and saline intertidal is not necessarily fixed and in fact there is a broad transitional (ecotonal) zone. The ecotone may at times seem fresh in terms of plants and water quality and at other times totally saline. It is a dynamic and rich zone for fauna and flora but is poorly known because (a) it is vaguely defined, (b) when wet it is almost inaccessible and (c) it has relatively few (though some) distinctive/unique plant and animal species.

Addressing this issue of wetland delineation is beyond this single ecological character description. However, it is important to note that any classification of the site into wetland types represents a compromise. The following is an estimate of the wetland types as defined under the Ramsar wetland classification system:

Marine/Coastal:

- *Estuarine waters*; permanent water of estuaries and estuarine systems of deltas.
- *Intertidal mud, sand or salt flats*.
- *Intertidal marshes*; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes
- *Intertidal forested wetlands*; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.
- *Coastal brackish/saline lagoons*; brackish to saline lagoons with at least one relatively narrow connection to the sea.
- *Coastal freshwater lagoons*; includes freshwater delta lagoons.

Inland:

- *Permanent rivers/streams/creeks*; includes waterfalls.
- *Seasonal/intermittent/irregular rivers/streams/creeks.*
- *Permanent freshwater marshes/pools*; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
- *Seasonal/intermittent freshwater marshes/pools* on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
- *Shrub-dominated wetlands*; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
- *Freshwater, tree-dominated wetlands*; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
- *Freshwater springs; oases*.

For the purposes of this ecological character description, the site has been divided into the following broad wetland areas, based on geographical location and wetland type (see Figure 4 above):

Parry Lagoons – this includes both the permanent (or near permanent) waterholes, such as Marglu Billabong, as well as the broader area of floodplain within the Parry Lagoons Nature Reserve that is subject to periodic inundation.

Ord Estuary – as the Ord River within the Ramsar site is under tidal influence, the area from the boundary near Adolphus Island to the Rocks has been grouped as "Ord Estuary". In some instances (e.g. for water quality measurements) this has been divided into two areas: open or outer estuary which is the area from Panton Island downstream to the boundary near Adolphus Island, and the upper estuary; upstream of Panton Island, which has a greater freshwater influence.

False Mouths of the Ord – the area of intertidal creeks and mudflats in the north of the site.

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

3. Critical Components, Processes, Benefits and Services

3.1 General Description

The Ord River Floodplain Ramsar site is comprised of depositional floodplain and estuarine environments associated with the mouth of the Ord River and Cambridge Gulf. There are three relatively distinct wetland units conserved within the site. The southern part of the Ramsar site is dominated by Parry Creek, including a 20 km length of seasonally flowing creek running through upland environments, and an alluvial floodplain complex. The floodplain is inundated to varying degrees during the wet season and when the rain ceases, except for a few permanent and semi-permanent waterholes associated with incised channels and claypans, it quickly dries out. The upstream (southern) portion of the floodplain is freshwater while the lower (northern) sections, if not inundated by saline water, are surrounded by salty soils.

Extending north from the floodplain of Parry Creek to the Cambridge Gulf is the lower reaches of the Ord River. Within the Ramsar site boundaries, the Ord River is under tidal influences and can be considered estuarine. The upstream end of the river channel is around 150 m wide, increasing to over 5 km wide at the mouth. Processes of sediment deposition dominate along the entire length of the river on the site, with unstable mud bars and islands common near the mouth.

North from the mouth of the Ord River, the site extends for some distance around the coast to include the False Mouths of the Ord, which consist of a deltaic maze of channels, tidally inundated coastal mudflats and islands. Only the northernmost channel in this complex receives much freshwater input, which comes from the relatively small and ephemeral Emu, Station and Tanmurra Creeks.

The seasonal wetlands south of the Ord River are fresh and sometimes fringed by low shrubs or trees, which are surrounded by a flat, grass covered plain. The mud flats along the river and the eastern side of Cambridge Gulf support patches of saline grassland and samphire. They are incised by numerous creeks and channels, along which extensive stands of mangroves grow. Mangroves also grow along the Ord River and the seaward side of the mudflats.

Ten main vegetation associations have been identified within the site including: dune systems, mudflats, mangrove, grassland, low woodland (subdivided into a further 7 associations), sandstone range open woodland, riverine woodland (subdivided into 5 associations), rainforest (aquifer forest) and spring vegetation, major rivers and lagoons (permanent and ephemeral), and savanna woodland (CALM 1998). A total of 335 native vascular plants from 89 families have been recorded from the Ord River Floodplain Ramsar site (CALM 1998) including a number of terrestrial as well as wetland communities. There are no nationally rare, threatened or endemic plants known at the site. However, a number of species that have been designated as “Priority 2: Poorly Known” under the State threatened species classification are known to occur in the site including the Golden Bladderwort (*Utricularia aurea*).

Over 200 species of birds have been recorded within the site including waterfowl, migratory shorebirds, mangrove birds and terrestrial species. Parry Lagoons, in particular is significant for waterbirds in terms of diversity, numbers and supporting critical lifecycle stages such as breeding. In addition, the site supports the Australian Painted Snipe (*Rostratula australis*), which is listed as vulnerable under the EPBC Act.

Mammal surveys conducted in 1986 in the False Mouths of the Ord recorded the first known population of the Mosaic-tailed Rat (*Melomys burtonii*) in Western Australia and a rich bat fauna, comprising of 17 species (CALM 1998). Other mammals known from the site include: the northern Nail-tailed Wallaby (*Onychogalea unguifera*), Agile Wallaby (*Macropus agilis*), the Long-haired Rat (*Rattus villosissimus*) and Woodward’s Rock Rat (*Zyzomys woodwardi*).

Thirty-five species of reptile have been recorded within or near to the Ramsar site, including two species of crocodile: Saltwater (*Crocodylus porosus*) and Freshwater (*Crocodylus johnstoni*). There are little or no data on frog populations, but up to six species may occur within or near to the Ramsar site (CALM 1998). Similarly, fish data from within the site is poor. However, over 50 species of fish have been recorded or are predicted to occur within the site including three threatened species listed at the national level. The site is also important for a number of commercial and recreational fish species including Barramundi (*Lates calcarifer*).

3.2 Critical Components and Processes

3.2.1 Identifying critical components and processes

The basis of an ECD is the identification, description and where possible, quantification of the critical components and processes of the site. Wetlands are complex ecological systems and the complete list of physical, chemical and biological components and processes for even the simplest of wetlands would be extensive and difficult to conceptualise. It is not possible, or in fact desirable, to identify and characterise every organism and all the associated abiotic attributes that are affected by, or cause effect to, that organism to describe the ecological character of a system. This would result in volumes of data and theory but bring us no closer to understanding the system and how to best manage it. What is required is to identify the key components, the initial state of the systems, and the basic rules that link the key components and cause changes in state (Holland 1998). Thus, we need to identify and characterise the key or critical components and processes that determine the character of the site. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would result in a significant change in the system.

Climate and geomorphology are accepted as the fundamental drivers of wetland ecology (Mitsch and Gosselink, 2000). Together with the hydrological regime they influence all other aspects of wetland ecology. Therefore, climate (as described in section 2.2 above), geomorphology and hydrology can be considered critical components of all wetland systems. Additional components and processes that can be considered critical to maintaining ecological character are likely to vary depending on the wetland; its position in the landscape and the benefits and services it provides.

DEWHA (2008) suggests that critical components and processes are those that are linked to the reasons the site was listed as a wetland of international importance. The linkages between the reasons the site was listed and the components and processes within the Ord River Floodplain Ramsar site are provided in (Table 4). This identifies not only the critical components and processes that are directly responsible for meeting each of the criteria, but also the components and processes that are important in supporting these.

It is difficult to separate components (physical, chemical and biological parts) and processes (reactions and changes). For example, aspects of hydrology such as rainfall or depth to groundwater may be considered as components, while other aspects of hydrology such as flow and tidal regime could be considered processes. Similarly the species composition of birds at a site may be considered a component, but feeding and breeding are processes. In many ways a separation of the ecology of wetlands into nouns (components) and verbs (processes) is an artificial boundary and in the context of this ECD does not add clarity to the description. As such components and processes are considered together.

Following the descriptions in (Table 4) the critical components and processes for the Ord River Floodplain Ramsar site have been identified as:

- Geomorphology;
- Hydrology;
- Water Quality (salinity, suspended solids, dissolved oxygen, nutrients and toxicants);
- Phytoplankton;
- Vegetation communities (mangroves, grasslands, freshwater aquatic vegetation and riparian woodland);
- Macroinvertebrates;

- Fish (including EPBC listed species);
- Birds (waterbirds and mangrove birds); and
- Crocodiles (Freshwater and Saltwater).

Table 4: Relationship between the Ramsar criteria met and critical components and processes in the Ord River Floodplain Ramsar site

Ramsar Criteria	Direct Components & Processes	Supporting Biotic Components & Processes	Supporting Abiotic Components & Processes
1. Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region	Extent and diversity of wetland types within the Ord River Floodplain Ramsar site	Vegetation communities (mangrove, grasslands, aquatic vegetation) Waterbird communities Fish and other aquatic fauna	Hydrology Geomorphology
2. Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	Freshwater Sawfish Northern River Shark Green Sawfish Australian Painted Snipe	Vegetation communities (mangrove, grasslands, aquatic vegetation) Primary Production Food webs	Hydrology Water Quality (salinity, nutrients, water clarity, dissolved oxygen, toxicants)
3. *Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region*	Mangrove community Mangrove birds	Invertebrates	Hydrology Geomorphology Water Quality (salinity, nutrients)
4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*	Fish (breeding & migration) Prawns (nursery habitat) Waterbirds (breeding & migration) Mangrove birds	Habitat extent and distribution (mangroves, mudflats, grasslands, aquatic vegetation) Phytoplankton Invertebrates	Hydrology Geomorphology Water Quality (Salinity, nutrients, water clarity, dissolved oxygen, toxicants)
5. *Regularly supports 20,000 or more waterbirds*	Waterbirds	Habitat extent and distribution (mangroves, mudflats, grasslands, aquatic vegetation) Phytoplankton Invertebrates	Hydrology Geomorphology Water Quality (nutrients)
6. *Regularly supports > 1% of the population of one or more species of waterbird*	Plumed Whistling Duck Little Curlew	Habitat extent and distribution (grasslands, aquatic vegetation) Phytoplankton Invertebrates	Hydrology Geomorphology Water Quality (nutrients)
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*	> 50 species of fish, many of which are migratory between fresh and marine habitats	Habitat extent and distribution Invertebrates, Phytoplankton	Hydrology Water Quality (salinity, nutrients, water clarity, dissolved oxygen, toxicants) Geomorphology

The attributes and characteristics of each of these critical components and processes are described below. Where possible, quantitative information has been included. However, as with many ecological character descriptions, there are significant knowledge gaps (see section 8). In the absence of direct evidence from within the Ramsar site, information from adjacent locations and general ecological theory has been used to provide some predictive descriptions (particularly for fish species). These are clearly marked in the text and can only be considered indicative of the probable ecological character of the site. These predictive descriptions will require confirmation from further monitoring and investigative studies.

3.2.2 Geomorphology

The 53,500 km^2 Ord River Catchment lies within the Victoria Bonaparte bioregion. The Victoria River Plateau, a large highly dissected plateau approximately 350 m above sea level dominates the upper catchment and consists of sandstone, mudstone and minor limestone. The Ord River Floodplain Ramsar site is located at the lower edges of the catchment within the Cambridge Gulf Lowlands.

The majority of the Ramsar site comprises alluvium and coastal silt / evaporite deposits of Quaternary origin (Figure 10). However, the area surrounding Parry Lagoons is comprised of black soils also formed in the Quaternary. Further to the south, parts of the Ramsar site contain much older Carpentarian quartz sandstone of the Kimberley group (GeoScience Australia http://www.ga.gov.au/map/index.jsp#geology). It should be noted that this area in the south of the Ramsar site (south of the black soils of Parry Lagoons) is not wetland, but a terrestrial environment.

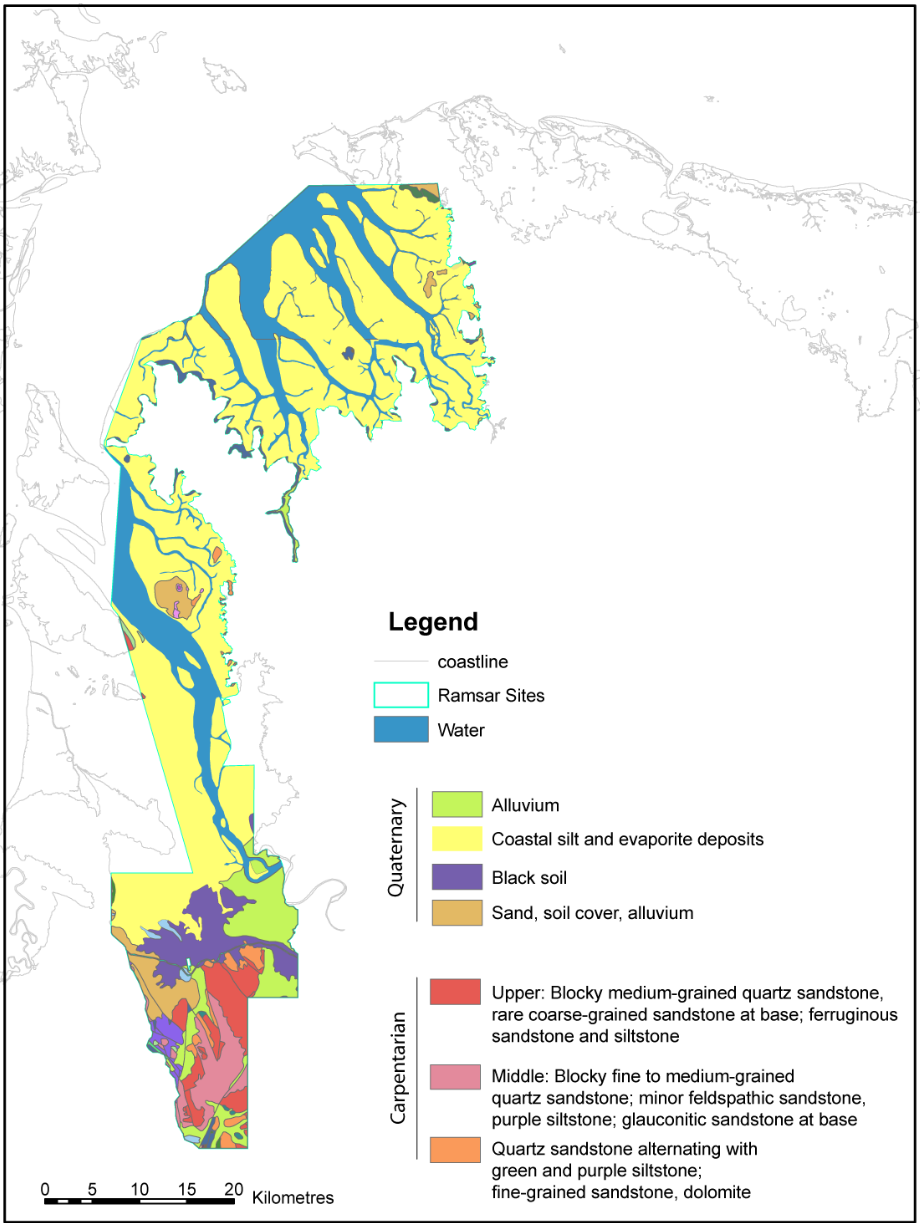


Figure 10: Major geological formations and soils of the Ord River Floodplain Ramsar site (data sourced from Geosciences Australia http://www.ga.gov.au/oracle/#geology).

Erskine et al. (2005) developed and applied a geomorphic based typology for Australian tropical rivers. The Ord River Floodplain Ramsar site contains four of the nine distinct river types described under this classification system. All of these are low-energy depositional environments (Figure 11):

- **Meandering rivers**
    - Characterised by a single channel with a sinuosity (ratio of channel length to valley length) of > 1.5;
    - Banks are generally steeper and more stable than those of the anabranching and anatomising sections downstream;
    - Applies to a very small section of channel within the Ramsar site furthermost upstream.
- **Island and ridge anabranching**
    - Characterised by multiple channels separated by vegetated islands that divide stream flows;
    - Applies to the section of river downstream of The Rocks and grades into the next classification as the channels become more braided and the valley wider.
- **Co-existent mud and braided anabranching**
    - Characterised by low slope, wide anastomosing channels and sediment loads dominated by mud;
    - The channels connect deeper permanent waterholes and dissect a broad muddy floodplain with braided shallow channels;
    - Highly depositional environment;
    - Applies to the furthest downstream sections of the river where a defined channel becomes difficult to discern.
- **Extensive freshwater wetlands and billabongs**
    - Includes both in-channel billabongs and floodplain wetlands that are intermittently inundated during high flows and floods;
    - Applies to the floodplain and waterholes of the Parry Lagoons complex.

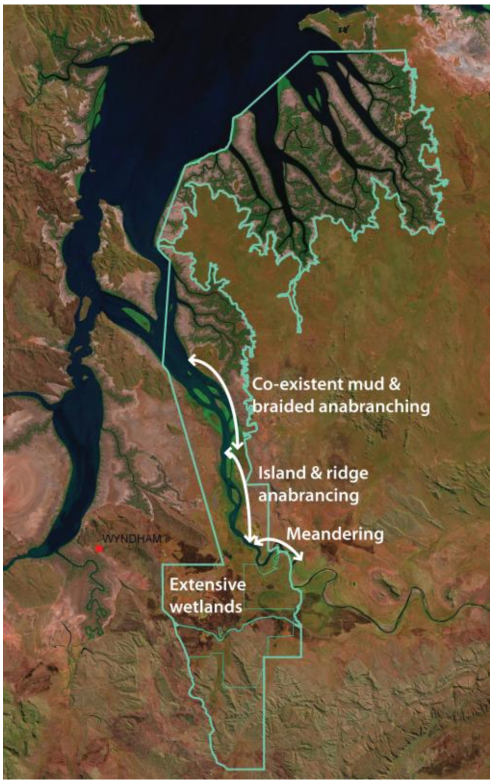


Figure 11: Erskine et al. (2005) river types within the Ord River Floodplain Ramsar site.

Parry Lagoons consists of both permanent waterholes as well as an intermittently inundated floodplain; comprising of both vegetated and claypan / mudflat areas. The floodplain area is some 7 to 10 m above the bed of the adjacent Ord River Channel and extends up to 12 km away from the river channel (Figure 12).

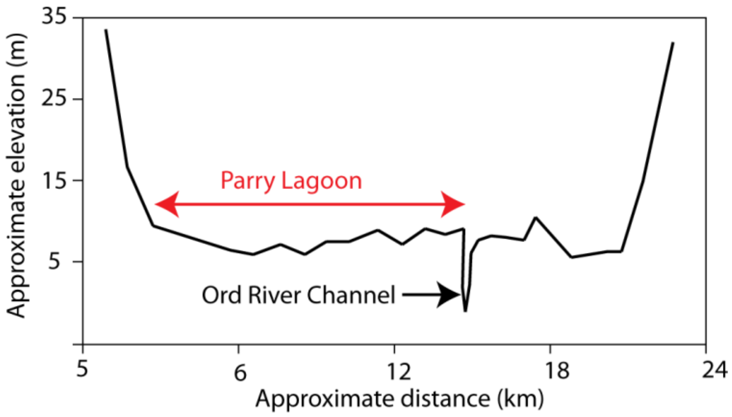


Figure 12: Cross section of the lower Ord River and Parry Lagoons (adapted from Braimbridge and Malseed 2007). Note that distances and elevations should be considered approximations only.

The geomorphology of the estuarine sections of the Ramsar site have also been described (Digby et al. 1998). The Australian Estuaries Database[2] recognises two distinct estuaries in the Cambridge Gulf: the "Ord River Estuary" (which includes an area much larger than the Ramsar site) and the "False Mouths of the Ord". The Ord River Estuary covers the entire length of the Ord River within the site, indicating that the river is tidally influenced throughout the Ramsar site. Both the Ord River Estuary and the False Mouths of the Ord are considered to be unconstricted branched estuaries with multiple mouths. The dendritic (branching in the form of a tree) drainage lines are most apparent on the False Mouths of the Ord (Figure 13). The two estuaries are classified as "tide dominated" with extensive areas of tidal creeks and flats (Figure 14).

Figure 13: Landsat image of False Mouths of the Ord showing dendritic drainage lines.

The geomorphology of parts of the Ramsar site had been modified by the time of listing in 1990. The hydrological impacts of the construction of the dams upstream (in 1963 and 1972) and the use of the river as a water supply channel (see section 3.2.3 below) altered the

[2] http://dbforms.ga.gov.au/www/npm.ozcoast.search?domain=www.ozcoasts.org.au

bathymetry of the estuary and river channels. Wolanski et al. (2001) reported that the reduction in floods has resulted in the East Arm of the Ord River Estuary becoming geomorphically unstable. The East Arm has silted measurably over the last 30 years and by the time of listing the cross sectional area had decreased approximately 50%. In addition, while the channel planform has remained stable, there have been reductions in both active and total channel widths of the river as a result of increased sediment deposition (Wyrwoll 2000).

Figure 14: Extent of tidal flats within the Ord River Floodplain Ramsar site (data from Geoscience Australia).

Geomorphology (literally the shape of the land) dictates where in the landscape surface water will occur. This component, together with hydrology (described below) is responsible for diversity of wetland types and habitats across the Ord River Floodplain Ramsar site. The depositional environment of the lower Ord River and estuary provides extensive mud flats, which are important in terms of invertebrate populations and the waterbirds that feed on them. The network of dentritic streams in the False Mouths of the Ord and the Lower Ord River provide a large inter-tidal area suitable for the establishment and maintenance of mangrove communities and the fauna that are associated with them. The expansive floodplain of Parry Creek, together with the deeper depressions provide an array of seasonal and permanent freshwater wetlands that are important not only for migratory shorebirds and fish populations when flooded, but refuge for resident aquatic flora and fauna during the dry season.

3.2.3 Hydrology

Hydrology is a primary driver of wetland ecology (Mitsch and Gosselink, 2000) and the principal constraint on the distribution and productivity of wetlands (Mendelssohn and Batzer 2006). The depth, duration and frequency of flooding as well as the duration of the inter-flood interval are all crucial for wetland plants (Roberts et al. 2000). In addition, fauna respond to hydrology both directly (e.g. hydrological cues for breeding or migration) and indirectly via vegetation distribution (e.g. mangrove birds of the False Mouths of the Ord).

The floodplain of the lower Ord River is a complex network of intermittent (and occasionally permanent) streams. The major sources of fresh water directly into the site are from the Ord River itself, Parry Creek (into Parry Lagoons) and the major tributaries of the False Mouths of the Ord; Emu, Tanamurra and Station Creeks (Figure 15).

The Ord River Irrigation developments have resulted in a large body of work characterising the flow components of the Ord River below the Kununurra dam. However, there is little information about the characteristics of the hydrology within the Ramsar site itself. In particular little is known about the freshwater inflows to the False Mouths of the Ord and no documented evidence quantifying this could be sourced.

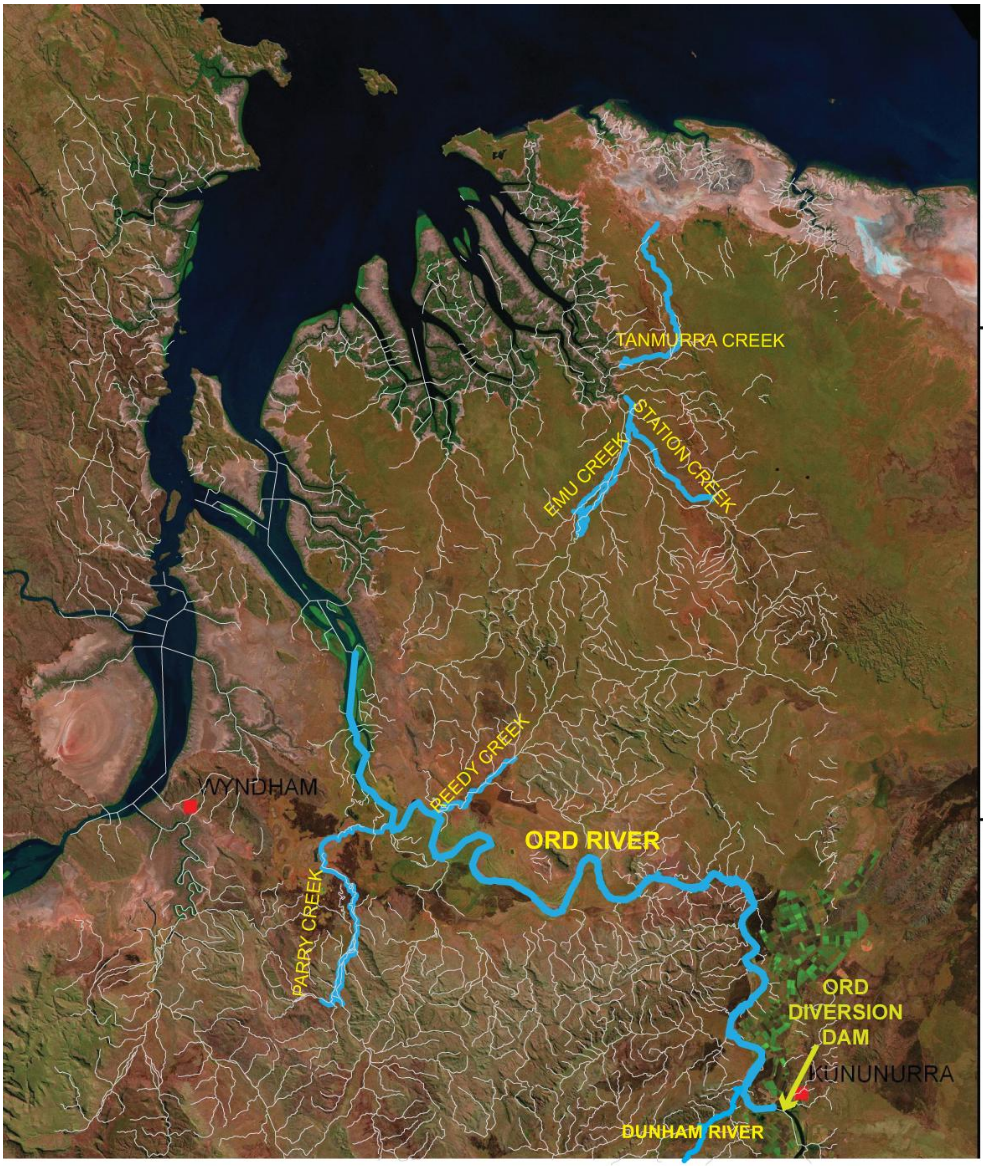


Figure 15: Network of surface water drainage surrounding the Ord River Floodplain Ramsar site with major tributaries and rivers highlighted.

Inflows to the site via the Ord River, however, have been characterised for sites located upstream of the Ramsar site. Of most relevance is the data downstream of the Dunham River (near Kununurra) as this represents the nearest upstream significant river inflow to the Ord. To characterise the inflows to the site at the time of listing (1990) it is important to take account of the effects of the two upstream dams that form Lakes Argyle and Kununurra as these had been in place for many years prior to the listing of the Ord River Floodplain as a wetland of international importance[3]. However, the raising of the spillway of the Ord River Dam, predominantly to allow sufficient water for hydropower, was completed in 1995, five years after the listing of the site. Therefore to characterise the inflows at the time of listing the flows need to account for the dams and demands for irrigation prior to site listing, but not the raising of the Ord River Dam and the demands for hydropower.

The Ord River Water Management Plan (DoW 2006) provides some information on flows in the Ord River below the Dunham River confluence pre construction of the Ord Diversion Dam extension and compares these to those past dam extension. Modelling indicates that there were only minor differences in flow volumes and variability following the dam extension. As such the more extensive descriptive dataset and modelling that describes current regulated hydrology has been used here to indicate hydrological characteristics at the time of listing.

Modelled post regulation (1974 – 2005) average annual streamflow for the lower Ord River is approximatley 4000 GL per annum (DoW 2006). However, there is a high inter-annual variability with total flows ranging from < 500 GL to > 8000 Gl over the 20 year period 1970 to 1990 (Figure 16).

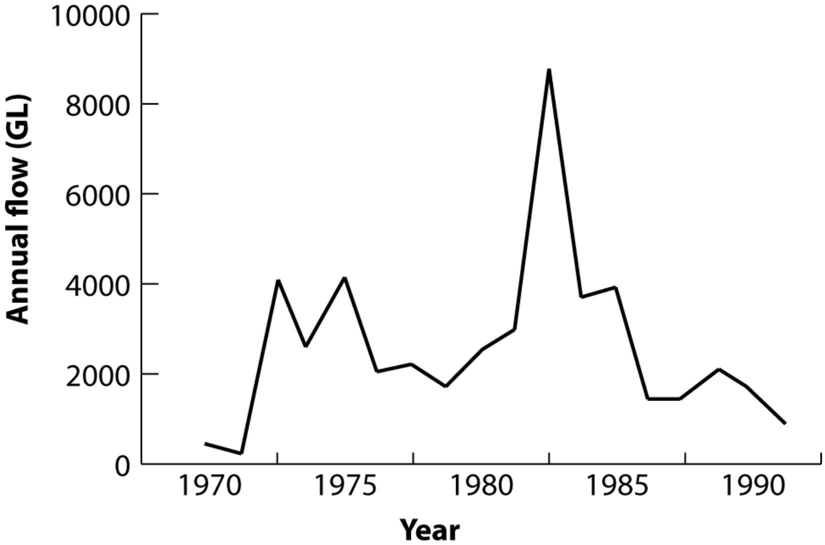


Figure 16: Annual streamflow in the lower Ord River (Water and Rivers Commission 1999).

Median and 90th percentile monthly flows (Figure 17) indicate that large floods occur predominantly in the wet season, particularly between February and April. However, median flows are only slightly greater in the wet than the dry seasons, as constant releases from the Ord River Dam over the dry season ensure that the river is a permanent system. Peak flows in the lower Ord River are now predominantly governed by inflows from the unregulated Dunham River and localised catchments. It is only during very wet years that releases from the dams contribute to flood flows (DoW 2006).

These flood flows are important for a number of reasons including inundation of Parry Lagoon (described below) as well as for flushing the estuary and removing the build-up of deposited silt. In the absence of these flows, it is likely that silt will continue to build up in the low Ord

[3] Ord Diversion Dam was completed in 1963 and resulted in the creation of Lake Kununurra. The Ord River Dam was constructed in 1973 and resulted in the creation of Lake Argyle.

Estuary, decreasing aquatic habitat, hydrological connectivity for fish and altering the geomorphology of the site.

Inundation of Parry Lagoon by the Ord River commences at daily mean flows of > 3700 – 4000 m^3/sec (Rogers and Ruprecht 2001). Flood probability distributions for the lower Ord River at the time of listing, indicate that this equates to approximately the 1 in 20 year Average Recurrence Interval (ARI); equivalent to a 5% probability exceedence (Rogers and Ruprecht 2001). That is, this has a 5 % likelihood of occurring in any given year and on average occurs once every 20 years. Flood inundation extent is illustrated for the 1 in 10 and 1 in 100 ARI in Figure 18.

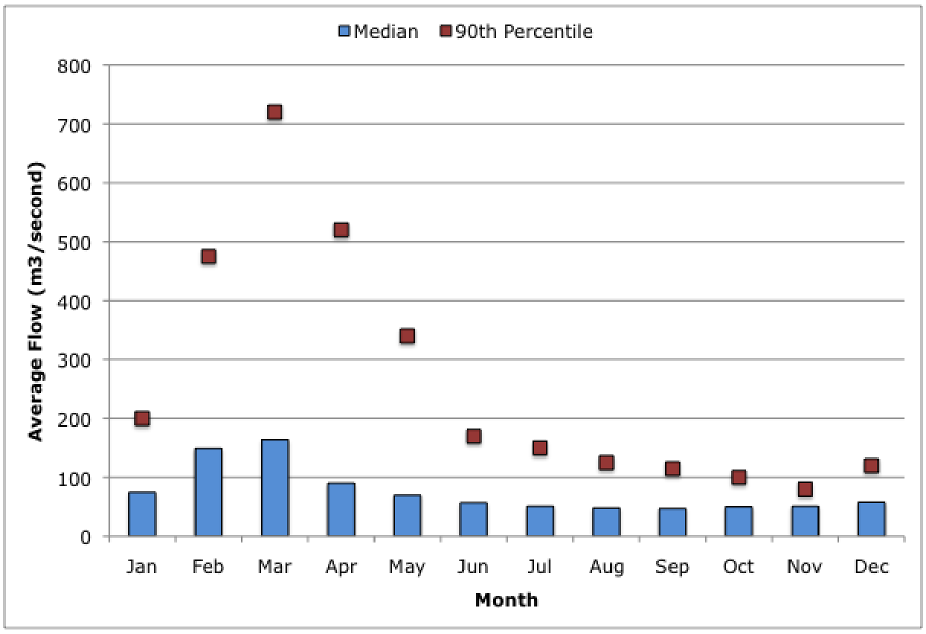


Figure 17: Average monthly and 90th percentile streamflow (m3/sec) for the lower Ord River below the Dunham confluence (DoW 2006).

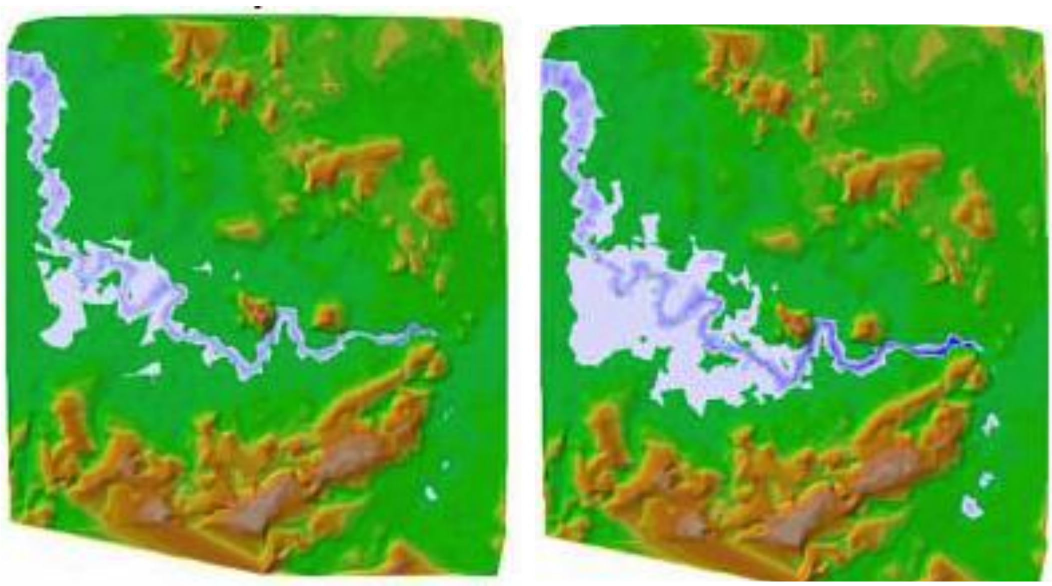


Figure 18: Flood inundation mapping (post regulation) of the Lower Ord River in the vicinity of Parry Lagoon for the 1 in 10 year ARI (left) and the 1 in 100 ARI (right) Rogers and Ruprecht 2001.

It should be noted, however, that Parry Lagoons are also inundated by Parry Creek and local run-off (separate from the Ord River flows). Anecdotal evidence indicates that since the regulation of the Ord River system, inundation of the floodplain area of Parry Lagoons is predominantly as a result of inflows from the Parry Creek Catchment. Jaensch and Vervest (1990) noted that in most years, inundation of Parry Lagoons (floodplain and waterholes) was via Parry Creek and that overbank flows from the Ord River were less frequent, but resulted in more extensive inundation. However, quantitative information on the hydrology of the floodplain is not known and there is no information for flows down Parry Creek.

Parry Lagoons contains both seasonal inundated floodplain as well as a series of permanent or near permanent waterbodies, both of which are inundated via overland flow (either from the Ord River or Parry Creek). Inundation is at its greatest (extent and depth) during March-April at the end of the wet season. The low relief claypans and marshes are typically less than 1 m deep, and dry out by June – July. The deeper waterholes, however, are permanent or near permanent.

The hydrology directly affects the vegetation communities associated with the site. True freshwater aquatic plants are generally confined to the permanent waterholes within Parry Lagoons. These species are adapted to permanent inundation with mechanisms for coping with anaerobic soils and are reliant on the presence of surface water for survival.

Similarly the seasonally inundated floodplain of Parry Lagoons contains vegetation communities that are adapted to this hydrological regime. They typically require seasonal inundation, but also periods of dry where air can fill soil pore spaces. Without the wet – dry cycles, these vegetation communities, together with the fauna they support could not exist.

Hydrology and inundation of the floodplain of Parry Lagoons is also critical for the waterbirds that are supported by the Ramsar site. Migratory species are reliant on the shallow inundated floodplain for feeding and many species (e.g. the Magpie Goose) require inundated vegetation for breeding. The inundated floodplain may also be important for juvenile fish. This aspect of the hydrological regime is therefore crucial for maintaining the ecological character of the site.

The majority of the Ramsar site (with the possible exception of Parry Lagoons) is subject to tidal influences. The Cambridge Gulf and Ord River Estuary is defined as a macro-tidal estuary with typical spring tidal ranges at the estuary mouth of approximately 7m (Figure 19; Wolanski et al. 2001). The tidal influence extends up the Ord River for the entire Ramsar site and spring tidal ranges of up to 2m can be experienced at The Rocks (DoW 2006). The effects of barometric pressure and other meteorological variables can greatly affect tidal amplitude. When spring tides coincide with cyclonic condition, king-tides of greater than 9 m can be experienced. Tidal characteristics for the five year period 1967 to 1971 are provided in Figure 20. The maximum tide during this period did not include a king-tide and was approximately 8.4m (Thom et al. 1975).

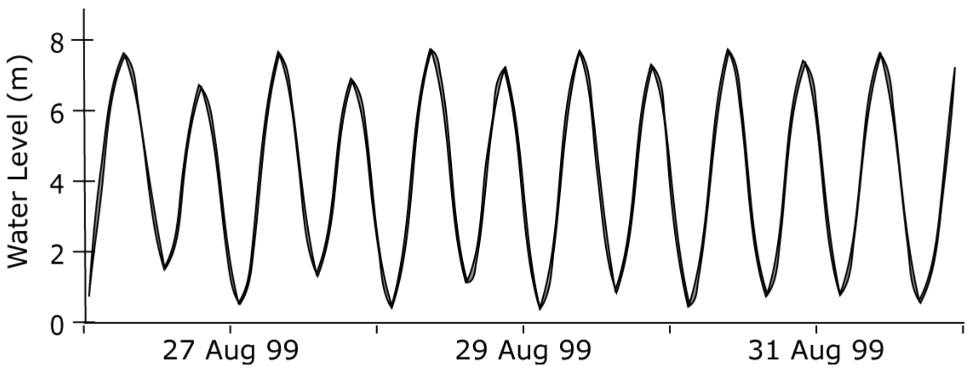


Figure 19: Daily spring tides recorded over a five day period in 1999 (Wolanski et al. 2001).

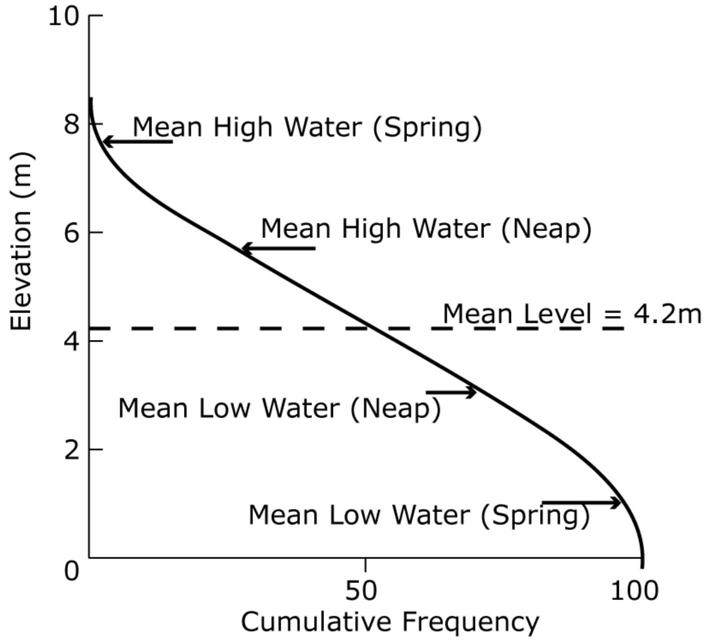


Figure 20: Tidal characteristics of the Ord River Estuary (Thom et al. 1975).

The macro-tidal regime is important for maintaining a number of habitats and vegetation communities within the system. Variation in inundation of the banks of the dentritic creeks provides for a range of habitats for different mangrove species and results in a distinct zonation (see section 3.2.6 below). Tidal cycles may also provide cues for invertebrate breeding (e.g. Banana Prawns) and influence productivity. In the Ord River Floodplain Ramsar site, these macro-tides are important for maintaining nutrient cycling processes by facilitating the export of nutrients from the catchment to the Indian Ocean (see section 3.2.4 below).

The final component of the hydrological regime for the Ord River Ramsar site that should be considered is groundwater. O'Boy et al. (2001) described the hydrogeology of the lower Ord River with a focus on irrigation areas. The contribution of groundwater flows to the lower Ord Rivers was not quantified, and there is no indication of the importance of groundwater flows to the ecological character of the site. However, they suggested that for the majority of the time water flowed from the Carlton and Mantinea flats proposed irrigation areas into the Ord River near the upstream limit of the Ramsar site (Figure 21). During high tides it is possible that the flow of groundwater could be reversed with saline water flowing back under the plains. In addition, they concluded that localised groundwater around this area had not changed substantially over the past 50 years. Therefore current conditions are likely to reflect the conditions at the time of listing.

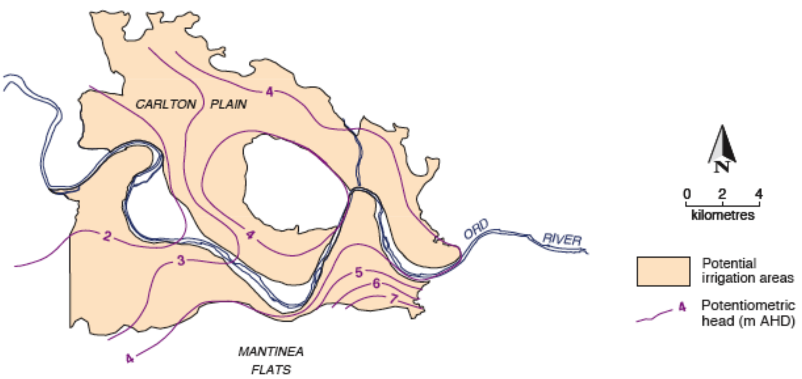


Figure 21: Groundwater contour adjacent to the Ramsar site (O'Boy et al. 2001). Note that the Ord River Floodplain Ramsar site abuts the proposed irrigation areas along their western boundaries.

The hydrology of the lower Ord River had changed dramatically from natural by the time of listing in 1990. The regulation of the river system by the installation of the two major dams and the use of the river as a storage and irrigation delivery system had lead to the following major hydrological changes (Trayler et al. 2006):

- A 35% decrease in total annual flow;
- A change in the seasonality with a 440% increase in average dry season flows (prior to regulation the Ord River dried to a series of pools with little or no flow during the dry season);
- A reduction in the variability of flows; and
- A reduction in overbank flows and inundation of the Parry Lagoon area (prior to regulation floodplain inundation had an ARI of approximately 1 in 2 years (AEP of 50%) as opposed to between 1 in 10 and 1 in 20 years (AEP of 10 – 5%) by the time of listing; Figure 22).

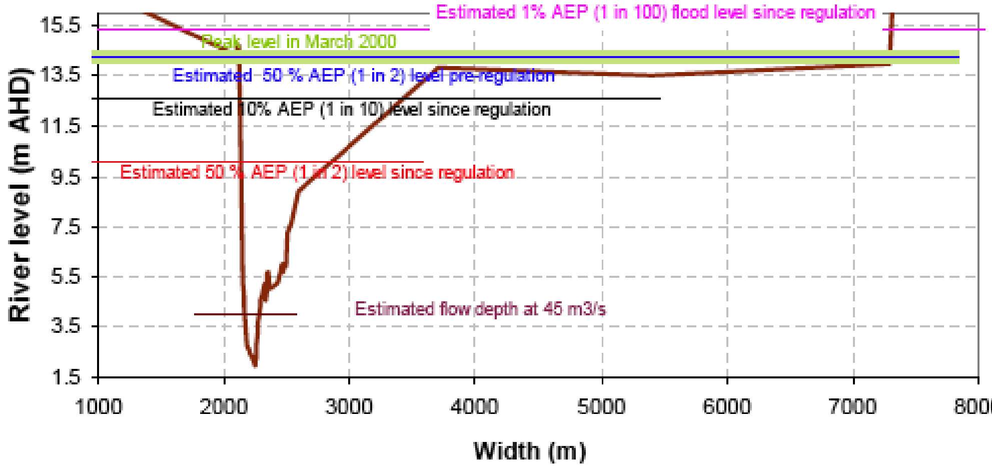


Figure 22: Flood levels immediately upstream of Parry Lagoon showing current and pre-regulation AEP (Average Exceedence Probability). Traylor et al. 2006.

3.2.4 Water quality

Salinity

The majority of the Ord River Floodplain Ramsar site is under tidal influence. This, coupled with the near constant freshwater flows, provides a salinity gradient from the upstream section near "The Rocks" to the estuary mouth (Figure 23). This also illustrates the difference in salinity between low and high tide at different points in the Ramsar site. Near Panton Island the difference can be as much as 20 ppt and this variability decreases with increasing distance upstream (Water and Rivers Commission 1999). This pattern was also reported by Wolanski et al. (2001) who recorded salinity fluctuations of between 10 and 25 ppt in a single tidal cycle near Panton Island.

The estuarine areas around the False Mouths of the Ord, except following heavy local rainfall, are typically saline with salinities between 32 and 36 ppt (Kenyon et al. 2004). However, in the East Arm of the Ord Estuary, the constant freshwater inflows affect the seasonal patterns of salinity. During the dry season salinity may be approximately 28 – 32 ppt, but during the wet season this can drop to < 4ppt (Parslow et al. 2003; Kenyon et al. 2004).

Further inland, water in the river is mostly fresh with salinities of < 4 ppt year round (Parslow et al. 2003). There are few data for Parry Lagoon, however, over two seasons salinity ranged from < 1ppt during the wet season to 1 – 4 ppt during the dry season (Water and Rivers Commission 2003a).

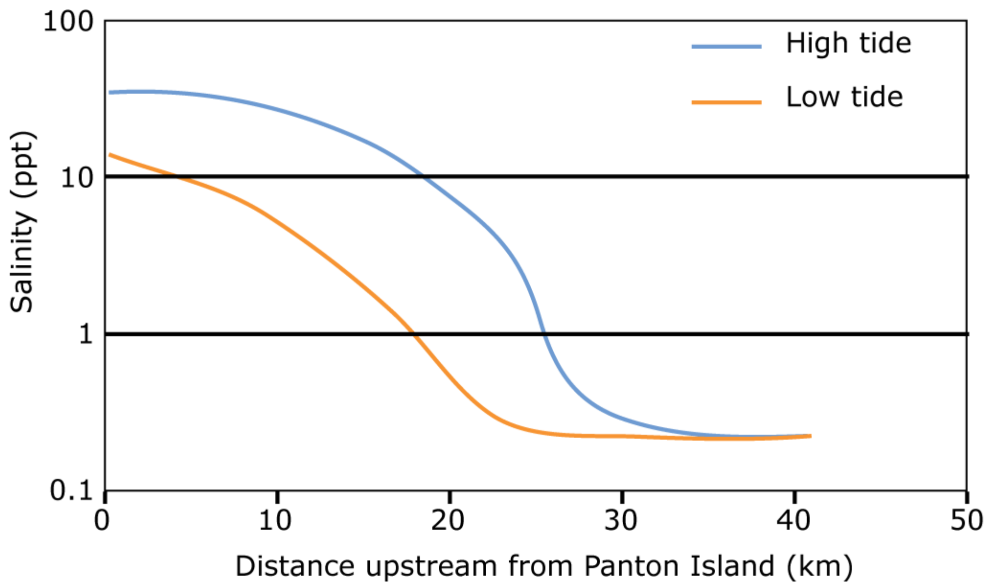


Figure 23: Changes in typical salinity at high and low tide at distances up the river (adapted from Water and Rivers Commission 1999). Note that Panton Island is approximately 10 km inside the boundary of the Ramsar site and the extent of the Ramsar site (The Rocks) is located approximately 30km upstream of Panton Island.

The salinity regime has a profound effect on the flora and fauna and hence the ecological character of the site. Salinity changes may affect aquatic organisms in two ways (ANZECC, 2000):

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

While some species, such as the Saltwater Crocodile have an enormous salinity tolerance (0 – 64 ppt; Taplin 1984) others have a much narrower range. Parry Lagoons is characterised predominantly by freshwater species, while the estuarine reaches of the Lower Ord and False

Mouths of the Ord contain salt-adapted mangroves and estuarine fish and invertebrates. An alteration of the salinity regime (making the estuarine areas less saline or the freshwater areas more saline) would result in changes to the system in terms of community composition and extent of floodplain vegetation and mangroves as well as directly affecting aquatic fauna.

Suspended Solids
The Ord River Estuary is characterised by high total suspended sediment concentrations, which influence light penetration and turbidity. The suspended solid concentrations are predominantly a result of tidal re-suspension of fine sediments that have accumulated in the estuary and channel (Wolanski et al. 2001). Suspended sediment concentrations are lower in the fresh water sections of the river and are typically <100 mg/L (Wolanski et al. 2001; Parslow et al. 2003). Suspended sediment concentrations are highest in the mid-estuary section of the East Arm with maximum values of between 4000 and 5000 mg/L recorded (Wolanski et al. 2001; Parslow et al. 2003). Beyond this zone, in the more open estuary areas, the suspended sediment concentrations are usually lower and typically < 500 mg/L.

Wolanski et al. (2001) used a numerical model to describe the suspended sediment characteristic within the East Arm of the Ord River Estuary. They hypothesised that the sediments are unconsolidated in the freshwater sections and are carried downstream to a point where salinity influences the suspended sediment characteristics causing it to flocculate into fine (< 100μm) particles. The strong currents created by the macrotides resuspended these particles causing extreme suspended sediment concentrations and turbid conditions.

Although a characteristic of the Ramsar site at the time of listing, Wolanski et al. (2001) suggested that this process is not entirely natural. Rather, regulation of the system, which has resulted in a decrease magnitude and frequency of large floods, has resulted in accumulation of these fine sediments, that otherwise would be carried out of the system to the Indian Ocean during large flood events.

A high suspended sediment load can affect both aquatic plants (via reduced light penetration through the water column) and animals, via clogging of gills or reduced visibility for visual hunters. While there is little information of these effects on flora and fauna within the site, it is a component that has the potential to affect ecological character if it changed significantly.

Dissolved Oxygen
The system is typically well oxygenated with dissolved oxygen concentrations between 6 and 8 ppt and 90 – 110% saturation (Parslow et al. 2003). Dissolved oxygen concentration were linked to primary production, with increased dissolved oxygen concentrations during times of high phytoplankton productivity and low dissolved oxygen linked to bacterial decomposition of organic material (Parslow et al. 2003).

Dissolved oxygen is an important component for obligate aquatic organisms (fish and macroinvertebrates) that rely on the extraction of oxygen from the water column. Low dissolved oxygen concentrations have resulted in fish kills in other systems and can result in decreased diversity of macroinvertebrates to species that are tolerant of low oxygen conditions. However, there have been no reports of negative impacts to fauna from within the well mixed aquatic environments of the Ramsar site

Nutrients
Data on nutrient concentrations from within the Ramsar site are limited with the majority of sampling and monitoring occurring in the river reaches and irrigation areas upstream. Parslow et al. (2003) reported the results of approximately 15 months monitoring during 2002 and 2003 with sites located within the Ramsar site. Although this is more than a decade after the site was listed as a wetland of international importance, there have been few changes in the catchment or adjacent to the site that would suggest that these would be significantly different from those during 1990.

The estuary within the Ramsar site can be divided into three approximate reaches: the open estuary (downstream of Panton Island) the mid-estuary (Panton Island to Green Island) and the upper estuary (Green Island to the Rocks)

Total Nitrogen concentrations ranged from < 300 μg/L to > 2000 μg/L and total phosphorous concentrations from < 40 μg/L to > 400 μg/L. Concentrations of these nutrients were correlated with suspended sediment concentrations and followed the same pattern described above. Highest concentrations were recorded in the mid-estuary during the dry season, while concentration in the upper estuary and the outer open estuary were typically lower.

Highest nitrate-nitrite concentrations (> 200 μg/L), however, occurred at the downstream open estuary section. Concentrations of nitrate-nitrite in the upper estuary were < 100 μg/L and most often < 50 μg/L. Similarly, phosphate concentrations were highest in the downstream sections (up too 40 μg/L) and lowest in the upper estuary sections (15 – 20 μg/L).

Parslow et al. (2003) hypothesised that the higher concentrations of dissolved, inorganic nutrients in the open estuary, downstream of the peaks in total nitrogen and phosphorus may represent the rapid mineralisation of particulate organic matter, or the result of the release of dissolved nutrients from the sediment during tidal exchange.

Average monthly nutrient concentrations are available for Carlton Crossing (a few kilometres upstream of the Ramsar site, but below all major river confluences) for the period 1998 to 2000 (data sourced from Lund and McCrae 2001). These indicate that nutrient concentrations are higher during the wet season than the dry. Average total phosphorous concentrations were around 10 μg/L during the dry season and up to 40 μg/L in the wet. Similarly, dissolved inorganic phosphate concentrations averaged < 2 μg/L during the dry season and > 10 μg/L during the wet season (Figure 24). Total kjeldahl nitrogen (total nitrogen without the nitrate-nitrite fraction) was approximately 150 – 170 μg/L during the dry season and > 250 μg/L during the wet (Figure 25).

Lund and McCrae (2001) calculated the nutrient loads entering the lower Ord River from the surrounding irrigation areas, the rangelands and the Kununurra Diversion Dam (Table 5). They estimated that approximately 54 tonnes of phosphorus and over 600 tonnes of nitrogen are discharged to the lower Ord River and estuary annually.

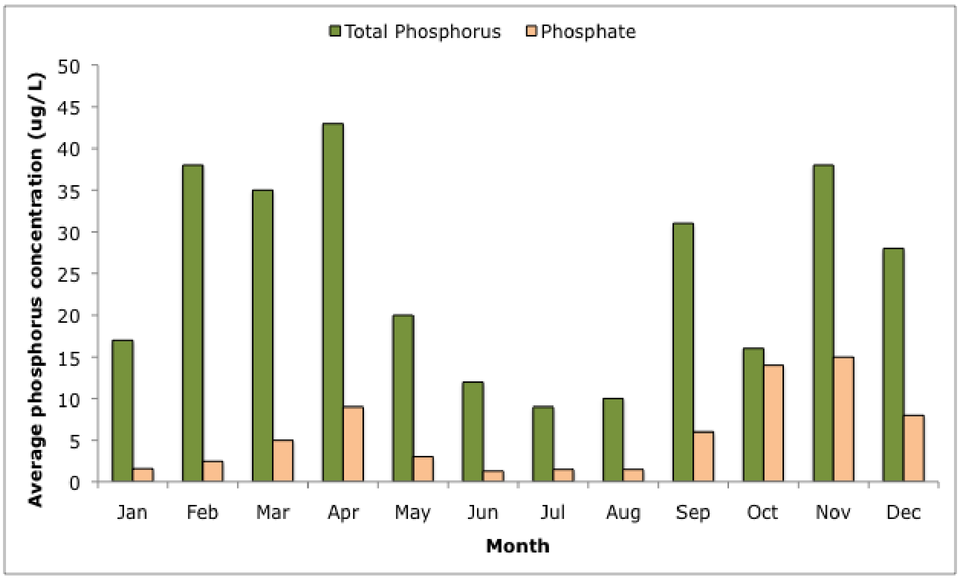


Figure 24: Average phosphorus concentrations in the lower Ord River (Carlton Crossing) 1998 – 2000 (data from Lund and McCrae 2001).

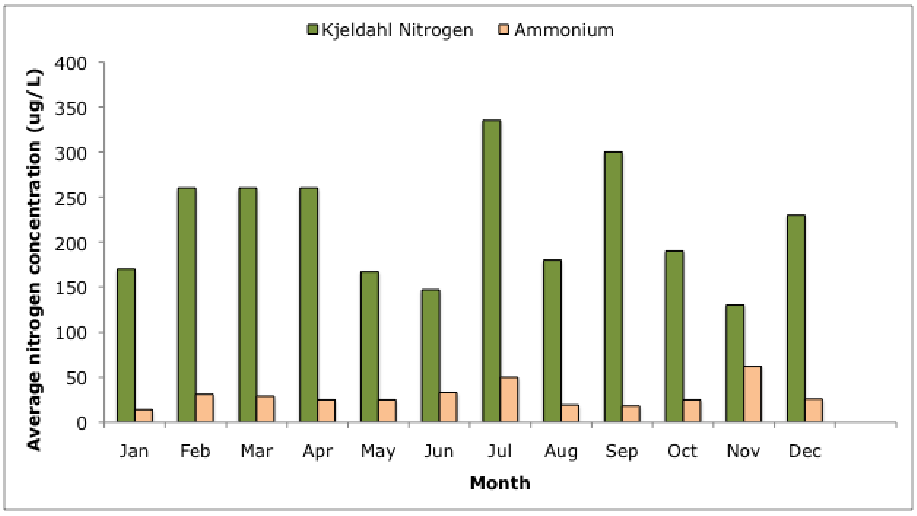


Figure 25: Average nitrogen concentrations in the lower Ord River (Carlton Crossing) 1998 – 2000 (data from Lund and McCrae 2001).

Table 5: Relative contributions to Ord River nutrient loads (adapted from Lund and McCrae 2001).

Parameter	Irrigated Area	Rangelands	Kununurra Diversion Dam	Total
Total phosphorus	22	11	21	54
Phosphate	10	2.4	9	21
Total nitrogen	128	153	429	710
Ammonium	11	14	55	80
Nitrate-nitrite	30	3.8	26	60

Nutrient concentrations in Parry Lagoons and are not known. Given that the water source is now predominantly from the Parry Creek Catchment, which does not have irrigated agriculture influences, it is possible that nutrient concentrations are lower than those in the Ord Estuary.

Nutrient cycling
Parslow et al. (2003) developed a nutrient budget for the lower Ord River and estuary. They concluded that the system was a net exporter of all forms of nutrients to the Indian Ocean during all seasons. There is however, a seasonal variation in export, with higher exports in the wet season than in the dry (Figure 26).

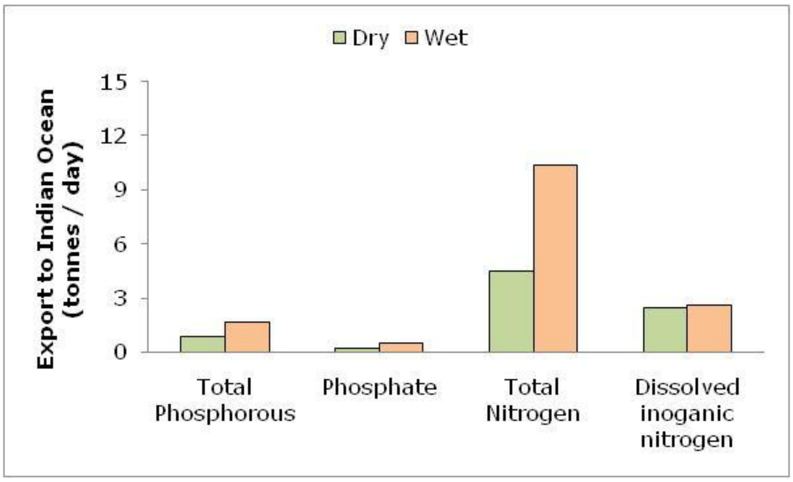


Figure 26: Mean daily export of nutrients from the lower Ord River to the Indian Ocean (data from Parslow et al. 2003).

Nutrients and nutrient cycling are important components and processes within the Ord River Floodplain Ramsar site. In this estuarine and floodplain system there is a balance between maintaining primary productivity (and supporting a diversity and abundance of flora and fauna) and maintaining meso-trophic conditions. Given the net export of nutrients to the Ocean in all seasons, inflows of nutrients from the catchment are important for maintaining productivity. However, given the potential for high nutrient loads from the irrigated catchment, it is important that the capacity for the system to cycle nutrients is not overloaded. Many other estuaries in Australia suffer the effects of cultural eutrophication with resulting algal blooms, low dissolved oxygen in the water column and often negative impacts on biodiversity. Therefore it is important that the balance in the Ord River Ramsar site be maintained.

Toxicants

The Water and Rivers Commission (2003b) has investigated the levels of two agricultural chemicals in the lower Ord River, Atrazine and Endosulphan. Atrazine is an herbicide used to control broad leaf grasses in sugar cane crops (Traylor et al. 2006). It has a half-life in freshwater of approximately two months and breaks down more rapidly under estuarine conditions (ANZECC 2000). Atrazine is not known to bioaccumulate and the recommended ANZECC (2000) trigger values are 0.7 μg/L for 99% protection and 13 μg/L for 95% protection. Median concentrations within the lower Ord River were between 0.23 and 0.38 μg/L (well within guideline levels). However, a maximum concentration of 0.82μg/L was recorded in the lower Ord River in 2001 (Water and Rivers Commission 2003b), exceeding the 99% protection level.

Endosulphan is a pesticide used in the Ord River Irrigation Area to control insects and mites in fruit and vegetable crops (Traylor 2006). Endosulphan is known to bioaccumulate and has lower ANZECC (2000) trigger levels; 0.03 μg/L for 99% protection and 0.2 μg/L for 95% protection. Median concentrations of endsulphan for 1998 to 2001 in the lower Ord River were 0.03 to 0.09 μg/L, above the 99% protection guideline value (0.03 μg/L). The maximum concentration in the 1998 to 200 period was 1.16 μg/L (Water and Rivers Commission 2003b) well above all trigger values for this chemical and potentially at hazardous concentrations for aquatic fauna.

From 1964 to 1974 cotton was grown in the Ord Irrigation Area and during this time 435 tonnes of DDT and 412 tonnes of toxaphane were applied to the cotton crop (Yoshikane et al. 2006). Although water quality data for DDT could not be sourced, there is evidence that this pesticide has bioaccumulated through the food chain (see section 6.2).

3.2.5 Phytoplankton

There is limited information on phytoplankton biomass and community composition from the Ramsar site (or from any location within the lower Ord River). Parslow et al. (2003) undertook sampling of chlorophyll a during 2002 and 2003 at a number of locations within the Ramsar site. Chlorophyll a concentrations ranged from < 4 µg/L to approximately 28 µg/L, with highest concentrations in the upstream section of the Ramsar site and the lowest in the open estuary. Phytoplankton biomass (as indicated by chlorophyll a concentrations) is generally higher in the wet season than in the dry across the site.

Parslow et al. (2003) found a close association between chlorophyll a and suspended sediments in the estuary and suggested that much of the chlorophyll a observed in the lower estuary could be attributed to re-suspended microphytobenthos rather than truly planktonic algae.

Parslow et al. (2003) also collected samples for phytoplankton identification and enumeration during the wet season (February 2003). Abundant nanoplankton were recorded in all samples, but quantitative counts were not possible due to high sediment loads. All samples were dominated by benthic diatom species (*Nitschia, Melosira, Navicula*) with only occasional planktonic species (Coscinodiscus). Dinoflagellates and chlorophytes were the other main groups recorded. Samples collected at different points from the outer estuary to the upstream extent of the Ramsar site indicate a decline in the percentage composition of diatoms from the open estuary (100%) to the upper estuary sections (50 – 85%). The upper estuary sections contained higher total counts than open estuary sites and the presence of chlorophytes and cyanobacteria, which were not recorded in the open estuary (Figure 27).

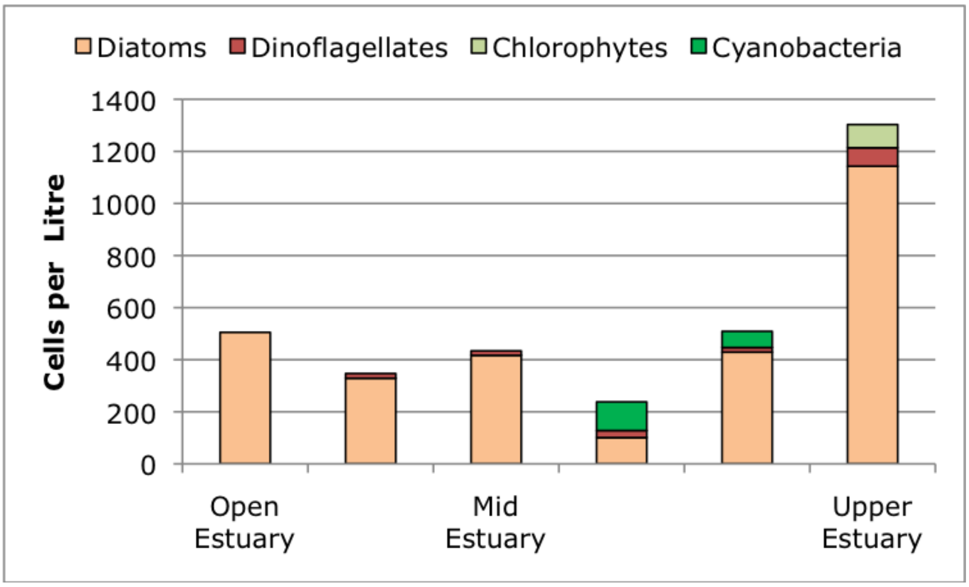


Figure 27: Counts (cells per litre) of phytoplankton (excluding nanoplankton) from sites within the Ord River Floodplain Ramsar site in February 2003 (data from Parslow et al. 2003).

Although information on phytoplankton is limited, it is thought that it is important in contributing to primary production within the Ramsar site, particularly with the estuarine areas. The lower Ord River and estuary has a highly mobile, loose sediment which provides for an unstable surface and low water clarity and inhibits the establishment of benthic plants (e.g. seagrass and benthic macro-algae). As such, primary production within the water column of these wetlands is comprised entirely of phytoplankton and benthic micro-algae. These organisms are providing the food directly for a range of fauna such as invertebrates and fish, and animals such as waterbirds and crocodiles through the food chain.

3.2.6 Vegetation

There are a large number (> 300) flora species that have been recorded within the Ramsar site (CALM 1998; Appendix D) and a range of vegetation communities. However the vegetation communities critical to the ecological character of the site comprise [4]:

- Mangrove and saltmarsh
- Wetland grasslands and sedges
- Riparian woodland
- Aquatic vegetation within the permanent waterholes of the Parry Lagoons.

Although there are varying levels of information about each of these vegetation communities, characteristics of each are considered below. Note that as taxonomy changes, species names are often updated, the species listed below are those considered current in Florabase (http://florabase.calm.wa.gov.au/) as of June 2008.

Mangrove and Saltmarsh
Mangroves are the most extensive vegetation community in the Ord River Floodplain Ramsar site. They cover approximately 26,800 hectares and extend from the False Mouths of the Ord to the upstream sections of the estuary within the Ramsar boundary (Figure 28). The majority

[4] Note that the vegetation community "Freshwater Spring Vegetation" has not been considered as a critical component. The extent is small and the composition and associated fauna are unknown. While this vegetation association should be afforded a high priority for further investigation and protection it is not a significant contributor to the ecological character of the Ramsar site.

of the mangroves exist as narrow fringing bands along the intertidal areas, with saltmarsh on higher elevations. The saltmarsh communities have not been mapped and occupy a portion of the area in Figure 28 that is given the collective name of “intertidal flats”.

There are fourteen species of mangrove that have been recorded within the boundaries of the Ramsar site (Johnstone 1990; Semeniuk and Semeniuk 2000) which is considered to be the greatest diversity of mangrove species in the Kimberley region and potentially Western Australia (Pedretti and Paling 2001). It is this community that contributes to the importance of the site in terms of bioregional biodiversity and listing as a wetland of international importance under criterion 3.

Saltmarsh within the Ramsar site is less extensive and less well documented. There are a small number of halophytic species that have been described in association with the mangrove communities. These include: *Tecticornia spp.*,*Batis argillicola, Salsola kali, Sesuvium portulacastrum, Sporobolus virginicus* and *Suaeda sp.* (Thom et al. 1975). Mangrove species recorded within the Ramsar site and their preferred habitats are provided in Table 6.

Table 6: Mangrove species recorded within the Ord River Floodplain Ramsar site. Habitat descriptions from AIMS (1993).

Species name	Common name	Habitat
Acanthus ilicifolius	Sea Holly	On the landward edge of marine systems especially in areas with freshwater influence
Aegialitis annulata	Club Mangrove	Often in sandy or rocky environments at the seaward edge of mangrove communities
Aegiceras corniculatum	River Mangrove	Riverbanks across a wide range of salinities
Avicennia marina	Grey Mangrove	On the seaward edge of marine systems but can be found in all mangrove environments
Bruguiera exaristata	Rib-Fruited Orange Mangrove	Upper intertidal zone
Bruguiera parviflora	Small-Leafed Orange Mangrove	River environments
Camptostemon schultzii	Kapok Mangrove	Inner, seaward edge of mangrove communities
Ceriops australis	Yellow Mangrove	Wide salinity tolerance, but high salinity stunts growth, taller trees are found in areas with freshwater influence
Excoecaria agallocha	Blind-Your-Eye-Mangrove	At or just above the high tide mark
Lumnitzera racemosa	Black Mangrove	Landward edge of mangrove communities
Osbornia octodonta	Myrtle Mangrove	Landward edge of marine mangrove communities where there is little freshwater
Rhizophora stylosa	Red Mangrove	Low on the intertidal zone where roots are submerged during high tide
Sonneratia alba	Mangrove Apple	Tolerate a wide range of salinities often found with Grey Mangrove
Xylocarpus mekongensis	Cedar Mangrove	River banks or the landward edge of marine mangrove communities

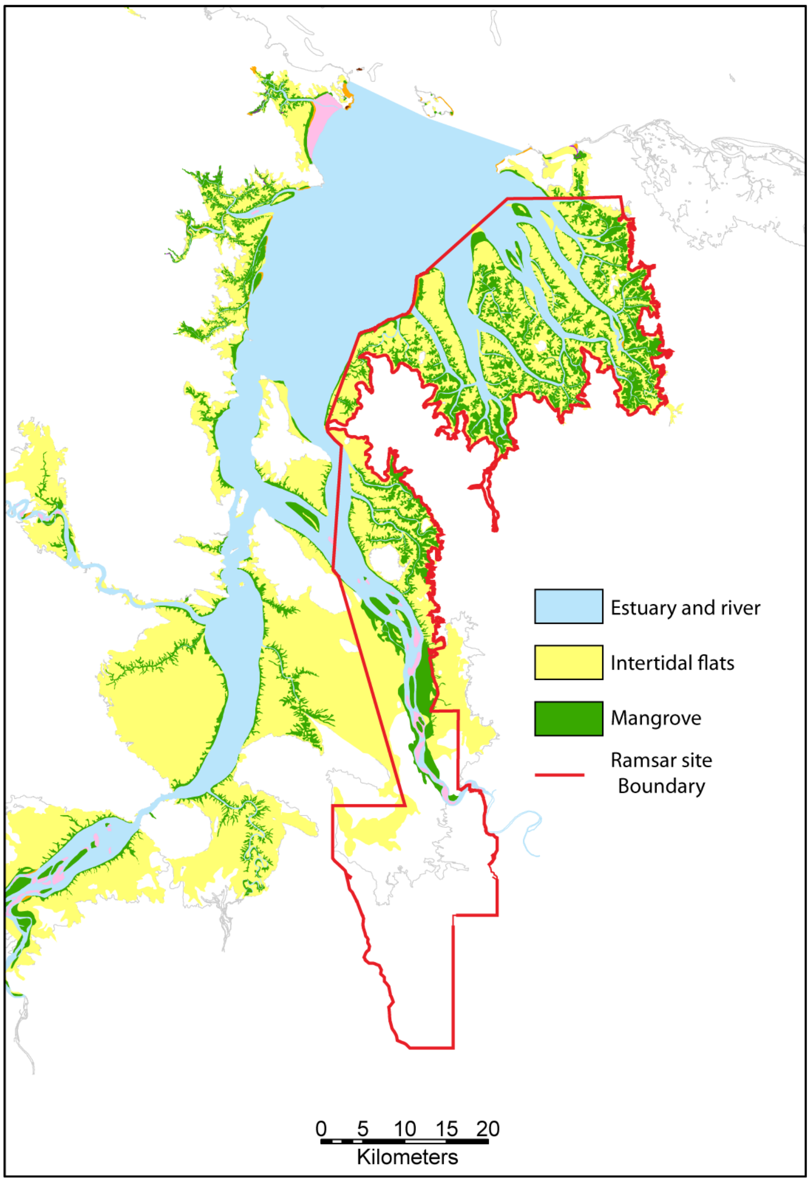


Figure 28: Map showing extent of mangrove and intertidal sand flats within the Ord River Floodplain Ramsar site (data from Geoscience Australia).

Thom et al (1975) described the zonation of the mangrove and associated saltmarsh communities from the estuary and river habitats within the Ramsar site. The outer estuary and False Mouths of the Ord are characterised by tall forest of Red Mangrove (*Rhizophora*) in the mid-tidal zone, with increased elevation this gives way to stunted woodland of Grey (*Avicennia*) and Yellow Mangroves (*Ceriops*). At the landward margins of this woodland an understorey of saltmarsh occurs (*Tecticornia, Suaeda* and *Batis*). The high tide zone is characterised by bare mudflats, which comprise the largest portion of the area (often over 80 %). At the highest elevation of the tidal zone, where inundation is infrequent, saline tolerant grasses such as Marine Couch (*Sporobolus virginicus*) occur (Figure 29).

Distinctive plant communities occur in this zone of infrequent tidal inundation, where seasonal freshwater inundation may often be significant. In addition to Saltwater Couch, as mentioned above, grasses such as *Xerochloa imberbis* occur in this mildly salty zone on marine plains. The tall sedge *Schoenoplectus litoralis* and short sedges such as *Fimbristylis ferruginea* and *Cyperus scariosus* are mixed in with the grasses to form a dense and complex ecotonal plant community.

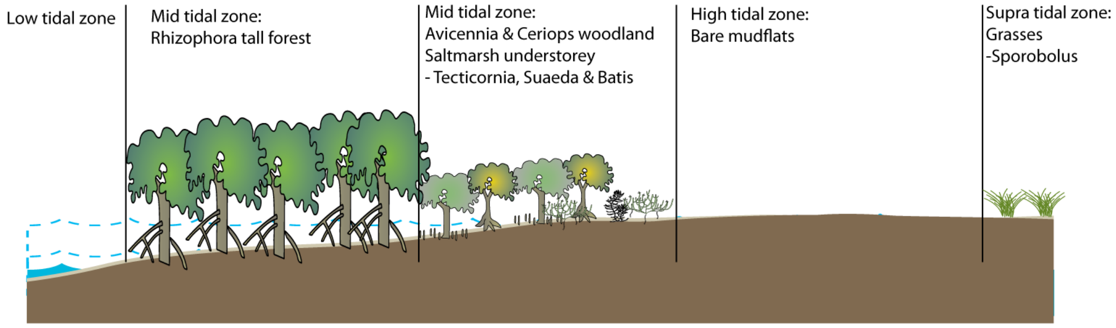


Figure 29: Typical zonation in the outer estuary and False Mouths of the Ord (adapted from Thom et al. 1975). Note the low and mid tidal zones are horizontally exaggerated, and the area of bare mudflats is much reduced).

Thom et al. (1975) undertook a number of transects in the mid estuary in the area adjacent to the Fossil Islands and found different patterns on accreting and eroding shorelines of the mid-channel islands and on the banks of the river. However, Red Mangrove is absent in these reaches and the mix of mangroves is one that is more tolerant of freshwater. The lower margins are characterised by low woodland of Grey Mangrove, which gives way to taller woodlands of the same species at higher elevations. Yellow Mangrove and Blind-Your-Eye Mangrove are also common. The understorey is comprised of saltmarsh species such as *Tecticornia, Suaeda* and *Sporobolus* (Figure 30).

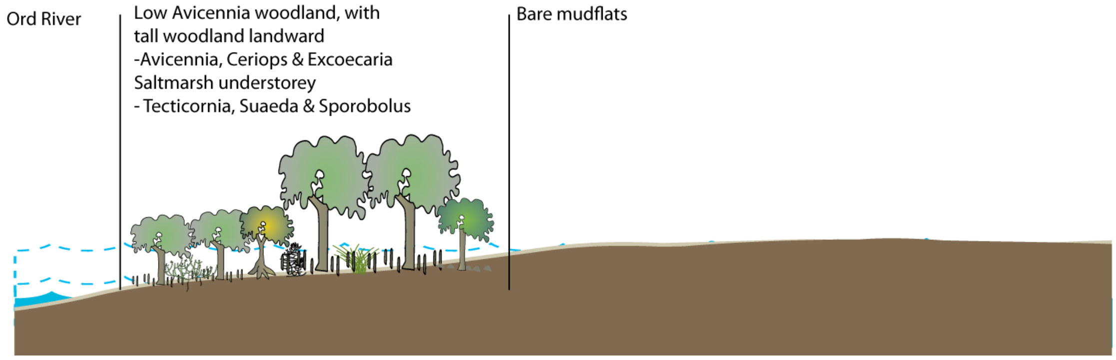


Figure 30: Typical zonation in the downstream reaches of the Ord River (adapted from Thom et al. 1975). Note the low and mid tidal zones are horizontally exaggerated, and the area of bare mudflats is much reduced).

At the upper estuarine reaches of the Ramsar site, the sedimentation and cut-banks of the channel create an unstable habitat for mangroves and Thom et al. (1975) noted that mangroves were being dislodged and uprooted into the river. In addition, they also noted that mangrove species in this area were being replaced with freshwater plants, possibly in response to the increasing period of freshwater flows.

The mangroves of the Ord River Floodplain provide important habitat for a number of faunal communities. The extensive mangroves surrounding the False Mouths of the Ord and lower Ord River support 16 species of bird, 12 of which are confined to this habitat (Johnstone 1990). The mangroves also support 17 species of bat and the only recorded occurrence of the Mosaic-tailed Rat (*Melomys burtonii*) is from the mangroves of the False Mouths of the Ord (CALM 1998). It is thought that the intertidal mangrove areas are significant breeding areas for Banana Prawns and may also be for mud crabs. The importance of mangroves in nutrient cycling and the detrital food chain remains an area of current research (Gehrke 2008) and although not documented, it is thought that the mangroves play a role in sediment stabilisation and erosion control in the macro-tidal estuary.

Wetland grasslands and sedges
The floodplain of Parry Lagoon is dominated by grassland communities, which are reported to be the most extensive in Western Australia (CALM 1998). Wetland annual grasses Australian Wild Rice (*Oryza australiense*) and Beetle Grass (*Diplachne parviflora*) dominate the grasslands of the Parry Lagoon floodplain. The annual wetland shrubs Sesbania Pea (*Sesbania cannabina*) and budda pea *Aeschynomene indica* can form extensive tall thickets across the floodplain following periods of major inundation; the dry stems of the desiccated plants provide extensive mulch. Some of the most frequently inundated, southern basins support dense beds of sedge dominated by *Eleocharis brassii* (CALM 1998). A range of short grasses, sedges and forbs such as Nardoo (*Marsilea* sp.) is associated with these plants.

These grasslands and sedge areas provide important habitat for waterbirds both in terms of foraging and breeding. Nesting sites for species such as the Magpie Goose have been regularly recorded within the inundated sedge communities (Jaensch 1994). The grasslands are the only area in Western Australia where Zitting Cisticolas (*Cisticola iuncidis*) occur and grassy wetlands are considered to be preferred habitat for the EPBC listed Australian Painted Snipe (Lane and Rogers 2000).

Riparian Woodland
The floodplain of the lower Ord River and Parry Creek within the Parry Lagoons area contains extensive woodland communities that are periodically inundated by floodwaters. Common canopy species include: River Red Gum (*Eucalyptus camaldulensis*), Northern Salmon Gum (*Eucalyptus bigalerita*), Darwin Box (*Eucalyptus tectifica*) and Guttapercha (*Excoecaria parvifolia*).

When inundated, this vegetation community provide roosting and nesting sites for a variety of waterbirds. Colonial breeding by Egrets and Spoonbills has been recorded within this vegetation community (Jaensch 1994) together with a large heronry (Jaensch and Vervest 1990).

Aquatic Vegetation
The permanent wetlands within the Ramsar site contain a diverse aquatic flora community. The species typical of these systems are provided in Table 7. It is worth noting that the Bulrush (*Typha domingensis*) which currently occurs in dense stands along most freshwater reaches of the Ord River, is probably a recent arrival to the Ramsar site in response to more permanent flows (CALM 1998).

Table 7: Common plants of the freshwater wetlands and streams within the Ord River Floodplain Ramsar site (CALM 1998)

Species name	Common name	Comments
Ipomoea diamantinensis	Desert Cow Vine	Creeper restricted to the margins of wetlands
Nymphaea macrosperma	Water Lily	Floating leaved annual found in wetlands
Nymphoides indica	Marshwort	Floating leaved perennial found in wetlands
Nymphoides crenata	Wavy Marshwort	Floating leaved perennial found in wetlands
Utricularia spp.	Bladderwort	Floating leaved perennial found in wetlands
Ceratophyllum sp.	Hornwort	Submerged perennial found in wetlands
Typha domingensis	Bulrush	Emergent aquatic found in dense stands within the freshwater reaches of the lower Ord River
Sesbania erubescens	Sesbania Pea	Tall perennial Sesbania that grows in semi-permanent water such as in the main waterhole and some nearby swamps

The aquatic vegetation of the permanent waterholes provides habitat and forage for a range of waterbirds both during the wet and dry seasons. Waterfowl such as ducks and Black Swans feed on a range of aquatic plants and the invertebrates associated with them and it is within this area that the high numbers of Plumed-whistling Ducks have been recorded (Jaensch 1994). Comb-crested Jacanas nest on the floating waterlilies within the waterholes and Eurasian Coots in the littoral vegetation at the margins of these waterholes. Although data on other species is limited, these permanent waterholes with aquatic vegetation would also provide habitat for frogs, Freshwater Crocodiles and freshwater fish.

3.2.7 Invertebrates

An intensive invertebrate survey was conducted in 2001 on the lower Ord River upstream of the Ord River Floodplain Ramsar site (Storey 2002). However, the sites were located upstream of the tidal influence and so are not likely to apply to the tidally influenced Ord River Estuary within the Ramsar site boundaries. A survey of the invertebrates of Parry Lagoons was undertaken as part of a larger study in May 2003 (Water and Rivers Commission 2003a). A total of 87 species from 37 families was recorded in the permanent wetlands within the floodplain with community composition similar to that recorded in the Ord River upstream of the Ramsar site. Abundance data are not provided for these samples, so little can be said about dominant taxa.

Little is known about the invertebrate fauna of the estuarine reaches of the lower Ord River and the False Mouths of the Ord and no investigations on species composition or abundance could be sourced. The estuary is known, however, to be an important nursery for Red-Legged Banana Prawns (*Penaeus indicus*). Significant numbers of post-larval and juvenile Red-Legged Banana Prawns were found in the mangrove environments of the False Mouths of the Ord and Ord River Estuary during 1998 surveys (Kenyon et al. 2004). The authors concluded that this area is important for maintaining stocks of this commercial species.

It is thought that the lower Ord River may also be important in the lifecycle of the White Banana Prawn (*Penaeus merguiensis*). Although Kenyon et al. (2004) recorded this species in lower numbers than the Red-Legged Banana Prawn; the estuary may nevertheless be significant in their life-cycle (Department of Water 2006).

Penaeid prawns (which include both the Red-legged and White Banana Prawns) have a diadromous lifecycle (Figure 31). Adult prawns spawn in the open ocean, after about 2 – 3 weeks the post-larval prawns migrate inshore to mangroves on a flood tide. They spend between 1 and 2 months feeding in the estuary and the juveniles then migrate back to the open ocean on an ebb tide. Staples and Vance (1986) suggested that rainfall, salinity and tide are all influencing factors in triggering juvenile emigration back to the ocean, which peak migration on ebb tides following heavy rainfall.

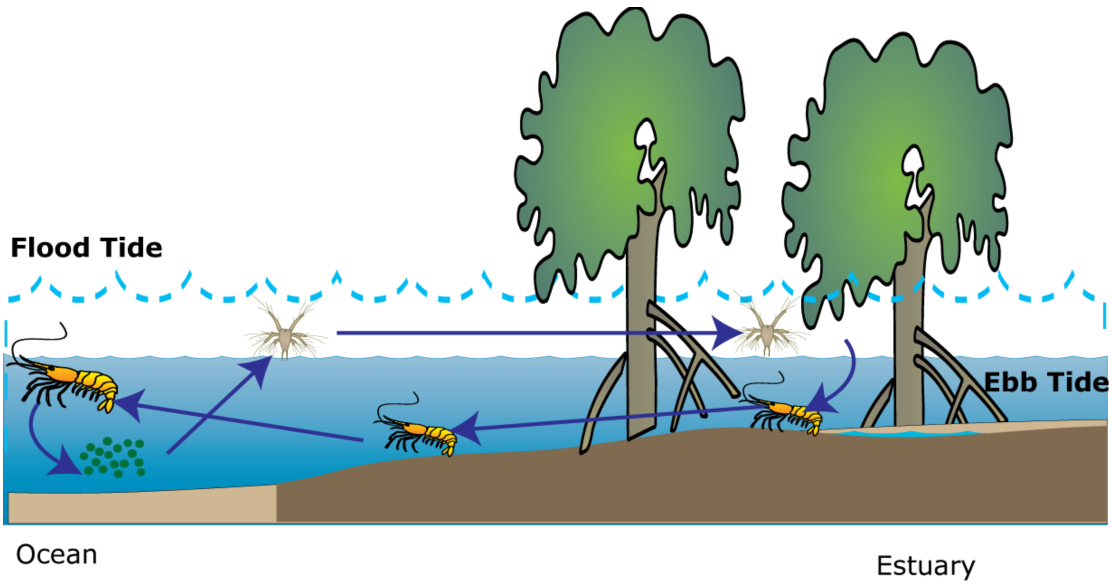


Figure 31: Lifecycle of penaeid prawns, showing immigration of post-larval prawns to mangroves and emigration of juveniles back to the open ocean.

Invertebrates are considered critical components of the Ord River Ramsar site both for their own intrinsic values (e.g. prawns described above) as well as their role in the provision of food for a large number of waterbirds and fish. Migratory waterbirds that use the site predominantly feed on invertebrates and it is only due to the presence of invertebrates in large numbers in shallow wetlands or mudflats that these important migratory species can be supported. In addition, many invertebrates play an important role in nutrient cycling and the detrital food chain, making them critical to the functioning of the wetland ecosystem.

3.2.8 Fish

The Ord River Floodplain Ramsar site provides a variety of habitats for fish ranging from purely freshwater species (in the upper reaches of the Ord River within the Ramsar site and in Parry Lagoons) as well as estuarine species and marine opportunists. In addition, as the Ramsar site connects the estuary and Indian Ocean with inland freshwater environments it is the migratory route for a number of diadromous species. Most migrations are for feeding or breeding with fish being classified in the following groups:

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

The types of fish that are supported by the Ord River Floodplain Ramsar site are illustrated in Figure 32.

Fish surveys and habitat investigations have been undertaken in the lower Ord River (Doupe et al. 2003; Thorburn et al. 2003; Morgan et al. 2004b; Storey 2003; Water and Rivers Commission 2003a; Gill et al. 2006; Gehrke 2008). However, fish survey data from the Ramsar site are very limited. Gehrke (2008) developed a fish species list by using available data from adjacent reaches of the Ord River, observations from local government agency staff and habitat preferences from the literature. The list provides predicted, observed and recorded fish species from a number of habitats including the freshwater / tidal influenced river and the estuary within the Ramsar site.

Based on the records and predictions of Gehrke (2008) the Ord River Floodplain Ramsar site supports over 50 species of fish (Appendix B). This includes 15 species that could be considered freshwater fish, which are not known to extensively use estuaries or marine environments. The remainder are either marine opportunists, utilising the estuary for feeding, or species that travel between freshwater and marine environments as part of their breeding cycle.

Fish are critical to the ecological character of the site, both for their own intrinsic values as well as in the provision of food for piscivorous birds and other predators (such as crocodiles). Specifically they contribute directly to the listing of the site as a wetland of international importance under criteria 2 and 8; and to supporting waterbirds which contribute to criterion 5.

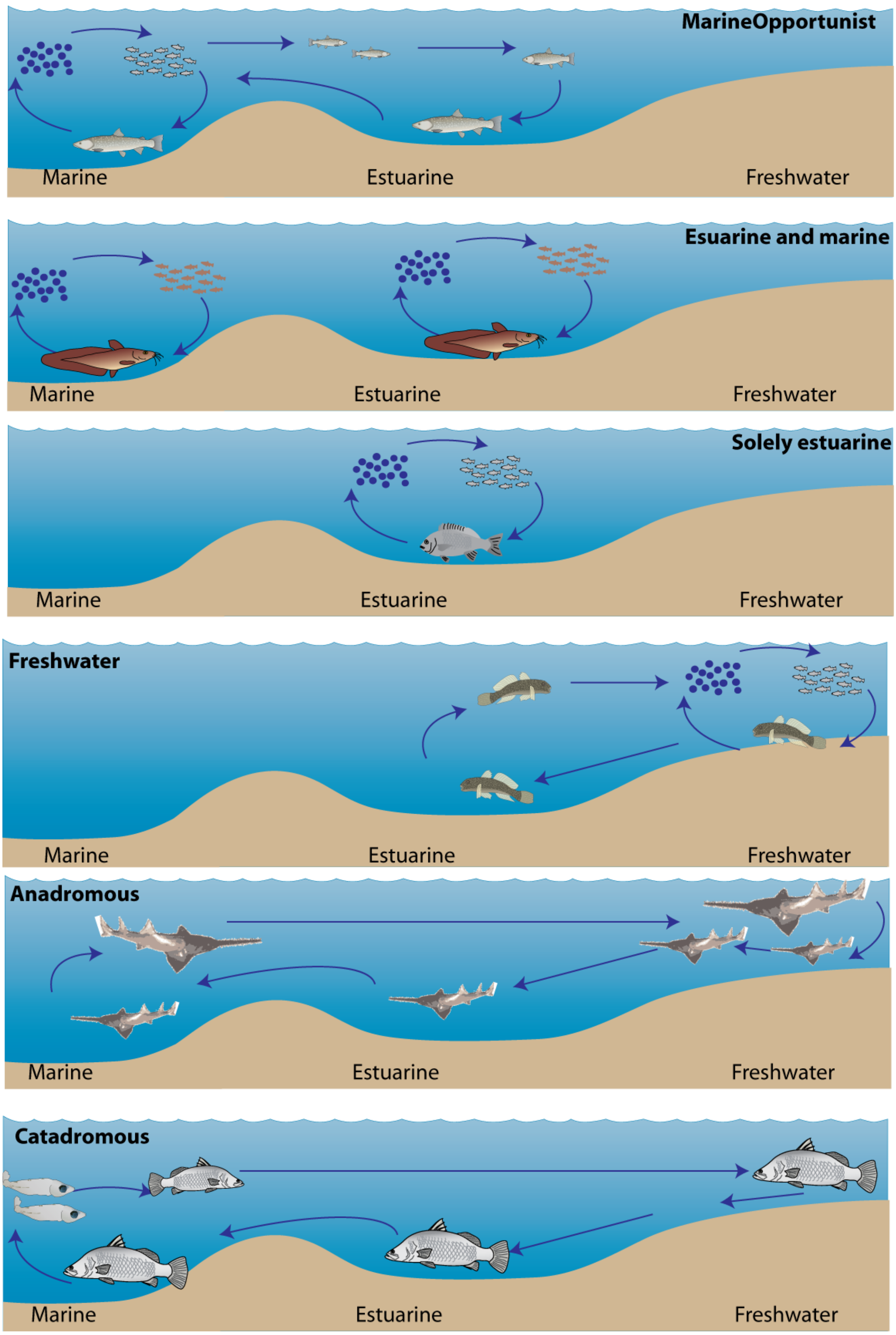


Figure 32: Fish use of the Ord River Floodplain Ramsar site (adapted from Hale and Butcher 2008; Potter and Hyndes 1999).

There are a number of commercially important fish species that are found within the Ramsar site and the mangrove areas act as nurseries for many of them. The most significant commercial fish supported by the Ramsar site are Barramundi (*Lates calcarifer*), Blue Threadfin Salmon (*Eleutheronema tetradactylum*) and Giant Threadfin Salmon (*Polydactylus macrochir*). These form the gillnet commercial fishery for the Cambridge Gulf for which Fisheries WA provides catch data (Figure 33). The commercial catch of these species has dropped from a total of > 11 tonnes in 2002 to under 5 tonnes in 2006 (Fisheries WA 2003 – 2007). However, there is no indication if this is representative of a decline in fish numbers or a decline in fishing effort[5].

Commercial fisheries also operate in the Cambridge Gulf for other species recorded or predicted to be supported by the Ramsar site, such as Grey Mackerel (*Scomberomorus semifasciatus*) and *Lutjanus spp*. However, data for the Cambridge Gulf are not reported separately from other fisheries in the Kimberley.

There are also a number of important recreational fish species supported by the Ramsar site. These include: Barramundi, Bream and Catfish (West et al. 1996). There are no quantitative data available for recreational fishing, but the majority of residents or visitors fished upstream of the Ramsar site in fresher waters.

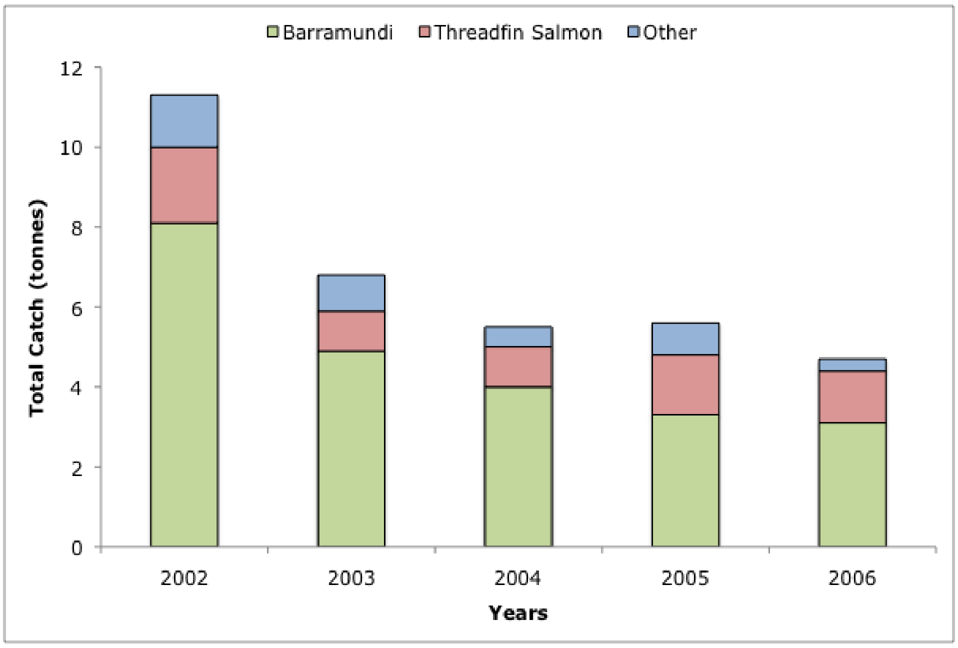


Figure 33: Commercial gillnet catch from Cambridge Gulf 2002 – 2006 (data from Fisheries WA 2003 – 2007).

A significant proportion (30%) of the fish species recorded or predicted to use the Ord River Floodplain Ramsar site have diadromous life cycles. That is, they migrate between fresh water and marine environments during some time in their lives. The majority of these are catadromous, spending their adult life in freshwater and migrating to the ocean to breed. The commercially significant species Barramundi and Threadfin Salmon are both protandrous (changes sex from male to female) and the former may be catadromous. The lifecycle of the Barramundi in particular has been well documented, but is highly variable and some individuals spend their entire life-cycle within the estuarine or marine environment (Moore and Reynolds 1982; Griffin 1993, Pender and Griffin 1996; among others).

Adult Barramundi inhabit marine, estuarine and inland, freshwater rivers and migrate to coastal / estuarine locations to spawn. Juveniles leave coastal nursery swamps when about 6 months old and by the end of their first year have become distributed throughout coastal

[5] Catch per Unit Effort (CPUE) data is not available for this fishery as there are < 5 licensed commercial fishing operators.

and estuarine regions. During their second or third year they may move upstream into inland freshwaters. Individuals can remain male for a number of spawning seasons but generally breed at least once before changing sex and becoming female. The number of adults that migrate to saline areas to spawn can be highly variable from year to year. It is thought that early wet season rainfall is a trigger for downstream migration (Griffin 1993). This trigger may simply be due to increased flows in the wet season being required to connect isolated pools, which form in the dry season in an unregulated tropical river. It has been suggested that regulation of the Ord River and the constant flows in the lower Ord have increased habitat and connectivity for Barramundi (and other catadromous fish species) in the lower Ord (Trayler et al. 2006). However, the converse viewpoint is that the barrier to upstream migration created by the two dams has severely restricted available habitat (Morgan et al. 2004b, Doupe et al. 2005). In addition, the loss of connectivity between the river / estuary and freshwater wetlands of Parry Lagoons, due to a decrease in overbank flooding, greatly reduces habitat for juvenile fish.

The Ord River Floodplain Ramsar site supports at least five species of fish that are considered threatened at the national and / or international levels:

- Freshwater Sawfish (*Pristis microdon*) - critically endangered (IUCN Red List); vulnerable (EPBC Act);
- Queensland Groper (*Epinephelus lanceolatus*) – vulnerable (IUCN Red List);
- Freshwater Whipray (*Himantura chaophraya*) – vulnerable (IUCN Red List);
- Northern River Shark (*Glyphis sp. C*) – critically endangered (IUCN Red List) endangered (EPBC Act); and
- Green Sawfish (*Pristis zijsron*) – critically endangered (IUCN Red List); vulnerable (EPBC Act).

Little is known about the ecology, lifecycle, breeding and population sizes of these species. However, the Queensland Groper and Freshwater Whipray are listed as vulnerable predominantly due to threats on their habitats in other countries and are not considered to be threatened within Australia (http://www.iucnredlist.org/search/details.php/7858/all).

The Northern River Shark is reported from the lower Ord in Thorburn (2006) and Stevens et al. (2005). To date only 29 specimens of this species have been recorded, five of which were recorded from the Ord River (Stevens et al. 2005). This species has only been recorded in highly turbid tidal rivers and estuaries. It is thought that breeding occurs prior to the wet season, with pupping most likely in river mouths and estuaries. Juveniles may migrate upstream to avoid predation from larger sharks and once mature, older animals are thought to move to more marine environments (Thorburn and Morgan 2004). The specimens caught in the Ord River were all < 80cm in length and are thought to be juveniles.

The Freshwater Sawfish (Figure 34) is considered threatened both in Australia and Internationally, and has been reported from the Ord (see Gill et al. 2006) with a recent biological description from the Kimberley (Thorburn et al. 2007, Whitty et al. 2008). While there are few quantitative species-specific data on sawfish abundance in Australia, their numbers appear to have declined drastically along the east coast with sawfish now virtually extinct in New South Wales and South East Queensland. It has not been recorded within the Ramsar site, however, it has been recorded in the lower Ord River upstream of the site boundary (Storey 2003) and the Ramsar site acts as a migratory route.

Although long considered to be primarily a freshwater species, the Freshwater Sawfish is a marine species that moves into freshwater environments to give birth, with juveniles spending the first 3 – 4 years in freshwater (Peverell 2005; Thorburn et al. 2007). It is thought that down stream migration of young adults occurs at the end of the wet season (Peverell 2005). Adults spend the majority of their life feeding in marine waters and move into fresh or estuarine waters to spawn at the beginning of the wet season. Females give birth to live young and the juveniles spend the first 3 – 4 years feeding in freshwater environment. Sawfishes feed on slow-moving fish, which are stunned by sideswipes of the snout, and molluscs and crustaceans that are swept out of the mud by the saw (Allen 1982).

Figure 34: Freshwater Sawfish (*Pristis microdon*). Photograph - David Morgan

The Green sawfish (*Pristis zijsron*) has a similar lifecycle to that of the Freshwater sawfish described above. It is significant that all of these species are long lived (30 – 50 years) and require passage from marine to freshwater environments. The Ord River Ramsar site provides critical habitat for these threatened species, with habitat connectivity of vital importance.

3.2.9 Waterbirds

General

Waterbirds in the Australian tropics can be divided into three fairly distinct groups (Frith 1982; Scott 1997): northern species which are nomadic within the tropics, but rarely venture outside of northern Australia (though large numbers of some are thought to visit New Guinea); continental species which range over the entire continent; and international migratory species that use Australian wetlands to feed during our spring / summer but breed in NE Asia. Nomadic species can move great distances to find suitable habitat and it has been suggested that the nomadic habit of many of the Australian waterbirds evolved in response to Australia's variable climate (Scott 1997). Rainfall and inundation of wetlands and floodplains, bringing food resources are the major factors that control the movements of Australian waterbirds (Kingsford 1996) and in the tropics this coincides with the wet season (October to April).

Waterbirds exhibit a range of feeding strategies, which ultimately affect how they use wetlands. As a result of these different physiological and morphological characteristics, different species are able to use the same areas by feeding on different resources (Kingsford and Norman 2002). Bill shape and size and length of legs or capacity to dive are often related to diet, and closely related species can use different habitats but eat the same or different food. Diet requirements affect the behaviour and patterns of habitat use; for example, it is typical to see herbivorous species feeding for extended periods, as their food is harder to digest.

Although Ramsar criteria 5 and 6 relate only to waterbirds, the Ord River Floodplain Ramsar site supports a number of other birds, which contribute to the ecological character of the site. Specifically, the mangrove birds and the Zitting Cisticola, which contribute to the listing of the site under criterion 3, are considered critical components of the Ord River Floodplain Ramsar site.

Birds critical to the character of this Ramsar site have been placed into the following broad groups:

- Ducks and allies (Anatidae, Anseranatidae) – ducks,swans and magpie geese. These feed on both plant or animal material or both, and require freshwater for drinking

- Grebes (Podicipedidae) – diving waterbirds that feed mainly on animals including fish and are associated with both saline and freshwater wetlands
- Pelicans (Pelecanidae), cormorants (Phalacrocoracidae), darters (Anhingidae) – piscivorous waterbirds (fish eating) although some species will also eat invertebrates such as crabs, prawns, crayfish; typically feeding in water >1 m deep.
- Herons and egrets (Ardeidae), ibises and spoonbills (Threskiornithidae) – these mainly forage in the shallows feeding on fish, frogs/tadpoles and invertebrates.
- Cranes (Gruidae), crakes and rails (Rallidae) – forage on open water by diving (coots), or in the shallows and amongst inundated vegetation, feeding on plants and/or animals.
- Shorebirds (Scolopacidae, Recurvirostridae, Charadriidae) – forage in the shallows and/or on exposed mud for benthic and other invertebrates.
- Gulls and terns (Laridae) – feed mainly on animals, especially fish, both in the shallows and in water > 1 m deep; some are omnivorous scavengers.
- Hawks and eagles (Accipitridae) – raptors that eat fish and/or waterbirds and/or nest in wetlands.
- Mangrove birds – associated with the mangroves of the site that contribute to the significance of the site with respect to bioregional biodiversity
- Small insect eating birds – birds that are wholly dependant on wetland habitat (e.g. Zitting Cisticola; Clamorous Reed-Warbler).

Diversity and Abundance

The Ord River Floodplain Ramsar site provides a variety of food resources and habitats for wetland birds and supports a diversity of species. A total of 105 wetland bird species have been recorded within the Ramsar site (Table 8). This includes species such as Radjah Shelduck and Comb-crested Jacana, which are present throughout the year, as well as temporary residents such as migratory shorebirds that use the estuary and floodplain seasonally. This list includes 32 species that are listed under international migratory agreements CAMBA (31), JAMBA (32) and ROKAMBA (27) as well as an additional 29 Australian nomadic species that are listed under the *Environmental Biodiversity and Conservation Act 1999* (EPBC). In addition, there are a number of records for the Australian Painted Snipe (*Rostratula australis*), which is listed as vulnerable under national threatened species legislation (EPBC) (Appendix C).

It should be noted that because waterbirds are highly mobile, some with continental or international ranges of occurrence, and because many are secretive or easily overlooked within dense aggregations, lists of species recorded at a particular site are rarely complete and tend to increase over time. This is particularly true for the Ord River Floodplain, where published bird records are limited and the mangrove habitats are difficult to survey. In addition, at the time of the greatest habitat and food resources (the wet season) access to wetlands to observe and count birds is extremely difficult. It is likely that this species list and the abundance values provided below will change with further monitoring and increased records.

Table 8: Birds critical to the ecological character of the Ord River Floodplain Ramsar site.

Bird group	Typical feeding requirements	Number of species
Ducks and allies	Shallow or deeper open water foragers Vegetarian (e.g. Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	15
Grebes	Deeper open waters feeding mainly on fish	3
Pelicans, Cormorants, Darters	Deeper open waters feeding mainly on fish	6
Heron, Ibis, Spoonbills	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	16
Hawks, Eagles	Shallow or deeper open water on fish and occasionally waterbirds and carrion	3

Bird group	Typical feeding requirements	Number of species
Crakes, Rails, Water Hens, Coots	Coots in open water; others in shallow water within cover of dense emergent vegetation such as sedge. Some species vegetarian, others mainly take invertebrates, some are omnivores	8
Shorebirds	Shallow water, bare mud and salt marsh Feeding mainly on animals (invertebrates and some fish)	37
Gulls, Terns	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats.	7
Mangrove birds	Mangrove specialists[1]	12
Total		**105**

[1]Note that the mangrove birds include one rail and one heron and as such the total is 105 (not 107).

One of the reasons that the Ord River Floodplain site is listed as a Wetland of International Importance is that it regularly supports greater than 20,000 waterbirds. Due to the paucity of published bird counts this is the result of surveys conducted prior to 1990 at Parry Lagoons (Jaensch and Vervest 1990). Records of > 20,000 waterbirds include: March 1980; March 1983 and May 1986 (Jaensch and Vervest 1990) with counts strongly linked to substantial floodplain inundation. In addition, the count from this area in May 1998 (18,900 waterbirds) would equate to > 20,000 if birds from other parts of the Ramsar site were to be included.

The only other published quantitative count is from 2005, when only 6400 waterbirds were recorded (Hassell et al. 2006). However, this count was undertaken in the dry season and the wet season count from the same year (total of 1600 birds) occurred at a time when the floodplain was not inundated.

The most abundant species recorded at the Ramsar site (based on data for Parry Lagoons) include ducks; Grey Teal (6980), Plumed Whistling Duck (15,000), Hardhead (4000), Pacific Black Duck (1000) and shorebirds: Red-kneed Dotterel (3000); Black-winged Stilt (1700); Sharp-tailed Sandpiper (1500) (data from Jaensch and Vervest 1990). In addition, maximum counts for two species exceed the 1% population thresholds (Wetlands International 2006):

- Plumed Whistling Duck – maximum count 15,000 (1% = 10,000); and
- Little Curlew – maximum count 2500 (1% = 1800).

In addition due to the size, and variety of habitats and abundant waterbirds the Ramsar site, is likely to support > 1% of the population size of at least several more species. This includes the Red-Kneed Dotterel and the Sharp-tailed Sandpiper. The 1% threshold for Red-kneed Dotterel was set at 260 in Watkins (1993) but revised to a more general range class, without a 1% threshold, in WPE 4th Edition (Wetlands International 2006) due to more recent general evidence of large but uncounted numbers across inland Australia. If the 1993 estimate was applied, then the Ramsar site would be clearly of international importance for this species but the more recent publication compels a more cautious approach. Similarly, the counts for the Sharp-tailed Sandpiper are just below the 1% level and as these undoubtedly represent only a partial count of the total number present, it is likely that the Ramsar site is also significant for this species.

In the absence of survey data from regular surveys, that is, multiple visits during the year and over many years, it is difficult to apply the Ramsar concept of “regularly supports > 1% of the population” to these maximum count data. However, the Ramsar guidelines for this criterion see Text Box 1, page 25, above – permit use of sparse evidence where surveys have been sparse or erratic. Furthermore, the congregatory habits of these species and the nature of the habitat at this Ramsar site give confidence to believe that such high numbers of the abovementioned species should recur.

Spatial and temporal variability in occurrence of waterbird species is common in wetland environments and waterbirds in Australia respond to environmental conditions beyond the local or site scale (Chambers and Loyn 2006). It is difficult to determine variability based on annual surveys (Underhill and Prys-Jones 1994) and with the low number of records available for the Ord River Floodplain site, characterising variability in numbers or species composition is not possible. Total counts from Parry Lagoons for all quantitative records that could be sourced are illustrated in Figure 35 (note that few if any of these counts have been for the complete Parry Lagoons floodplain system). This suggests that the number of birds observable at the site at any given point in time is highly variable and at first glance may be indicative of a decline in total numbers. However, the number and consistency of counts is too low to draw any conclusions. Without quantitative counts conducted when the floodplain is substantially inundated, it is unlikely that a full and adequate appreciation of waterbird usage of the site will be obtained. Furthermore, large areas of the Ramsar site (marine plain swamps and saltmarsh) on either side of the Ord River to the north of the Parry system, have rarely if ever been surveyed systematically for waterbirds yet are likely to hold large numbers when inundated (R. Jaensch; Wetlands International pers. com.).

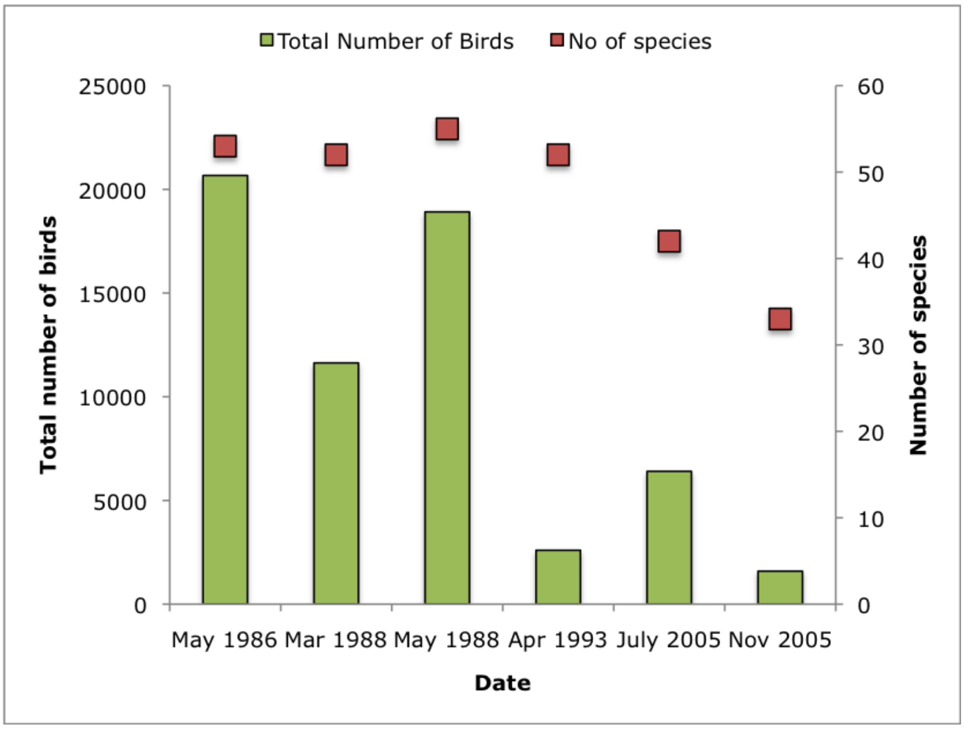


Figure 35: Total counts (bars) and number of species (points) for waterbirds at Parry Lagoons (Jaensch and Vervest 1990; Jaensch 1994 and Hassell et al 2006).

The wetland birds within the Ord River Floodplain Ramsar site utilise a variety of habitats. The locations of observations and the feeding / dietary guilds (after Jaensch 2002) are provided in Appendix C. The greatest number of wetland bird species has been observed at Parry Lagoons (75) compared to only 15 species in the Ord Estuary and False Mouths of the Ord. However, once again, the difficulty in observing and counting birds in dense mangrove communities must be taken into consideration.

The mangroves of Cambridge Gulf and the False Mouths of the Ord provide extensive habitat for a wide range of bird species. Johnstone (1990) listed 21 mangrove bird species within these areas, of which two could be considered waterbirds (Striated (Mangrove) Heron, Chestnut Rail) and a further ten terrestrial species considered totally reliant on mangrove habitat in this area (Table 9). The populations of the Black Butcher Bird and the Collared Kingfisher within the Ramsar site are considered significant due to their isolation from other populations of these species (Johnstone 1990).

Table 9: Mangrove birds recorded in the Ramsar site (Johnstone 1990)

Common Name	Species	Ecology
Bar-shouldered Dove	*Geopelia humeralis*	Favours mangroves along rivers Feeds on seeds of grasses and sedges including Sporobolus.
Black Butcherbird	*Cracticus quoyi*	Favours tall forest of Red Mangrove (Rhizophora) Feeds on invertebrates, crabs, and small fish
Lemon-breasted Flycatcher	*Microeca flavigaster*	Forages in all mangrove forest and woodland Feeds on invertebrates (mainly flying insects)
Mangrove Flycatcher	*Gerygone levigaster*	Favours open mangroves woodlands Feeds on invertebrates (mainly flying insects)
Mangrove Golden Whistler	*Pachycephala melanura*	Prefers closed canopy mangrove Feeds primarily on terrestrial invertebrates
Mangrove Grey Fan-tail	*Rhipidura phasiana*	Wide range of mangrove communities Feeds on invertebrates (mainly flying insects)
Collared Kingfisher	*Halcyon chloris*	Favours tall forest of Red Mangrove (Rhizophora) Feeds at the seaward edge of mangroves on crabs and small fish
Mangrove Robin	*Eopsaltria pulverulenta*	Only in stands of extensive Red Mangrove (Rhizophora) Feeds predominantly on ants, also other invertebrates
White-breasted Whistler	*Pachycephala laniodes*	Favours woodlands of Grey mangrove (Avicennia) Feeds on invertebrates such as beetles and crabs
White-breasted wood Swallow	*Artamus leucorynchus*	Favours edges and breaks in mangroves, roosts in emergent trees Feeds on invertebrates (mainly flying insects)

The Ord River Floodplain site is the only known site in Western Australia where Zitting Cisticolas (*Cisticola iuncidis*) occur. This small warbler is common throughout Queensland and the Northern Territory, but the grasslands of Parry Lagoons represent the western extent of their range (Birds Australia). This species is also known to breed at the site (see below).

The Ord River Floodplain site also supports the Australian Painted Snipe (*Rostratula australis*), which is listed under the EPBC Act as vulnerable and under the Western Australian threatened species legislation (Wildlife Conservation Act 1950) as rare or likely to become extinct. This wading species of bird is highly cryptic and rarely gregarious. It feeds on mudflats or in shallow waters on invertebrates and is considered to be nomadic, although some populations may be sedentary (Lane and Rogers 2000). Within the Ord River Floodplain site it has been recorded at Parry Lagoons in May 1986 and again in May 1988 (Jaensch and Vervest 1990) in drying swamps with samphire and tussock grass, both of which are extensive. Given the usual seasonal drying-out of this habitat, it can be assumed to be a visitor but due to the paucity of bird records it is not possible at this time to confirm if this species is a resident or a regular visitor to the site. Most records of Australian Painted Snipe from northern Australia are from summer-autumn, very few are from spring.

<u>Breeding</u>

The Ord River Floodplain site, and Parry Lagoons in particular is considered to be regionally significant for waterbird breeding. In total 16 species have been recorded breeding within the site (Appendix C). This includes species 13 species reported by Jaensch and Vervest (1990) and Jaensch (1994) as breeding in Parry Lagoons from 1980 to 1993 and 3 bird species reported by Johnstone (1990) breeding in the mangroves of the Ord Estuary. The number of waterbirds recorded breeding is almost certainly incomplete, given the extensive and diverse nesting habitat (from wooded swamps to open marshes, with plenty of dense cover) and an eventual comprehensive list of at least 30 if not many more breeding waterbirds can be expected from further survey work in the late mid-wet season

Given the paucity of data from the site and the difficulties with observing bird breeding behaviour in mangroves and during the wet season, it is likely that this list will increase over time.

3.2.10 Crocodiles

The Ord River Floodplain Ramsar site supports significant populations of two species of crocodile:

- Saltwater Crocodile (*Crocodylus porosus*); and
- Freshwater Crocodile (*Crocodylus johnstoni*)

The Saltwater Crocodile and Freshwater Crocodile are the only crocodilian species in Australia. While the Saltwater Crocodile occurs (decreasingly) throughout South East Asia and New Guinea, the Freshwater Crocodile is endemic to Australia (Webb and Manolis 1989). Both species occur in the tropics commonly in separate habitats but with broad overlap. The Freshwater Crocodile prefers upstream freshwater areas and is found in rivers and billabongs. In contrast the Saltwater Crocodile is found mostly in downstream estuarine river reaches (Webb et al. 1983) but ranging at times far upriver. The Ord River Floodplain Ramsar site is an area where the two ranges overlap with both species recorded at Parry Lagoons (CALM 2003).

Although young males of both species may be nomadic (Tucker 1997; Kay 2004) adults rarely move outside their home river system. Freshwater crocodiles, in particular are static, moving < 2km (Tucker 1997) while Saltwater Crocodiles may move further (up to 60 km for females and 90 km for males) in the breeding season (Kay 2004). Both species are known to breed within the Ramsar site. Some of the characteristics of the ecology of the two species are provided in Table 10.

Table 10: Characteristics of Saltwater and Freshwater Crocodiles (Webb and Manolis 1989; Webb et al. 1983).

Characteristic	Saltwater Crocodile	Freshwater Crocodile
Adult size	5 – 6m	2 - 3 m
Diet	Crustaceans, birds, lizards, turtles, mammals	Fish, crustaceans and small invertebrates
Physical habitat	Mainly coastal areas and estuaries, but ventures farther inland during the wet season when food is plentiful	Mainly rivers and freshwater billabongs. In the dry season they remain in isolated pools and do not feed again until the wet season
Breeding	Female makes a nest mound of vegetation and mud on river banks and in dense freshwater swamps and guards this from predators. Upon hatching, she will aid young by digging out the mound.	Females nest in holes in sandy embankments (usually July – August). There is no parental guarding of nest, but adults will return on hatching to aid young.

Populations of these two species of crocodile in the lower Ord River and Cambridge Gulf have been monitored for the last decade (CALM 2003). There are substantially more Freshwater Crocodiles in the lower Ord River (mean of 400) than Saltwater crocodiles (mean of 80), which would be expected based on their size and trophic requirements. Populations for both species show some inter-annual variability (Figure 36 and Figure 37). Populations of Saltwater crocodiles have been increasing in the Ord River at a rate of 2 - 4 % per annum since annual monitoring commenced in 1992 (Wildlife Management International 2007). The distribution of sizes is indicative of a breeding environment, with higher numbers of small to medium crocodiles, than very large individuals.

There is considerable variability between years for Freshwater crocodile numbers. However, environmental (e.g. temperature, water levels, wind) and other factors (e.g. wariness) influence sightability during surveys and the degree to which animals may move between areas. As such, the population of this species is considered stable in the Ord River (Wildlife Management International 2007).

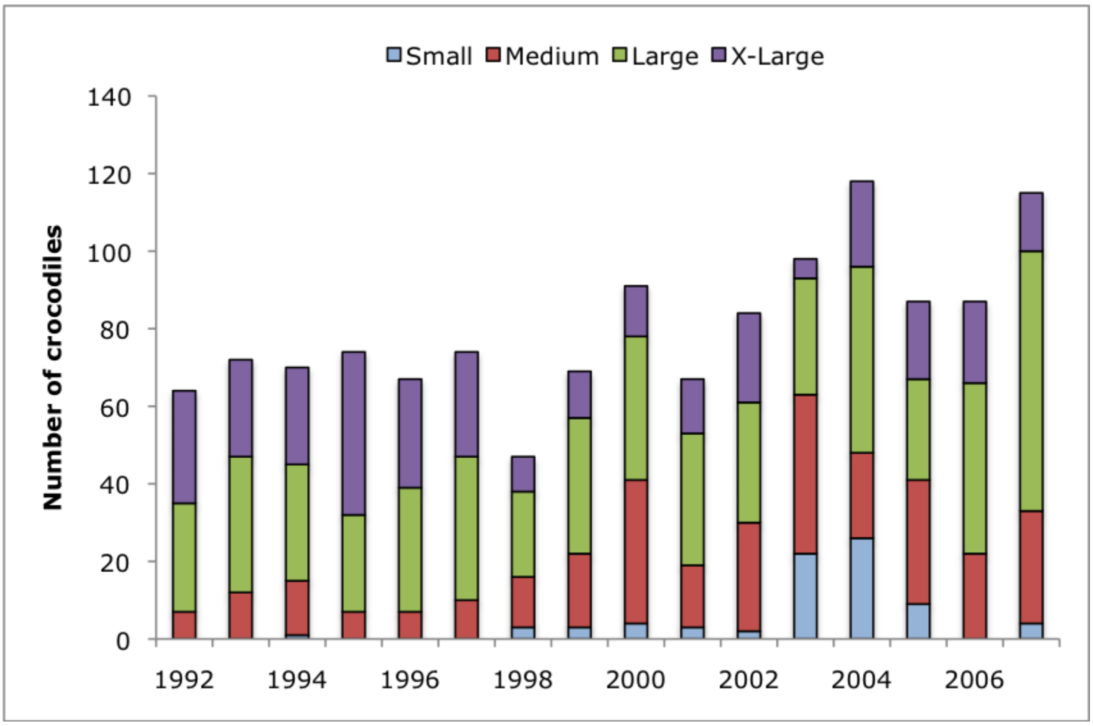


Figure 36: Population estimates for Saltwater Crocodile in the lower Ord River based on helicopter survey data (data from CALM 2003). Size classes: small (0.6 – 1.2 m); medium (1.2 – 2.2 m); large (2.2 – 3.5 m) and extra large (> 3.5 m).

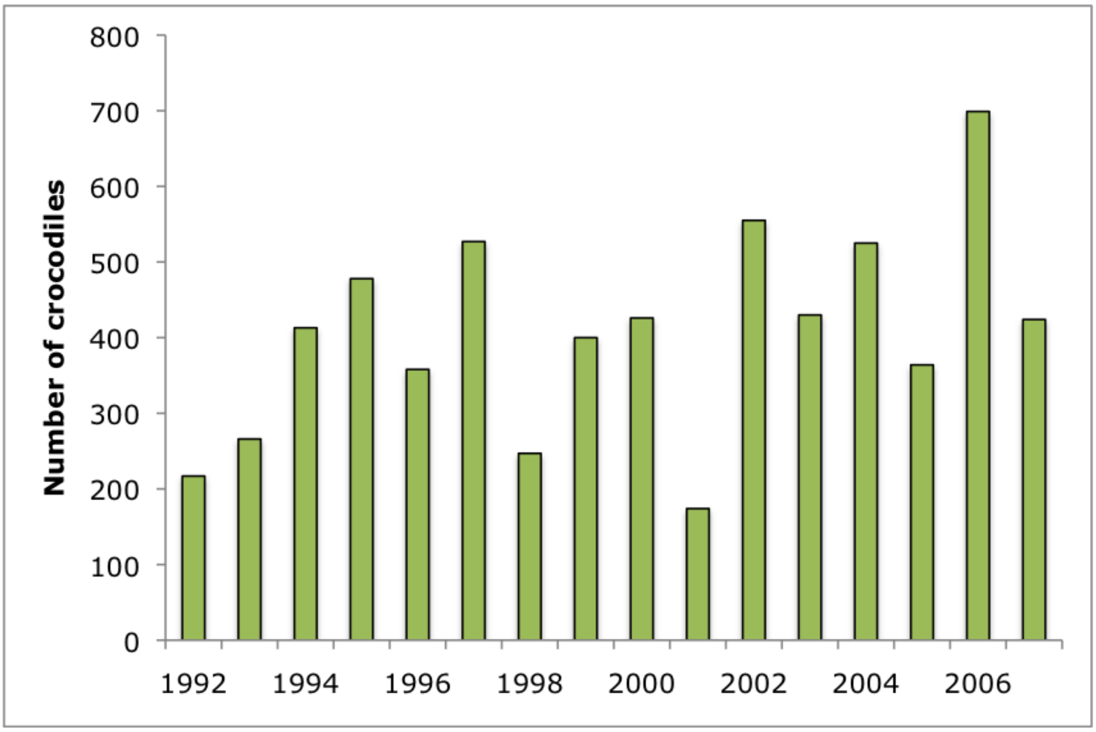


Figure 37: Population estimates for Freshwater Crocodiles in the lower Ord River, based on helicopter surveys (data from CALM 2003)

3.3 Benefits and services

3.3.1 Overview of benefits and services

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

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

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

The ecosystem benefits and services of the Ord River Floodplain Ramsar site are outlined in Table 11.

Table 11: Ecosystem services and benefits provided by the Ord Floodplain Ramsar site.

Category	Description
Provisioning services	
Wetland products	Commercial fisheries for a number of species of fish, as well as prawns and crabs
Genetic resources	Plausible, but as yet no documented uses
Regulating services	
Erosion control	The mangroves of the estuary protect the coast from erosion
Climate regulation	Data deficient – plausible but not documented.
Cultural services	
Recreation and tourism	Parry Lagoons and the Ord River Estuary are important for tourism: bird watching, crocodile watching and recreational fishing.
	Passive recreational activities such as bird watching occur both in the estuarine and wetland areas within the site, although access is unreliable.
Spiritual and inspirational	The wetlands and estuarine areas are spiritually significant for the Miriuwung, Gajerrong and contain a number of specific culturally significant sites.
	The site has inspirational, aesthetic and existence values at regional, state and national levels.
	The site contains a number of non-indigenous historical sites
Scientific and educational	The Lower Ord River and Estuary have been the focus of a decade long CSIRO investigation.
Supporting services	
Biodiversity	As evidenced by the listing of the Ord River Floodplain site as a wetland of international importance. The system provides a wide range of biodiversity related ecological services critical for the ecological character of the site including: • Hydrological connectivity • Supporting critical life stages • Supporting threatened species • Supporting waterbird populations • Supporting fish populations
Nutrient cycling	The Ord River Floodplain plays a role in nutrient cycling, but its significance beyond the site is not known
	Carbon sequestration – data deficient but plausible

Similar to the process for identifying critical components and processes outlined in section 3.2.1, the critical ecosystem services and benefits have been identified in relation to the reasons the site was listed as a wetland of international significance (see section 3.3.3 below). However, as there are no criteria for listing that relate to cultural and economic services, and the site is culturally significant to both indigenous and non-indigenous communities, a brief description of the cultural and economic services provided by the site is provided in section 3.3.2.

3.3.2 Cultural and economic services and benefits

Commercial Fishing

Cambridge Gulf is an important gillnet commercial fishery for both Barramundi and Threadfin Salmon (Fisheries WA 2007). In addition, the mangrove communities provide an important nursery habitat for red-legged and banana prawns, supporting the major northern prawn commercial fishery (Loneragan et al. 1997). The Ord River is also a popular recreational fishery for Barramundi and Black Bream. The nearby town of Wyndham supports a small commercial mud crab fishery. It is not known whether this extends into the Ramsar site.

Recreation and Tourism

The Lower Ord River and the False Mouths of the Ord are popular destinations for locals and visitors for recreational fishing, crabbing and boating. The Parry Lagoons Nature Reserve is also important for passive recreational activities such as bird watching and bush walking. Nature based commercial tourism is an important source of income for the region (CALM 1998).

Historical sites

There are two main historical sites[6] within the Ord River Floodplain Ramsar site that are of local significance and act as tourist attractions. The sites are located within the Parry Lagoons area:

Old Halls Creek Road: A section of the original road from Wyndham 300km to Halls Creek that was constructed in 1894 during the Gold Rush. The hand-laid stones that line the edges are still intact along some stretches. The road is still open for through traffic (4WD only).

Telegraph Hill: Contains the ruins of a wireless station constructed in 1914 by the navy. When in operation, the station was used to guide ships into the Port of Wyndham. After World War 1 the building was re-located to Wyndham and all that remains on the site is the foundations.

Indigenous Values

The Ord River Floodplain Ramsar site lies within the boundaries of six indigenous language groups: Miriuwung, Gajerrong, Dulbung, Guluwaring, Djangade and Baimbarr. The Ramsar site was part of a Native Title Claim by the Miriuwung and Gajerrong people, which commenced in the 1990s and was ratified in 2003. The Ord Final Agreement (2007) provides for co-management by the Miriuwung Gajerrong and DEC over 8 reserves in the Kimberley region including the Ord River Nature Reserve and Parry Lagoons Nature Reserve which comprise part of the Ramsar site. In addition, the area to the west of the Ord River, including a portion of the Ramsar site is subject to a native title claim by the Balangarra people. This is still before the Native Title Tribunal. The Ord River Floodplain is of great cultural significance to local indigenous people (Text Box 2) and there are a significant number of Aboriginal sites within the Ord River Floodplain Ramsar site including (CALM 1998):

- Burial sites
- Artefact Scatters
- Mythological Sites
- Quarries
- Paintings; and
- Ceremonial Sites

[6] Note that the 2003 RIS also mentions “Goose Hill Station” but this is to be excised from the Ramsar boundary and given freehold status to the local indigenous community.

Our ancestors created Miriuwung and Gajerrong country in the Ngarranggarni, the Dreaming. At the dawn of time our land was covered by the waters of an enormous flood. The waters eventually receded, placing some of the Dreamings, the ancestral beings, on the landscape. Other Dreamings roamed the land, creating creeks, billabongs, hills and escarpments on tracks through our country. They created the different soils, plants and animals, and all the seasons of our country, ying-geng (the wet season), gerloong (big storm), barndinyirriny (dry season) and wan-gang (cold weather). During these sagas of journey and creation, our ancestral beings, who were simultaneously human and animal, also established the all-encompassing moral and practical rules by which succeeding generations of Aboriginal people have lived for thousands of years—our Law, languages and ceremonies.

Our Dreamings became different features of our landscape, and are still present in our country today. Every part of our country has a song. Our Dreamings make connections between our people, plants, animals and parts of our country like water holes, creeks, hills, mountains and tracks through our country. Yarndungarll (dingo) lemoogeng (blue-tongue lizard), diwanang and jalareng (wedge-tailed eagle and egret), bilbiljing (grass-hopper) goorrgoorrjing (tawny frog-mouth owl), and gerdan (frill-necked lizard) are some of the Dreaming stories and places on our country

Text Box 2: Miriuwung and Gajerrong culture (Hill, R. and Miriuwung-Gajerrong Peoples. 2007).

3.3.3 Identifying critical ecosystem services and benefits

The critical ecologically based ecosystem services and benefits of a Ramsar site have been identified based on the reasons for listing as a wetland of international importance (Table 12). The descriptions of these identified critical ecological services integrate the components and processes that contribute to the wetland providing the services. Conceptually, it is the components and processes and the interactions between them that characterise each of the critical ecological services. Each of the identified critical ecological services is described below.

Table 12: Critical ecological services, the Ramsar criteria they contribute to and the components and processes responsible for creating them.

Critical Ecological Service	Ramsar Criteria	Components & Processes Creating the Service
Supports diverse physical habitats	1. *Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region* 3. *Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region*	The interactions between hydrology and geomorphology that provide a physical template for diverse vegetation and physical wetland habitats.
Supports Threatened Species	*2. Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.*	The habitat (physical and biological) provided for threatened species
Supports Critical Life Stages	4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*	The habitat (physical and biological) provided to support migration and breeding
Supports abundant and diverse waterbirds	5. *Regularly supports 20,000 or more waterbirds* 6. *Regularly supports > 1% of the population of one or more species of waterbird*	The habitat (physical and biological) provided to support waterbirds
Supports diverse fish populations	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.*	The habitat (physical and biological) provided to support fish.

3.3.4 Supports diverse physical habitat types

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

- Mudflats (intertidal and freshwater);
- Mangroves;
- Grasslands and sedges;
- Aquatic vegetation; and
- Riparian woodland.

This diversity of habitat is brought about by the interactions between geomorphology, hydrology and vegetation. On the low relief plains of the Parry Lagoons, flows down Parry Creek (and more rarely the Ord River) spill over their banks during the wet season to inundate large areas of the floodplain. The interaction between the topography, soils and hydrology results in a mosaic of water regimes with different depths, and durations of inundation. Water regime is the single biggest determinant of wetland vegetation, with different groups of species having different morphological adaptations to patterns of inundation. Most commonly, it is a plants ability to adapt to low oxygen in the soil following inundation that determines its optimum water regime. Brock and Cassanova (1997) classified plants into functional groups based on water regime and adaption to flooding (Figure 38).

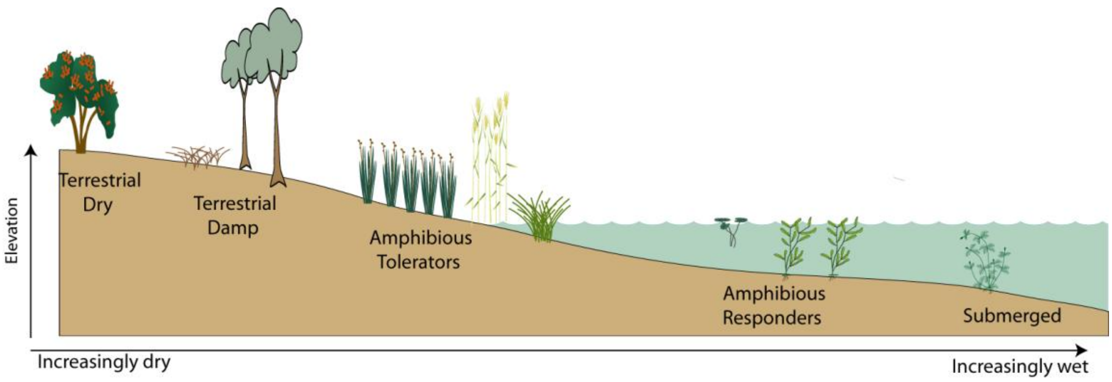


Figure 38: Functional plant types (from Brock and Cassanova 1997).

Mangroves, riparian woodland species and the grasslands (dominated by Australian Wild Rice and Beetle Grass) and the sedges can all be described as amphibious tolerators. These are species that thrive under periodic inundation, but have no morphological change in response to flooding. The Sesbania Pea, however, can be considered an amphibious responder as it has been demonstrated to morphologically change is root system to increase oxygen uptake in response to flooding (Shiba and Daimon 2003). The amphibious groups of plants occur on the floodplain where inundation is intermittent or seasonal. In areas of more permanent inundation, such as the waterholes, or areas on the floodplain of lower relief that hold water for longer periods, amphibious responders such as water lilies and submerged species are found. Finally, in the claypan areas of the floodplain, seasonal mudflats form. A combination of a number of factors may contribute to the lack of colonisation of these by plant communities including the rate of water rise and fall, the suspension of fine clays resulting in high turbidity (and suppression of photosynthesis) and / or soil characteristics.

In the intertidal areas of the estuary, water regime in the form of tidal inundation affects the zonation of mangrove, samphire species and intertidal mudflats (see section 3.2.6). Similarly, freshwater flows down the Ord River, interacting with the tide affect the salinity regime, which influences mangrove species composition and extent.

The interaction between these components (hydrology, geomorphology and vegetation) results in a diversity of habitat types across the Ord River Floodplain. The site contains saline intertidal and freshwater non-tidal ecosystems, seasonally inundated floodplains, marine plains and tidal creeks all of which contribute to a complex and diverse system that is variable both spatially and temporally.

3.3.5 Supports threatened species

The Ord River Floodplain Ramsar site supports one bird and three fish species that are listed as vulnerable or endangered under national legislation (EPBC Act). A combination of components and processes within the site combine to provide the conditions and habitat to support these species and provide this service. The ecological requirements of these threatened species are poorly understood, and a summary of existing knowledge for each of the species is provide in Table 13.

Table 13: Summary of habitat and ecology of threatened species supported by the Ord River Floodplain Ramsar site.

Threatened Species	Habitat / Ecology
Australian Painted Snipe (*Rostratula australis*)	Most commonly observed in freshwater, shallow inundated wetlands with areas of grasslands or dense low vegetation (Lane and Rogers 2000). Forages at night on mudflats and shallow water, feeding on invertebrates (e.g. worms, snails) and seeds. Rests in the day under the cover of low vegetation such as grasslands or sedges (Marchant et al. 1994). Possibly nomadic or migratory, but movements are not well understood (Lane and Rogers 2000).
Freshwater Sawfish (*Pristis microdon*)	Breed in the wet season in rivers (freshwater) Juveniles spend first 3 – 4 years in freshwater Adults move to marine environments (Peverell 2005; Thorburn et al. 2007)
Green Sawfish (*Pristis zijsron*)	Similar habitat and life-cycle to the Freshwater Sawfish
Northern River Shark (*Glypis sp. C*)	High turbidity tidal rivers and estuaries Breed in the wet season in river mouths and estuaries Juveniles migrate upstream Adults move to marine environments (Thorburn and Morgan 2004)

The key components and processes and their interactions that support the Australian Painted Snipe are illustrated in Figure 39. Central to the provision of this service is the seasonal inundation of the Parry Lagoon floodplain with fresh water from either Parry Creek or, less frequently, the Ord River. This supports the grassland and sedge communities in which the snipe can find cover during the day. In addition, the inflow of water onto the floodplain and claypan areas results in the release of nutrients from the sediment and dead plant material, starting the high productivity cycle that is characteristic of temporary wetland systems (Boulton and Brock, 1999). This in turn results in a “boom” in macroinvertebrates, providing food for the snipe.

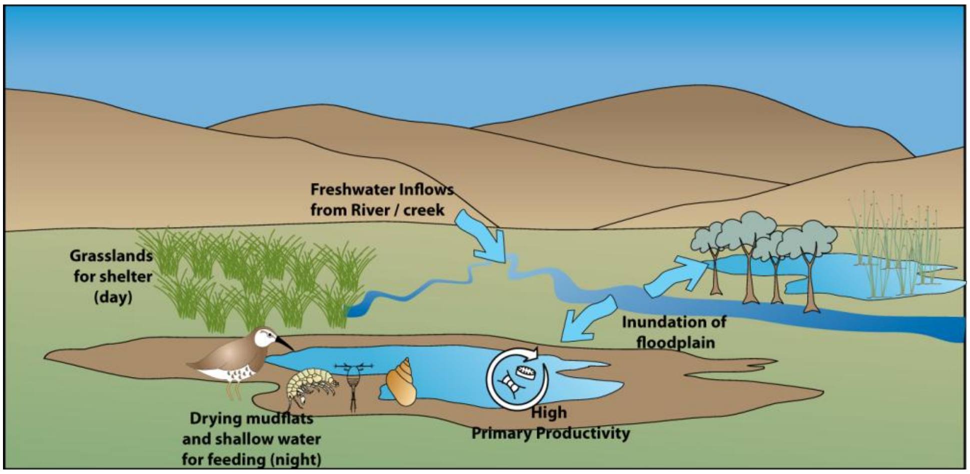


Figure 39: Components and processes contributing to the support of the Australian Painted Snipe.

The critical component / process that supports the three threatened fish species (Freshwater Sawfish, Green Sawfish and Northern River Shark) is longitudinal hydrological connectivity between the Ord River and estuary. All three of these species are thought to be diadromous, migrating between freshwater river environments to the ocean during parts of their lifecycles. Although the Diversion Dam upstream of the Ramsar site acts as a barrier to fish passage, there are freshwater, river environments upstream of the Ramsar site where these species have been recorded. To migrate between these freshwater areas to the ocean, requires passage through the Ramsar site. As such it is essential that there are sufficient flows down the Ord River to maintain this hydrological connection and periodic flushing flows to remove the sediment build up in the estuary mouth, which could potentially limit fish passage opportunities.

3.3.6 Supports critical life stages

The Ord River Floodplain Ramsar site supports the critical life stages of migration (for fish and waterbirds) and breeding (for fish and birds). Each of these is considered separately below.

Migratory waterbirds

Waterbirds at the Ord River Ramsar site can be divided into three categories: those that rarely leave the tropics, Australian nomadic species that range over the continent and international migratory shorebirds (Frith 1982). Migratory shorebirds in Australia are a part of the East Asian-Australian Flyway. They migrate from breeding grounds in NE Asia and Alaska to non-breeding grounds in Australia and New Zealand, covering the journey of 10,000 km twice in a single year. The preferred habitat for a number of migratory shorebirds (including some supported by the Ord River Floodplain Ramsar site have been described (Table 14).

Table 14: Habitat preferences for some of the migratory shorebirds supported by the Ord River Floodplain Ramsar site (from DEW 2005).

Shorebird	Breeding Area	Preferred Habitat in Australia
Common Sandpiper	Eastern Russia	Wide variety of inland and coastal wetlands - varying levels of salinity - muddy margins or rocky shores
Ruddy Turnstone	Northern Siberia, Alaska	Wide variety of habitats - generally mudflats or rocky coastline – not normally on non-tidal waters
Red-necked Stint	Northern Siberia, Alaska	Mostly coastal sheltered inlets and estuaries with intertidal mudflats - occasionally on ocean beaches, commonly on inland lakes
Great Knot	Northern Siberia	Coastal habitats, intertidal mudflats, estuaries, lagoons and sandflats
Greater Sand	Siberia	Coastal wetlands, intertidal mudflats or sandflats, sheltered

Shorebird	Breeding Area	Preferred Habitat in Australia
Plover		sandy beaches
Red-capped Plover	Mongolia, China	Inland - grasslands, roost on beaches or muddy margins of terrestrial wetlands
Swinhoe's Snipe	Central Siberia, Mongolia	Freshwater wetlands, usually grass/sedge swamps or damp to wet grasslands
Oriental Pratincole	China, India	Open country often near water, grassy flats and mudflats but primarily an aerial feeder
Grey-tailed Tattler	Siberia	Sheltered coasts with reef or rock platforms or intertidal mudflats
Bar-tailed Godwit	Northern Russia, Alaska	Mainly coastal, usually sheltered bays, estuaries and lagoons with large intertidal mudflats or sandflats
Black-tailed Godwit	Russia, China	Mainly coastal, usually sheltered bays, estuaries and lagoons with large intertidal mudflats or sandflats but often also found in freshwater swamps in small numbers
Little Curlew	Siberia	Coastal plains, grasslands, often recreational areas; may forage in dry habitat, but congregate at freshwater eg. Shallow inland pools
Whimbrel	Siberia, Alaska	Intertidal coastal mudflats, river deltas and mangroves, occasionally sandy beaches
Ruff	Russia	Usually non-tidal wetlands with exposed mudflats at edges
Pacific Golden Plover	Northern Siberia, Alaska	Mainly coastal, beaches, mudflats and sandflats and other open areas such as recreational playing fields
Grey Plover	Arctic tundras, Siberia, Alaska	Coastal, intertidal mudflats, sandflats, sandy beaches, rocky coastline
Wood Sandpiper	China, Siberia	Freshwater wetlands, usually with areas of short vegetation (not normally found on bare open water bodies)
Common Greenshank	Arctic circle, Siberia	Wide variety of inland and sheltered coastal wetlands - mudflats, saltmarshes, mangroves
Marsh Sandpiper	Siberia	Coastal - Permanent or ephemeral wetlands of varying degrees of salinity, commonly also inland in non-tidal wetlands, both marshy and bare
Terek Sandpiper	Russia	Intertidal coastal, - mainly saline mudflats, lagoons and sandbanks

The information in Table 14, together with that on feeding and dietary guilds for shorebirds (Appendix C) indicates that the majority of these birds are reliant on shallow water or exposed mud areas, feeding mostly on small animals such as invertebrates within these habitats. It is the hydrology and geomorphology of the system that are the critical components in providing the habitat requirements for these shorebirds. Inundation of the claypans and shallow grasslands of the floodplain at Parry Lagoon, as well as the intertidal areas around the Ord River estuary and the False Mouths of the Ord is critical to providing both physical habitat as well as driving the high productivity required to support migratory shorebirds. The floodplains of Parry Lagoons support large numbers of migratory shorebirds and it is perhaps the combination of seasonal inundation followed by rapid drawdown that provides the mud flat feeding areas that supports these species.

Fish migration
The Ord River Floodplain Ramsar site supports 17 species of fish have diadromous life cycles (Appendix B). That is, they migrate between fresh water and marine environments during some time in their lives. The majority of these are catadromous, spending their adult life in freshwater and migrating to the ocean to breed, although there are a number of species (including the threatened Freshwater Sawfish, Green Sawfish and Northern River Shark) that are anadromous.

As described above in section 3.3.5, it is longitudinal hydrological connectivity that is critical in the provision of this service, connecting upstream freshwater habitats with those in the estuary and ocean.

Waterbird Breeding

The Ord River Floodplain Ramsar site supports breeding of at least 16 species of birds (and more likely a larger number given that surveys are rarely done during breeding the breeding season). The species recorded breeding at the site utilise a range of different habitats within the system (Table 15). Again it is the hydrology of the Parry Lagoon system, which is the driving force in supporting this ecosystem service as the majority of bird species recorded breeding in the Ramsar site nest in inundated vegetation. In terms of the mangrove species, inundation is provided via the tidal cycle. However, most species have been recorded breeding at Parry Lagoons in inundated grass, sedge or woodland communities. Inundation of these vegetation communities may act as a stimulus for breeding to commence, and for successful breeding for a number of species (e.g. egrets) floodwaters must persist until offspring have fledged. Inundation of the floodplain also stimulates the high productivity phase of these temporary wetland areas, providing sufficient food resources to breed and raise chicks.

Table 15: Requirements of waterbirds recorded breeding in the Ord River Floodplain Ramsar site (adapted from Jaensch 2002; Marchant et al 1994; Johnstone 1990).

Species	Breeding behaviour
Magpie Goose	In emergent sedge or reed vegetation over water during the late wet season Breeds in loose colonies or as dispersed pairs. Goslings fledge in approximately 10 weeks.
Australasian Grebe	Nests in deep open water building a nest of floating aquatic vegetation Dispersed breeding pairs. Young leave nest soon after hatching, but are dependant on adults for approximately 8 weeks.
Darter	Nests in horizontal branches and forks of trees (Eucalyptus, Melaleuca, Barringtonia, Guttapercha) in or over water. Breeds as dispersed pairs or in small colonies. Requires water to remain until nestlings are independent. Hatchlings leave nest after 4 weeks, first flight at approximately 8 weeks.
Royal Spoonbill	Nests in wooded swamps or Typha beds. Breeds in colonies Requires inundation until young fledge.
Australian White Ibis	Nests in a wide variety of habitats including wooded swamps, mangroves and dense emergent vegetation. Breeds in colonies Requires inundation until young fledge. Young leave nests after 48 days but dependent on parents for several weeks
Intermediate Egret	Nests high (up to 15 m) in a tree above standing water. Invariably nests in colonies, often with other colonial species, both in mangroves and wooded swamps Young leave the nest approximately 164 days after hatching
Little Egret	Nests high in a tree (freshwater swamp or mangrove) above standing water in the wet season. Invariably nests in colonies, often with other colonial species. Young fledge in approximately 5 weeks
Chestnut Rail	Nests in Mangrove trees approximately 1 – 2 m above the ground in nests constructed of sticks. Chicks leave the nest soon after hatching and fledge some 5 – 6 weeks later
Black-tailed Native-hen	Nests over water in shrubs or sturdy tussocks; breeds as dispersed pairs or in loose clusters. Young leave nest soon after hatching, but are dependent on adults for some time after
Eurasian Coot	Nests in or over water in vegetation (shrubs, trees, sedges) building a supported nest at the water line or a partly floating mound. Dispersed pairs or loose clusters. Young leave nest soon after hatching, but are dependent on adults for approximately 5 weeks.
Purple Swamphen	Nest in clumps or beds of reeds, sedge or *Typha*, over water. Dispersed pairs Young leave the nest after a few days, but are fed by adults for 2 months.
Comb-crested Jacana	Males build sparse nests of soft plant material in floating leaves of water lilies. Breeds as dispersed pairs. Males incubate eggs and protect hatchlings. Incubation approximately 4 weeks.

Species	Breeding behaviour
Black Butcherbird	Nests high (>5m) in dense mangrove trees with nest constructed of sticks lined with grasses
Collared Kingfisher	Nests in hollow logs within Mangrove trees (Avicennia) or by building a hole in the ground. Hatchlings are naked (no down) and take a period of weeks to develop adult feathers. During this time they are extremely vulnerable to disturbance
Yellow Chat	Nesting in robust grass tussocks, tall sedges or samphire shrublands, in or beside seasonal wetlands; nests as dispersed pairs.
Ziting Cisticola	Weave nests in short tussock grasses and/or sedges beside or in seasonal wetlands; dispersed pairs.

Fish breeding

The number of fish that spawn within the Ord River Floodplain Ramsar site is not known. However a range of reproductive strategies are present in the fish that have been recorded from the site. This includes species that migrate between fresh and marine waters (as described above) as well as freshwater specialists for which the inundated floodplain may be important. Hydrological connectivity is a critical process in provision of this service in the Ramsar site. As described above, longitudinal connectivity (river to estuary to ocean) is important, but equally important in this case is lateral connectivity (river to inundated floodplain). Floodplain inundation is important for many species of fish because the flooding of the lateral plains increases the area of food rich habitat and shelter from predators and provides ideal sites for young fish to develop (Welcome and Halls, 2003). The contribution of the floodplain of Parry Lagoons to fish productivity in the estuary has not been systematically assessed but is likely to be substantial.

3.3.7 Supports abundant and diverse waterbirds

The Parry Lagoons portion of the Ord River Floodplain Ramsar site supports large numbers of waterbirds (> 20,000) and more than one percent of the flyway population of at least two species of waterbird (Plumed Whistling Duck and Little Curlew). The diversity and large extent of habitats within the Parry Lagoons and the high productivity stimulated by floodplain inundation are the key factors in the provision of this service. Once again, hydrology and in particular floodplain inundation is a driving factor.

Parry Lagoons (as described in 3.3.6 above) contains areas of deeper, more permanent water, claypans (which become mudflats following inundation) grass- sedge wetlands and wooded wetlands. All of these different habitats provide for a diversity of waterbirds, with a range of feeding strategies and diets (Appendix C).

The Plumed Whistling Ducks rest during the day on open water bodies or at the margins of wetlands, and feed at night in grassy wetlands, predominantly on vegetation (Marchant et al. 1994). At Parry Lagoons resting and feeding habitats are in close proximity with open water in permanent wetlands as well as extensive grassland communities.

The Little Curlew is a migratory shorebird that occurs in Australia in the non-breeding season. It is most closely associated with floodplain grasslands and in these environments seeds of Wild Rice (Oryza) can contribute significantly to its diet (Bellio et al. 2004). The grasslands of Parry Lagoons, which are dominated by Wild Rice, provide a large feeding habitat for this species.

3.3.8 Supports diverse fish populations

The Ord River Floodplain Ramsar site supports a diverse community of over 50 species of fish from 32 families. This includes freshwater species, marine opportunists, estuarine specialists as well as species that migrate between the different habitats. The components and processes that are primarily responsible for providing this service are hydrological connectivity (longitudinal and lateral), inundation of the floodplain (stimulating productivity) and the tidal regime, resulting in a well mixed and oxygenated aquatic environment.

4. How the Ord River Floodplain System Works: Interactions between components, processes & services

4.1 Primary determinants of ecological character

Harris (1999) argued that it is not possible to understand complex systems such as wetlands, simply by looking at their component parts, because we have to understand not only the parts themselves, but also the interactions between them. The interactions between ecological components and processes within any wetland system are too complex to unravel by looking at the micro-level. What is required is to identify the critical components and processes (see section 3 above) and the basic rules that link these together.

However, attempting to identify and characterise all of the interactions between the critical components and process described in section 3 above, would still be excessively complex. Conceptualisation of the system needs to be simplified further, focussing on the drivers or "primary determinants" of ecological character.

Phillips and Muller (2006) introduced the concept of "primary determinants" in the context of ecological character descriptions of Ramsar sites. Primary determinants are the components and processes that are central to maintaining the ecological character of a site. Phillips and Muller (2006) contested that if the primary determinants are maintained within certain limits, then it can be expected that the system as a whole, and its individual components will also be maintained. Hale and Butcher (2008) developed this concept further by identifying primary determinants as the components and processes of the site that are crucial to the maintenance of all the components and processes for which the site has been listed. Here this concept is applied with the addition of the critical ecological services (Figure 40).

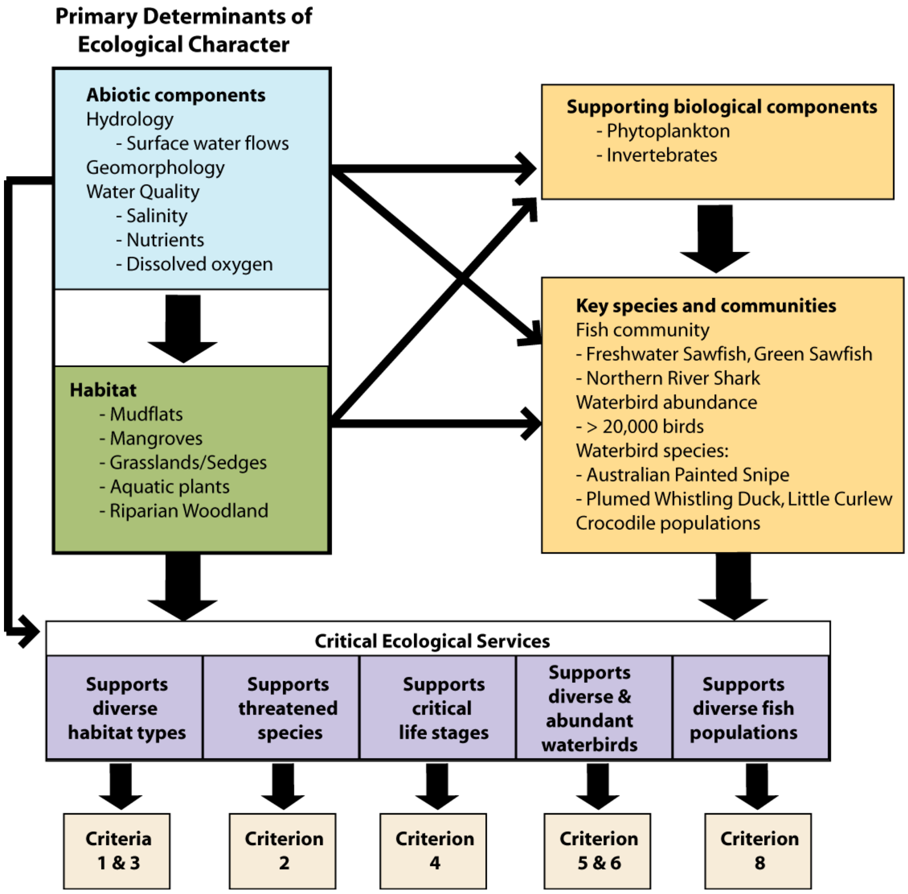


Figure 40: Primary determinants of ecological character at the Ord River Floodplain Ramsar site (adapted from Hale and Butcher 2008).

The key species and communities that are directly responsible for the Ord River Floodplain site being recognised as a wetland of international importance are:

- Vegetation
  - Mangroves (extent and diversity)
  - Grasslands and sedges
  - Aquatic vegetation
  - Riparian woodland
- Fish community:
  - 50 species of fish
  - Species listed under the EPBC Act as endangered (Northern River Shark) and vulnerable (Freshwater Sawfish and Green Sawfish)
  - Migratory route for 17 diadromous species;
- Waterbird abundance:
  - regularly exceeds 20,000 individuals
  - two species for which the site maintains > 1% of the flyway population (Plumed Whistling Duck and Little Curlew)
- Waterbird species
  - Australian Painted Snipe listed as vulnerable under the EPBC Act
  - Migratory and breeding waterbird species
- Crocodile populations

These key species and communities are dependent on a range of biotic and abiotic components and processes within the Ord River Floodplain Ramsar site. This includes habitat and food requirements as well as tolerances to abiotic factors such as salinity. Although the interactions between components and processes are complex, the conceptual models provided in the following section together with the descriptions of critical ecological services (section 3.3), highlight some of the primary determinants of ecological character for the Ord River Floodplain site. These are:

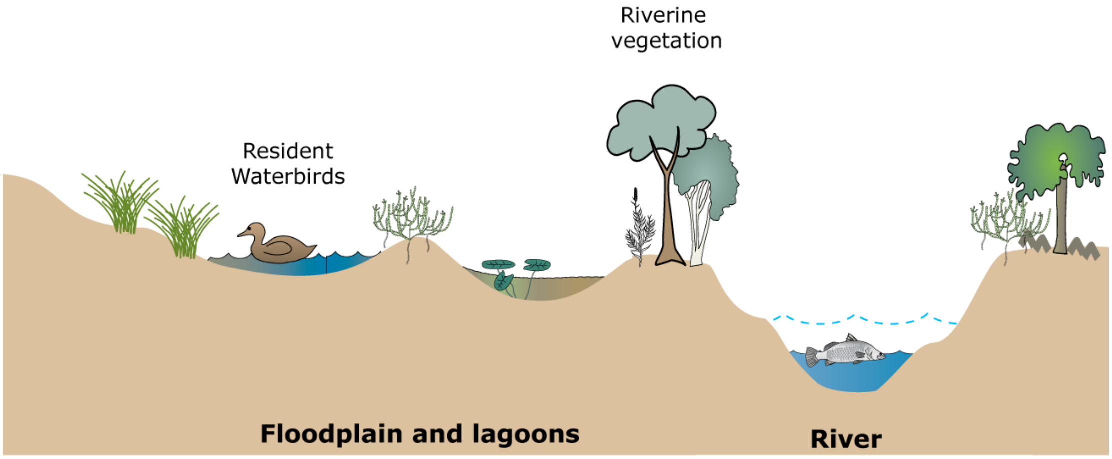
- Abiotic components
  - Hydrology (surface water flows)
  - Geomorphology
  - Salinity
  - Nutrients
  - Toxicants
  - Turbidity

- Habitat
  - Mudflats
  - Mangroves
  - Grasslands and sedges
  - Aquatic vegetation
  - Riparian woodland

4.2 Abiotic components

In general the abiotic components and processes of wetland ecosystems determine the ecological signature of wetlands. There is a growing recognition that hydrology is the key driver of river and floodplain ecology (Poff et al. 1997). This is evidenced from the descriptions of critical ecological services (section 3.3) in which hydrology was identified as a critical component and process in providing all five of the critical services described. The Ord River Floodplain system, due to the dry tropical, monsoonal climate has two distinct hydrological states; a low flow typical of the dry season and a flood event that occurs during wet seasons with above average rainfalls. Given the alteration to the hydrology of this system, inundation of Parry Lagoons by the Ord River does not occur with the same frequency as under natural conditions. Therefore, a third state has also been described; inundation of the Parry Lagoons by Parry Creek and local catchments. While there is no empirical data to inform this model, anecdotal evidence suggests that inundation from Parry Creek occurs more regularly, but with a reduced extent and duration of inundation.

Simple conceptual models of each of these states have been developed for the Parry Lagoon Floodplain, the Ord River and the mangrove creeks and estuary (Figure 41 and Figure 42). These models do not attempt to show every interaction that occurs within the systems, but rather highlight the links between the abiotic primary determinants, ecosystem responses and feedback loops which in turn determine the sites' ecological character.



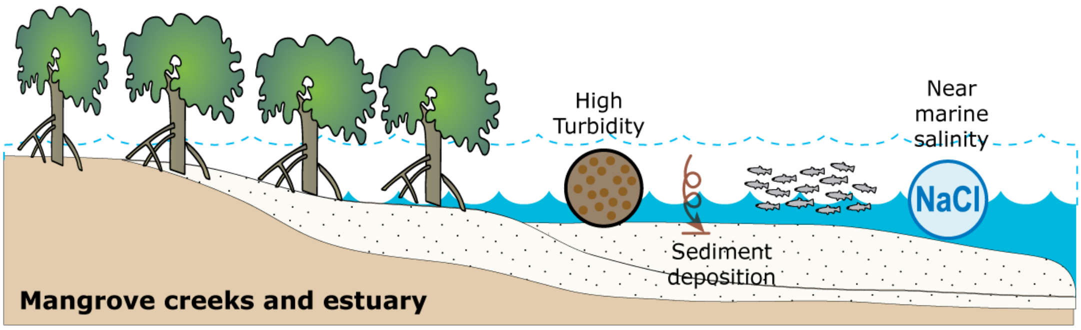


Figure 41: Simple conceptual model of the Ord River Floodplain Ramsar site during low flows.

In times of low flow, a constant baseflow of freshwater through the river system is released from the Kununurra Diversion Dam (Department of Water 2006). The permanent wetlands at Parry Lagoons are disconnected from the river and the floodplain becomes a terrestrial environment. Some waterbirds (e.g. Radjah Shelduck) are residents and remain in the system and the wetlands support some aquatic plants. However, productivity and diversity are comparatively low (Water and Rivers Commission 2003a).

The river within the Ramsar site is dominated by tidal movements and the salinity is relatively high, but variable with the tide (4 – 28 ppt). The constant baseflow maintains longitudinal connectivity for fish (Braimbridge and Malseed 2007). Freshwater Crocodiles remain upstream in fresher waters and Saltwater Crocodiles inhabit the open estuary and coastline (Kay 2004). Water in the tidally influenced reaches within the Ramsar site remains well mixed and oxygenated (Parslow et al. 2003).

The mangrove creeks and estuary are also tidally dominated and salinity in this area is near seawater (28 – 35ppt); suitable for mostly estuarine and marine opportunist fish species and marine macroinvertebrates. The combination of baseflow freshwater inflows and the macro-tide results in constant resuspension of sediments in the estuary area and turbidity is high

(Parslow et al. 2003). The high turbidity and corresponding light reduction may inhibit growth of phytoplankton and microphytobenthos. Flows are insufficient to mobilise sediments out of the estuary to the ocean and there is sediment deposition and accumulation in the estuary and lower Ord River (Wolanski et al. 2002).

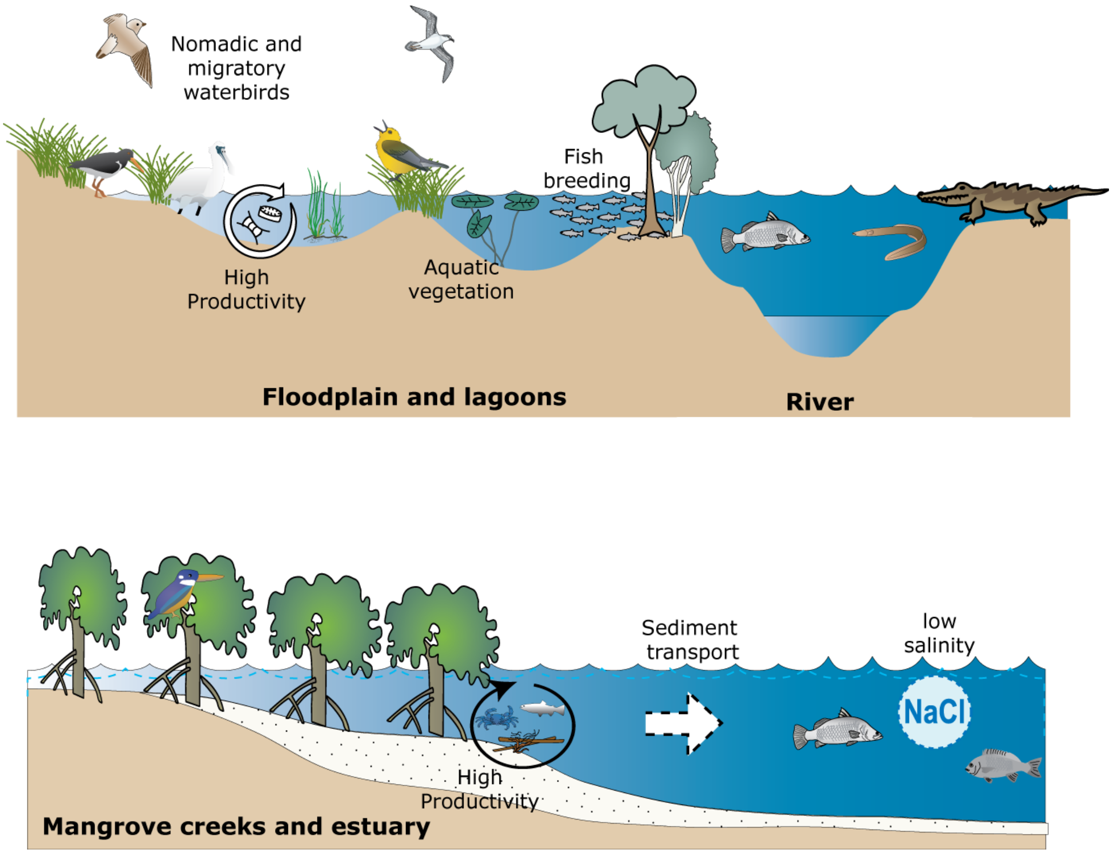


Figure 42: Simple conceptual model of the Ord River Floodplain Ramsar site during flood events in some wet seasons.

In above average wet seasons, under conditions when there is sufficient rainfall to cause significant volumes of water to be released from the Kununurra Diversion Dam, or when there is extreme rainfall in local catchments, flow in the river exceeds 4000 m^3/sec and inundation of Parry Lagoons floodplain from the Ord River occurs (Department of Water 2006). The river, floodplain and wetlands become hydrologically connected with lateral movement of floodwaters; at times this movement may be both from Parry Lagoons to the Ord and also from the Ord to Parry Lagoons. Inundation of the floodplain mobilises organic carbon, nitrogen and phosphorus from vegetated debris into a dissolved mineralised form ready for uptake by bacteria and phytoplankton and the system enters a highly productive “boom” phase. This, together with the hydrological connectivity, supplies organic carbon and nutrients to the river, stimulating in-channel productivity (Water and Rivers Commission 2003a). Although the river is still influenced by tides, the large freshwater flows maintain salinity at < 1ppt on the floodplain and < 4 ppt in the estuary (Water and Rivers Commission 2003a; Parslow et al. 2003).

High phytoplankton productivity provides food for a high abundance and diversity of macroinvertebrates, which in turn provides plentiful food for fauna higher in the food chain (see Figure 40 below). Inundation of the floodplain provides a diversity of habitats with different water depths. Deep water holes provide habitat for floating and submerged plants, whose diversity and abundance is at it’s highest during or following these floods. It also provides feeding habitat for deep water feeding guilds of birds such as cormorants (see Appendix C). Shallow inundated floodplain areas are diverse with emergent aquatic plants, legume thickets, grasses and herbs. This provides shelter and nesting sites for waterbirds that were confined to persistent waterholes during the dry season; these birds may now range right across the floodplain. They are joined by birds arriving from far away, including international migrants. Some barer areas of floodplain are shallowly inundated and provide habitat for short-legged wading birds.

Inundation of riparian trees stimulates both growth and recruitment. In addition, this inundation of trees and emergent vegetation provides suitable habitat for waterbird breeding. For example, Magpie Geese in inundated *Eleocharis* and Darters in inundated trees.

Connectivity between the river and the floodplain allows for movement of fish into the productive floodplain and wetlands and this provides opportunities for fish feeding and breeding. The abundance of waterbirds and fish provides food for both Freshwater and Saltwater Crocodiles, which both inhabit the floodplain.

In the mangrove lined creeks and open estuary fresh water flows reduce salinity to < 4ppt. If flows are of sufficient magnitude, the fine sediments accumulated over previous years can be flushed out to the ocean.

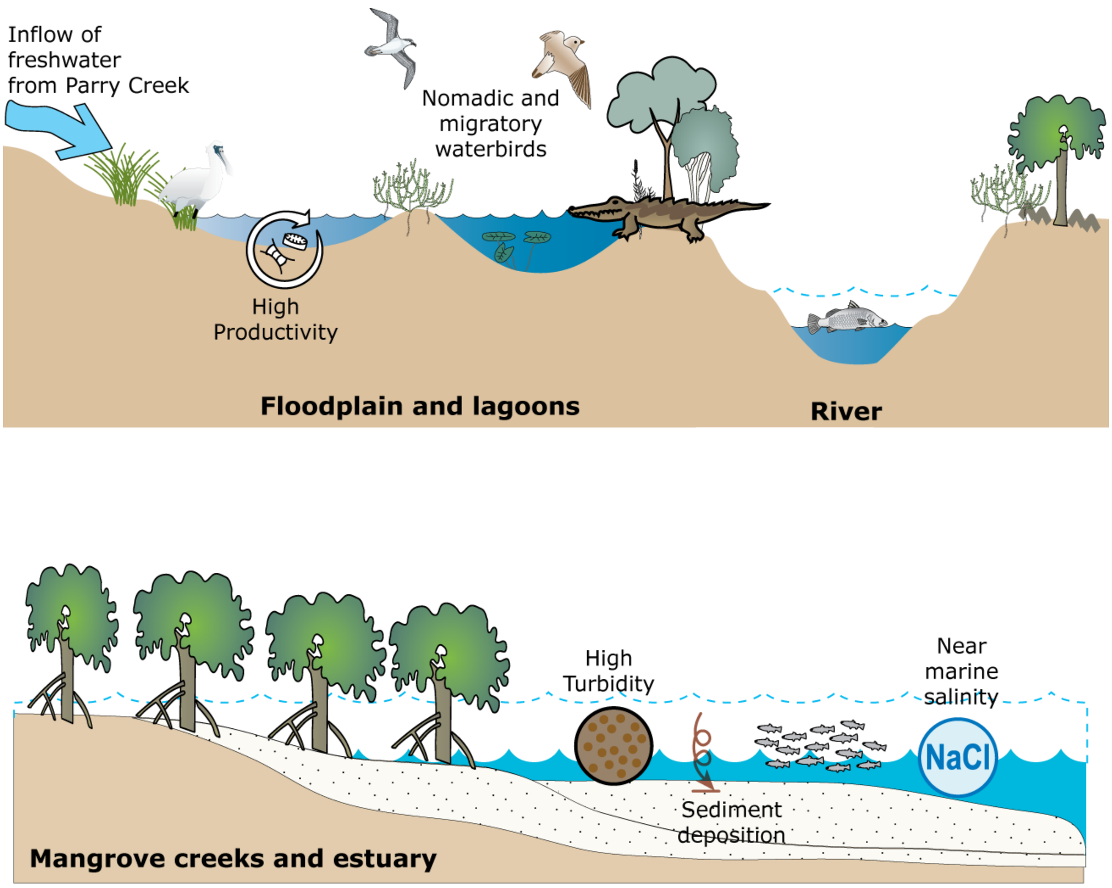


Figure 43: Simple conceptual model of the Ord River Floodplain Ramsar site during inundation via Parry Creek.

Inundation of the floodplain via overbank flows from the Ord River occurs only periodically (1 in 10 to 30 years). More common is inundation of the floodplain via local rainfall and flows from Parry Creek. There is no quantitative information on the frequency or extent of inundation under this flow scenario and this remains a significant knowledge gap. As such, the conceptual model shown in Figure 43 is hypothetical, based on anecdotal evidence.

The key points illustrated here is that while inundation may be sufficient to cover part of the floodplain and perhaps connect some of the permanent waterbodies, it is not sufficient to connect the Ord River and Estuary with Parry Lagoons. This limits the opportunities for fish breeding / habitat for juvenile fish and has no effect on the deposition of sediment in the mangrove creeks and estuary. However, it stimulates productivity, attracting fish, birds and other fauna providing localised areas of high biodiversity.

4.3 Habitat

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

Trophic relationships

Gehrke (2008) developed a quantitative trophic model of the freshwater reaches of the lower Ord River. This provided not only the food chain linkages, but also quantitatively tracked the movement of organic carbon through the species and groups of organisms. However, he stated that there was insufficient data and knowledge of the estuarine reaches of the river and the open estuary to develop a similar model of these zones.

As a consequence, all that is attempted here is a simple food web (Figure 44). This model shows both the well recognised pelagic system and also the important, but often under recognised, detrital system. This provides an example of one method by which primary producers within the system are a primary determinant of ecological character. Plant taxa form the basis of the food chain for all of the key biota within the Ord River Floodplain, through both primary production and detrital pathways. Gehrke (2008) suggested that approximately 32% of the organic carbon on the system was of algal origin and a further 20% from macrophytes, the remaining 48% was detrital, which was not traced back to the original sources.

However, these figures are for the freshwater section and they may not be applicable to the estuary. In particular the importance of mangroves in the food chain is contentious.   It was long thought that mangrove detritus constituted the major source of carbon for estuarine systems. Mangroves contribute carbon to organisms higher in the food chain both indirectly (through the breakdown of detritus by bacteria) and directly, through grazing by crabs (Robertson 1986). However, it is now thought that mangroves contribute only a minor source of carbon to estuarine systems, with the major contributions coming from benthic algae, phytoplankton and saltmarsh plants (Gehrke 2008). The relative importance of these different plant communities in the food web of the Ord River Floodplain Ramsar site is not known. As such, for the management of the system, the precautionary principle should be applied and each considered to be significant until proven otherwise.

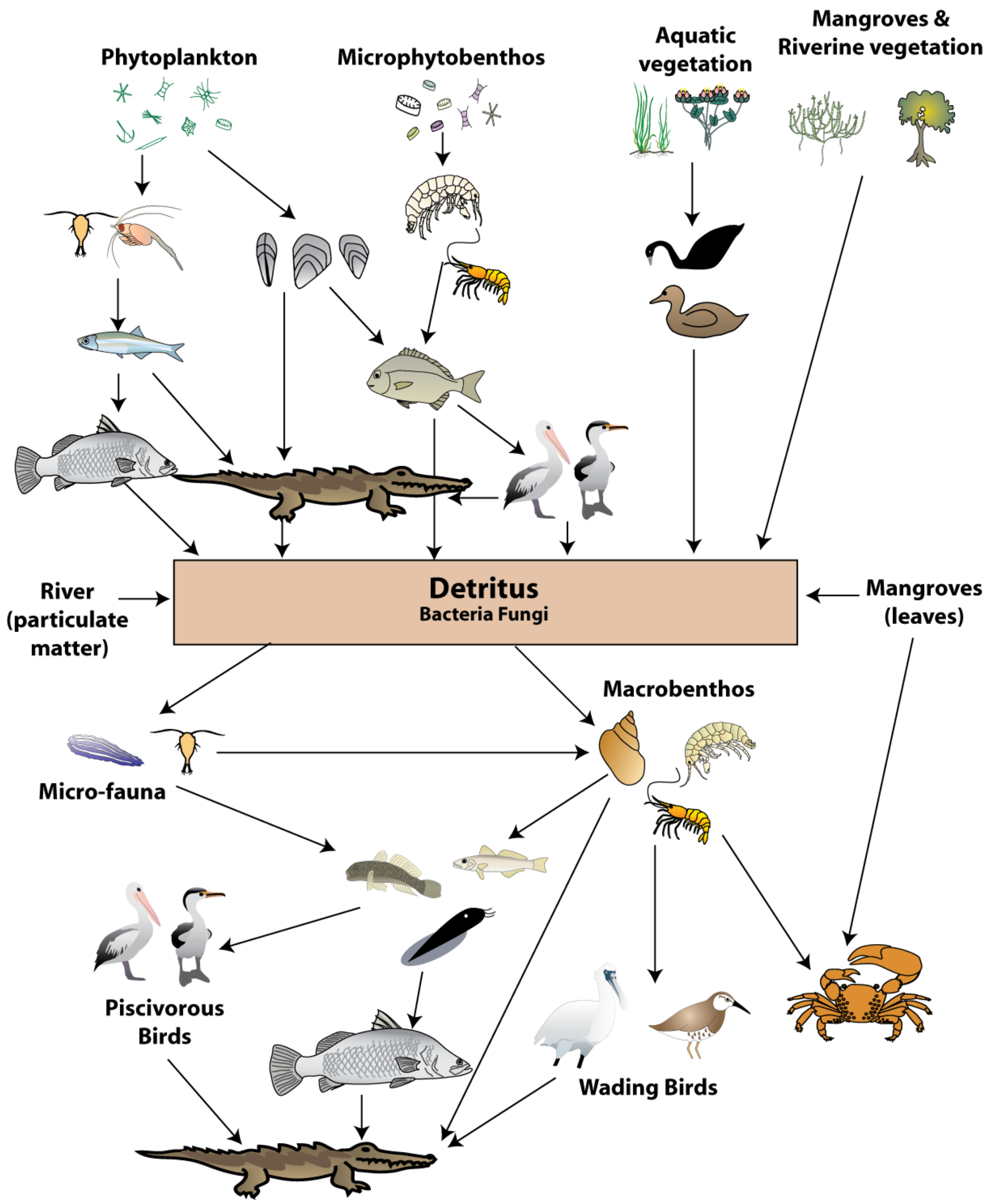


Figure 44: Simple food web for the Ord River Floodplain Ramsar site (adapted from Gehrke 2008 and Hale and Butcher 2008).

Habitat type and availability

Supporting diverse habitat types was identified as a critical service provided by the Ord River Floodplain Ramsar site. The following physical habitat types provided by both vegetation and abiotic environments have also been identified as primary determinants of ecological character in the Ord River Floodplain site:

- Mudflats
- Mangroves
- Grasslands and sedges
- Aquatic vegetation; and
- Riparian woodland

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

The extent, condition and use of habitat types have not been consistently or recently assessed across the Ord River Floodplain site. What is known, or can be deduced through ecological principles about habitat types within the system is described in Table 16.

Table 16: Probable habitat usage within the Ord River Ramsar site.

Habitat	Description	Key fauna
Open Water	Small areas in the open estuary (saline to brackish) and in the Parry Lagoons (fresh to brackish). Some available all year, but increases in wet season, particularly in floods and on the floodplain in early stages of extensive inundation. May be deep or shallow.	Fish, macroinvertebrates, waterbirds foraging (mainly ducks, herons, coots, terns and gulls) Crocodiles
Mudflats	Intertidal (also under samphire communities) Approximately 50,000 hectares (Oz Estuaries)	Invertebrate communities, foraging for wading species of birds (at higher elevations)
Mangroves	Approximately 27,000 hectares Comprises of 14 species of mangrove with zonation based on tidal inundation and salinity. Samphire and/or saline grasses at higher elevations Intertidal (at various tidal ranges)	Mangrove birds - roosting, nesting, foraging (9 species exclusive habitat) Macroinvertebrates – including mangrove crabs and banana prawns Foraging for wading species of birds Foraging for fish
Grasslands and sedges	Extensive at Parry Lagoons (area unknown) Inundated in the wet season. Comprises of grasses, sedges and legume thickets	Macroinvertebrates, fish, foraging for wading birds and nesting for waterbirds such as Magpie Geese, Coots and Swamphens (when inundated).
Aquatic vegetation (including wooded swamps on the floodplain	In the permanent waterholes in Parry Lagoons. Area unknown, but seasonally variable, expanding n the wet season and contracting in the dry. Comprises of floating plants (e.g. water lilies) as well as submerged and emergent species.	Macroinvertebrates, fish, foraging for waterbirds (Black swans, Ducks, Jacana) Nesting for waterbirds (Jacana) Roosting and nesting for water birds, dry season roosts for large mobs of whistling-ducks
Riparian Woodland	Along the streams and rivers across the Parry Lagoon Floodplain. Inundated under large flood events Comprised of River Red Gum and Guttapercha	Roosting sites for waterbirds and nesting for colonial species such as Herons and Egrets as well as Darters.

5. Limits of Acceptable Change

5.1 Process for setting LAC

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

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

Limits of acceptable change and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that limits of acceptable change should be beyond the levels of natural variability (Figure 45). Setting limits in consideration with natural variability is an important, but complex concept. As indicated in Sections 3 and 4 above, wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability such that trends away from "natural" can be detected with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is far from straight forward. This is especially difficult to achieve in northern Australia where great natural variability of wetland conditions occurs and where our knowledge of ecosystem components and processes, let alone their variability, is far from adequate.

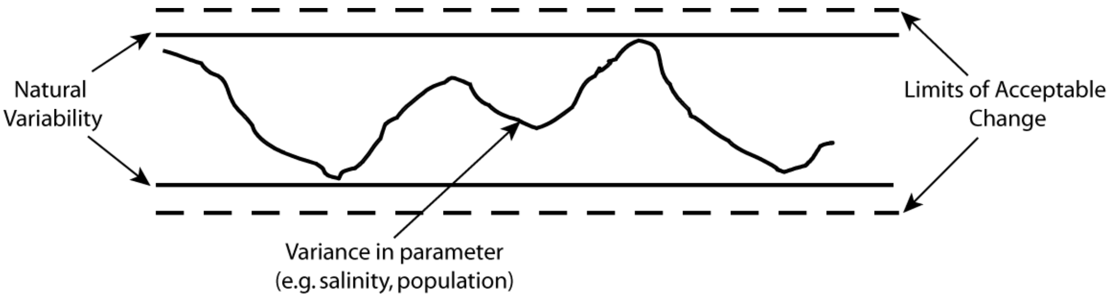


Figure 45: Relationship between natural variability and limits of acceptable change (Phillips 2006).

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set limits of acceptable change beyond those limits. They provided examples where a parameter could change in ways that are detrimental to the ecological character of the site but do not result in a change in the maximum or minimum values (Figure 46). This holds true as well for the Ord River Floodplain Ramsar site, where changes in salinity as a result of water regulation may not result in changes to maximum and minimum salinity values in the estuary, but significantly alter the distribution.

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

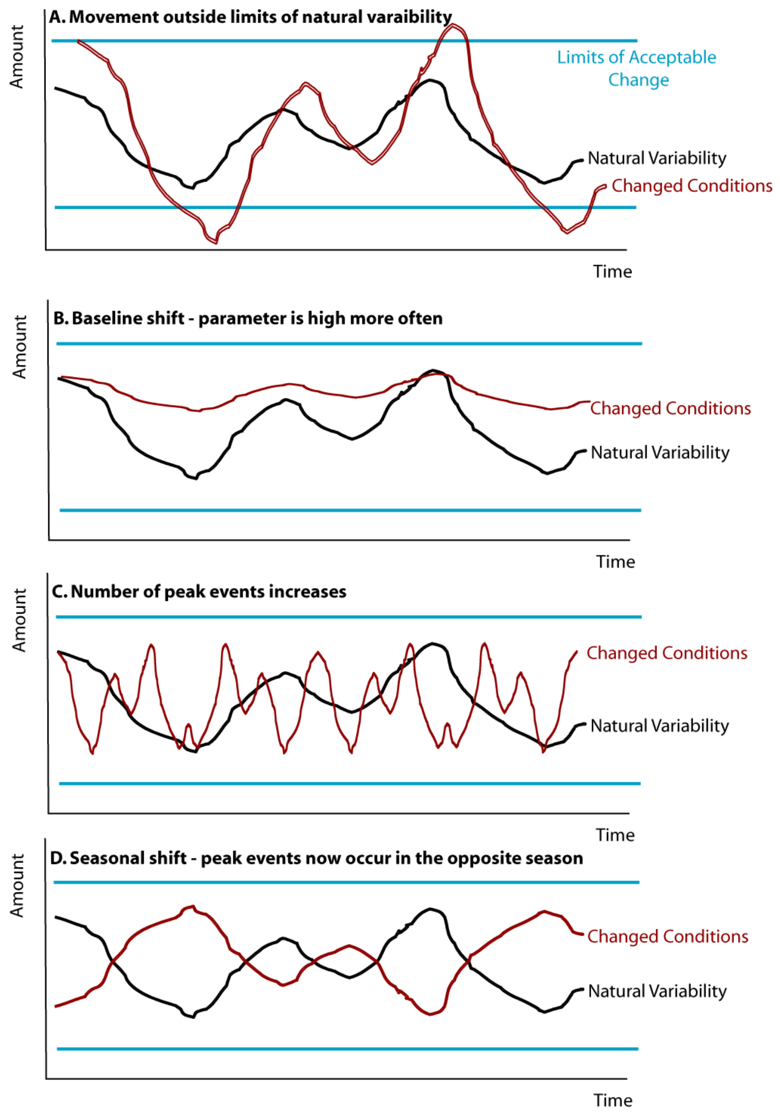


Figure 46: Illustration of the complexity of setting limits of acceptable change. If these are set to be outside the extremes of natural variability (A) then this will only capture a change in maximum or minimum values. Situations that involve a shift in the baseline values, an increase in the number of peak events or a seasonal shift (B – D) will not be captured (Hale and Butcher 2008).

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

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

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

Adopting the methodology of Hale and Butcher (2008), this principle has been applied to the setting of limits of acceptable change for the Ord River Floodplain Ramsar site by setting conservative limits of acceptable change, which can be reviewed in light of monitoring and additional information.

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

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

There are a number of critical components and processes within the Ord River Floodplain Ramsar site that do not meet these criteria. An example of this would be the mangrove dependant bird species in the Ord Estuary and False Mouths of the Ord. It is not practical to quantitatively monitor these populations with the necessary statistical rigour to detect changes in a timely manner. Therefore, again the method of Hale and Butcher (2008) that was developed for the Peel-Yalgorup Ramsar site is applied here to the Ord River Floodplain (Figure 47).

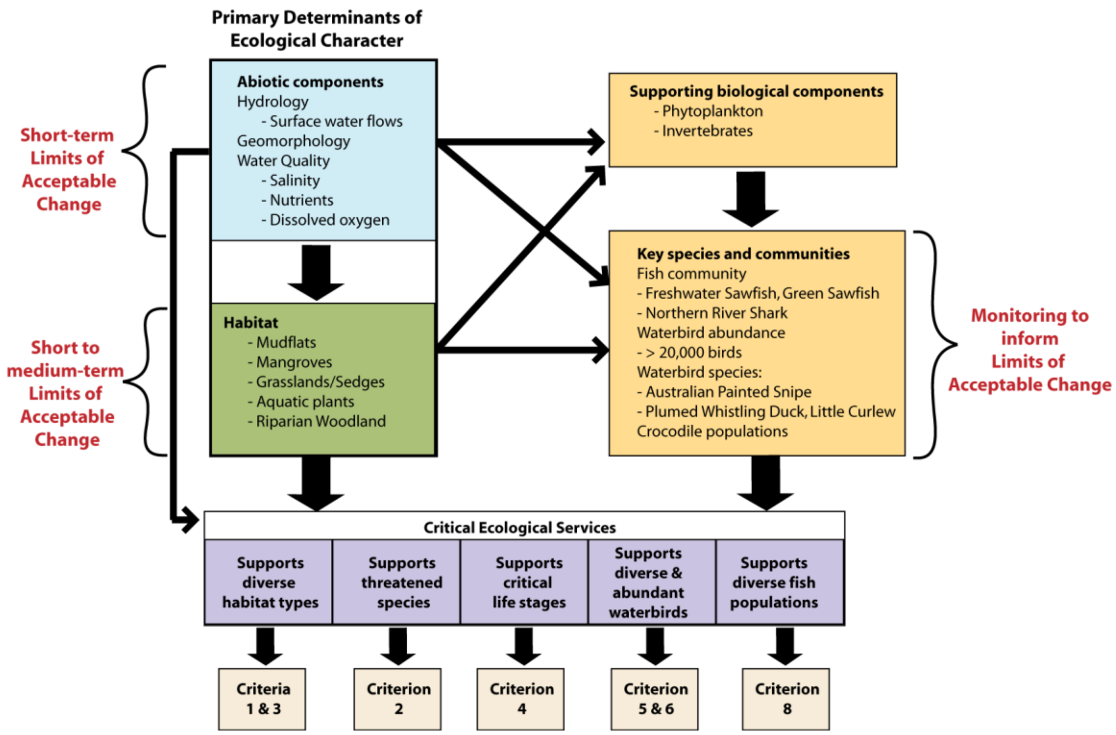


Figure 47: Hierarchical system for setting limits of acceptable change.

This approach sets short-term limits of acceptable change (with a corresponding intensive monitoring program) on the key abiotic factors within the system. Abiotic components and processes impose a strong influence on the biotic components of wetland systems and are often considered the primary control factors (Mitsch and Gosselink 2000; Batzer et al. 2006). These are usually the easiest to monitor and change can be detected in the short term (within 1 or 2 years). The approach adopted with respect to abiotic components, follows the ANZECC (2000) guidelines for water quality in freshwater and marine systems. A set of guideline or trigger values[7] have been established for key components, based on site specific information, where possible, and using general values for Australian ecosystems in situations where there is insufficient data for the local system. In the case of the Ord River Floodplain system there are few existing limits and guideline values. Braimbridge and Malseed (2007) developed environmental water requirements for the Lower Ord River. However, the requirements of the estuary and estuarine reaches of the system were not considered and therefore, many of these hydrological guidelines are not applicable to the Ramsar site.

The second set of parameters for which limits of acceptable change can be set, is the primary responses to the abiotic components and processes. This includes primary production, and physical / biological habitat (mudflats, mangroves and wetland vegetation) extent and condition. Once again the focus is on the identified critical components and processes (key determinants of ecological character). Limits are set against baseline data and the habitat requirements or tolerances of key fauna. The limits of acceptable change for these parameters are set at time scales reflecting the different response times of the flora communities. For example, phytoplankton, which can respond rapidly, has shorter-term limits of acceptable change than woody vegetation communities.

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

Additional LAC explanatory notes

1. Limits of Acceptable Change are a tool by which ecological change can be measured. However, Ecological Character Descriptions are not management plans and Limits of Acceptable Change do not constitute a management regime for the Ramsar site.
2. Exceeding or not meeting Limits of Acceptable Change does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting Limits of Acceptable Change may require investigation to determine whether there has been a change in ecological character.
3. While the best available information has been used to prepare this Ecological Character Description and define Limits of Acceptable Change for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The Limits of Acceptable Change may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.
4. Users should exercise their own skill and care with respect to their use of the information in this Ecological Character Description and carefully evaluate the suitability of the information for their own purposes.
5. Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

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

5.2 LAC for the Ord River Floodplain Ramsar site

Using the method described above, preliminary limits of acceptable change have been set for the Ord River Floodplain Ramsar site (Table 17). However, it should be noted that for many of the critical components and processes there is limited quantitative data on which to set limits. In these instances, qualitative limits have been recommended, but these will require careful review with increased information gained from future monitoring.

Table 17: Limits of acceptable change for the Ord River Floodplain Ramsar site.[8]

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
Abiotic Components and Processes		
Hydrology	Flooding of riparian vegetation in the wet season to support: large bodied fish; maintain carbon sources to the river and estuary; and maintain native riparian vegetation communities. (Braimbridge and Malseed 2007)	Wet season flows sufficient to provide: 4 or more spells over 125 m^3/s, 2 or more spells over 200 m^3/s and at least one over 300 m^3/s. Total annual durations of at least 10, five and one day(s) for 125 m^3/s, 200 m^3/s and 300 m^3/s spells respectively.
	Peak flows in the Ord River to maintain inundation of Parry Lagoons including the floodplain and to scour sediment build-up in the lower Ord River and Estuary. (Braimbridge and Malseed 2007) recommended a Target ARI for peak events in the vicinity of 3,700 to 4,000 m3/s every 27-35 years. However, given that connectivity between Parry Lagoons and the estuary and river is important for ecological processes and fish breeding, this may not be conservative enough to maintain the ecological character of the site	Data deficient, however connectivity between Parry Lagoons and the estuary every 3 – 5 years is optimum for maintaining ecological character.
	Flows in Parry Creek to maintain inundation of Parry Lagoons to support flora and fauna	Data deficient – baseline must be established before limits can be set. However annual inundation is essential
Nutrients	The estuary (which includes the Ord River within the Ramsar site) is highly productive and efficient in cycling and exporting nutrients (Parslow et al. 2003). The system requires a minimum nutrient load to maintain productivity, however high loads of bioavailable nutrients entering the system from upstream irrigation could have a detrimental effect.	Median nutrient concentrations within the Ord Estuary and Parry Lagoons of: < 50 µg/L nitrate-nitrite and < 20 µg/L phosphate. To be revised when further data becomes available.
Dissolved oxygen	The estuary are well mixed and baseline dissolved oxygen concentrations range between 90 – 110% saturation	Dissolved oxygen concentrations in the estuary no less than 90% saturation
Salinity	Greatest mangrove diversity occurs in areas that experience moderate salinity; rather than prolonged exposure to freshwater (Ball et al.1997). Red Mangrove is tolerant of	Salinity during the dry season in the Estuary and False mouths of the Ord to average 30 – 35 ppt

[8] Where "no significant change" is used in the context of LAC, this will need to be based on exert opinion of experienced resource managers / ecologists.

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
	high salinities, but is displaced by other species in fresher conditions (Duke et al. 1998)	
	Little is known of the salinity tolerance of the sedge/grasslands and aquatic vegetation at Parry Lagoons. Limits have been set based on existing baseline data	Annual median salinity in Parry Lagoons < 1ppt
Toxicants	Two agrichemicals of concern, Atrazine and Endosulphan have ANZECC (2000) trigger values. The values for 99% protection have been applied as this site is considered to be of high conservation value	Atrazine < 0.7 µg/L Endosulphan < 0.03µg/L
Primary Responses		
Phytoplankton	The Ord River Floodplain Ramsar site is driven by phytoplankton / mircrophytobenthos primary production (Water and Rivers 2003a). Baseline data of chlorophyll a concentrations is limited to a 15 month period in the estuary reaches (Parslow et al. 2003)	Annual median chlorophyll a concentrations 10 – 15 µg/L (Note this is an estimate based on limited data and should be reviewed with additional monitoring)
Mangrove	Mangrove extent within the Ramsar site is approximately 26,000 ha. There are 14 species of mangrove.	Mangrove extent > 26,000 ha Mangrove species ≥ 14 No significant change in mangrove distribution and zonation
Sedge/grassland	Current extent and community composition not known	Baseline must be established before quantitative limits can be made No significant change in community composition or extent
Aquatic vegetation	Current extent and community composition not known	Baseline must be established before quantitative limits can be made No significant change in community composition or extent
Key Communities		
Invertebrates	Insufficient information to set a baseline	Baseline must be established before quantitative limits can be made No significant change in community composition or abundance
Fish	Insufficient information to set a baseline with the possible exception of barramundi and Threadfin Salmon based on commercial fishing data. However, total catch of Barramundi has decreased substantially since the time of listing (Fisheries WA 2003 – 2007), but without Catch per Unit Effort Data it is not possible to determine if this is a reflection of the population.	Baseline must be established before quantitative limits can be made No significant change in community composition or abundance
	Significant species such as the Freshwater Sawfish, Green Sawfish and Northern River Shark require additional protection. However, without population estimates, quantitative limits are difficult to set.	Baseline must be established before quantitative limits can be made.
Wetland dependant	Abundance, breeding and species	In a majority of the years in which

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
birds	composition is data deficient, with quantitative counts limited to two years prior to listing and one since. Preliminary, LAC set based on Ramsar criteria and reason for listing.	the Parry Floodplain Wetlands is extensively inundated, the system supports: • > 20,000 waterbirds • substantial numbers of migratory shorebirds • substantial breeding by waterbirds • large numbers of Plumed Whistling-Duck and Little Curlew • at least occasional (1 in 20 year) occurrence of Australian Painted Snipe provided that appropriately frequent, systematic and comprehensive surveys of waterbirds have been conducted at these times
Crocodiles	Mean population estimates for the Saltwater Crocodile = 80 and Freshwater Crocodile = 400 in the lower Ord River	No significant change in mean populations for each of these species

6. Threats to the Ecological Character of the Ord River Floodplain Ramsar site

As stated above, wetlands are complex systems and an understanding of components and processes and the interactions or linkages between them is necessary to describe ecological character. Similarly threats to ecological character need to be described not just in terms of their potential effects, but the interactions between them. One mechanism for exploring these relationships is the use of stressor models (Gross 2003). The use of stressor models in ecological character descriptions has been suggested by a number of authors to describe ecological character (Phillips and Muller, 2006; Phillips et al. 2005; Hale and Butcher 2008) and to aid in the determination of limits of acceptable change (Davis and Brock 2008).

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

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

In evaluating threats it is useful (in terms of management) to separate the driver or threatening activity from the stressor. In this manner, the causes of impacts to natural assets are made clear, which provides clarity for the management of natural resources by focussing management actions on tangible threatening activities. For example, increased nutrients may be identified as a threat for wetlands in the Ramsar site. However, management actions cannot be targeted at increased nutrients without some understanding of why the increase is taking place. By identifying the threatening activities that could contribute to increased nutrients (e.g. irrigation, sewage treatment) management actions can be targeted at these threatening activities and reduce the impact to the wetland.

The stressor model (Figure 48) illustrates the major drivers (threatening activities) stressors and resulting effects in the Ord River Floodplain Ramsar site. A description of each of these drivers is provided below, together with a brief description of more minor threats to the system.

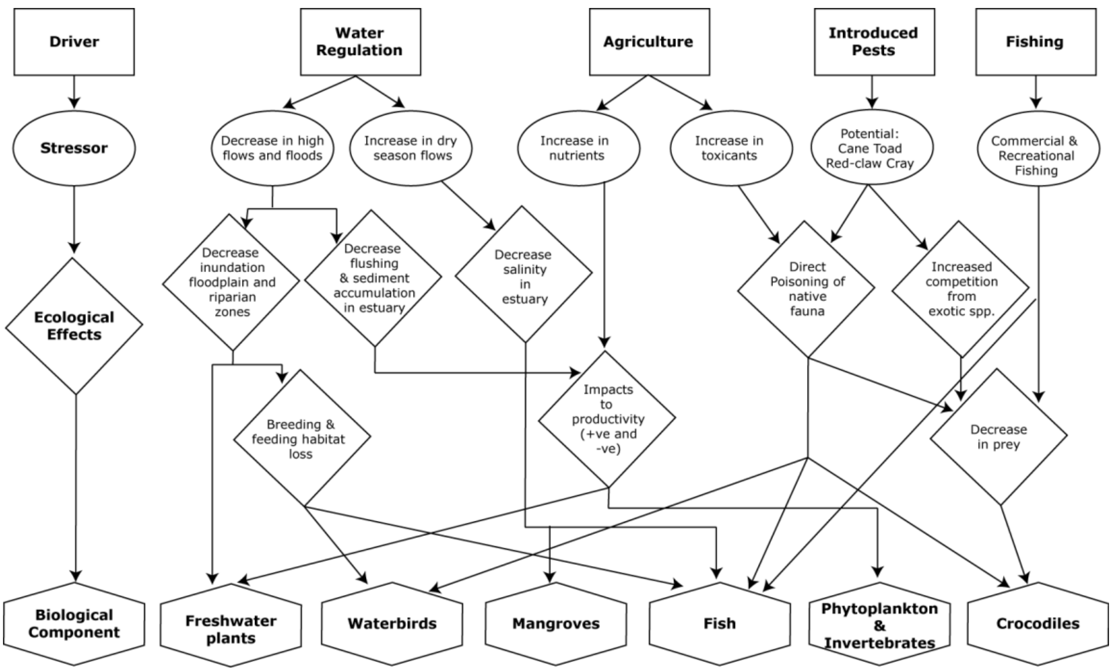


Figure 48: Stressor model of the Ord River Floodplain Ramsar site (after Gross 2003 and Davis and Brock 2008).

6.1 Water resource development and management

Water resource development and agriculture are inextricably linked in the Ord River Catchment. Lund and McCrea (2001) developed a risk assessment model of the two activities (Figure 49). In the context of this ECD, the two threatening activities have been separated such that “water resource development” encompasses hydrological changes, and “agriculture” covers water quality impacts from irrigation drainage.

As stated previously, the Ord River Floodplain Ramsar site was declared a wetland of international importance long after water resource development commenced in the catchment and the Ord River Irritation Area 1 (ORIA 1) had been in effect for a number of years. This does not mean, however that current water resource development poses no threat to the system. In addition, there are plans to expand irrigation activities in the catchment with the ORIA 2 development, which would further alter the hydrological regime of the Ramsar site.

The water demands of the initial stages of ORIA 2 are expected to be in the order of 400 GL/year bringing the total allocation for irrigation to 750 GL/year (DoW 2006). In addition to this are requirements for hydroelectricity generation and potential requirements for mining operations. The outcome of this is likely to be a further reduction in flows below Kununurra Diversion Dam in the lower Ord River (Lund and McCrea 2001).

The effects of water regulation on the flow regime from ORIA 1 (and which may be further impacted by ORIA 2) are an increase in dry season flows, a decrease in high flows in the wet season and a decrease in flow variability. The effects that these have had (and are likely to continue to have) on the lower Ord River include:

- Disruption to riparian tree regeneration due to altered seasonality of flows (Doupe and Petit 2002);
- Reduced frequency and extent of inundation of Parry Lagoons (Rogers and Ruprect 2001);
- Increase in inchannel vegetation such as *Typha* (Start 2000);
- Invasion by weed species (Start 2000);
- Impacts to fish and macroinvertebrate communities (Morrissey 2000); and
- Increased sedimentation in the mouth of the estuary (Wolanski et al. 2001).

The majority of impacts to vegetation are likely to be more strongly felt in the freshwater reaches of the Ord River upstream of the Ramsar site. Predicted impacts to mangroves and estuarine communities are considered to be minor to negligible (Semeniuk and Semeniuk 2000). However, the issue of loss of hydrological connectivity is a serious one for the ecology of the Ramsar site. The reduction in flood flows and overbank flooding from the Ord River has reduced the hydrological connectivity between Parry Lagoons (and associated floodplain) and the estuary. This is likely to have effects on productivity, fish migration and breeding and a reduction in habitat for wetland fauna.

Finally, there is a knowledge gap with respect to the effect of ORIA 2 on overland flow hydrology and hydraulics. The area immediately upstream of the Ramsar site that is proposed for the Mantinea irrigation region is partially located on an area of existing wetland / floodplain. Development for irrigation would require a system of levees and / or drainage of floodwaters (Government of Western Australia 2008). The impact of this on water flowing into or from the Ramsar site has yet to be assessed but has the potential to significantly alter the extent, duration and magnitude of floodplain inundation for Parry Lagoons.

6.2 Agriculture

The ORIA 1 is located some distance upstream of the Ramsar site near Kununurra. However, ORIA 2 is proposed for land immediately adjacent to the southern end of the Ord River Floodplain Ramsar site. Lund and McCrea (2001) in their risk assessment of the effects of irrigation on the lower Ord River considered that there was a moderate to high risk from increasing nutrients and pesticides to the ecology of the river (Figure 49).

Although Parslow et al. (2003) considered that the estuarine reaches of the river were adept at exporting nutrients to the Indian Ocean; there will be a limit to which even the most adaptive natural system can maintain its ecological function. However, perhaps of greater concern is the risk from pesticides and herbicides. The close proximity of the proposed ORIA 2 does not provide a large buffer or distance for dilution of accidental spills or spray drift.

Concentrations of pesticides on the lower Ord River upstream of the Ramsar site have been above ANZECC guideline levels (data from Water and Rivers Commission 2003b). There is evidence of fish kills within the river attributed to pesticides from the 1970s and more recently (Morrissey 2000). In addition, there is evidence of bioaccumulation of pesticides (DDT) in Barramundi (Morressey 2000) and Freshwater Crocodiles (Yoshikane et al. 2006) in the lower Ord River.

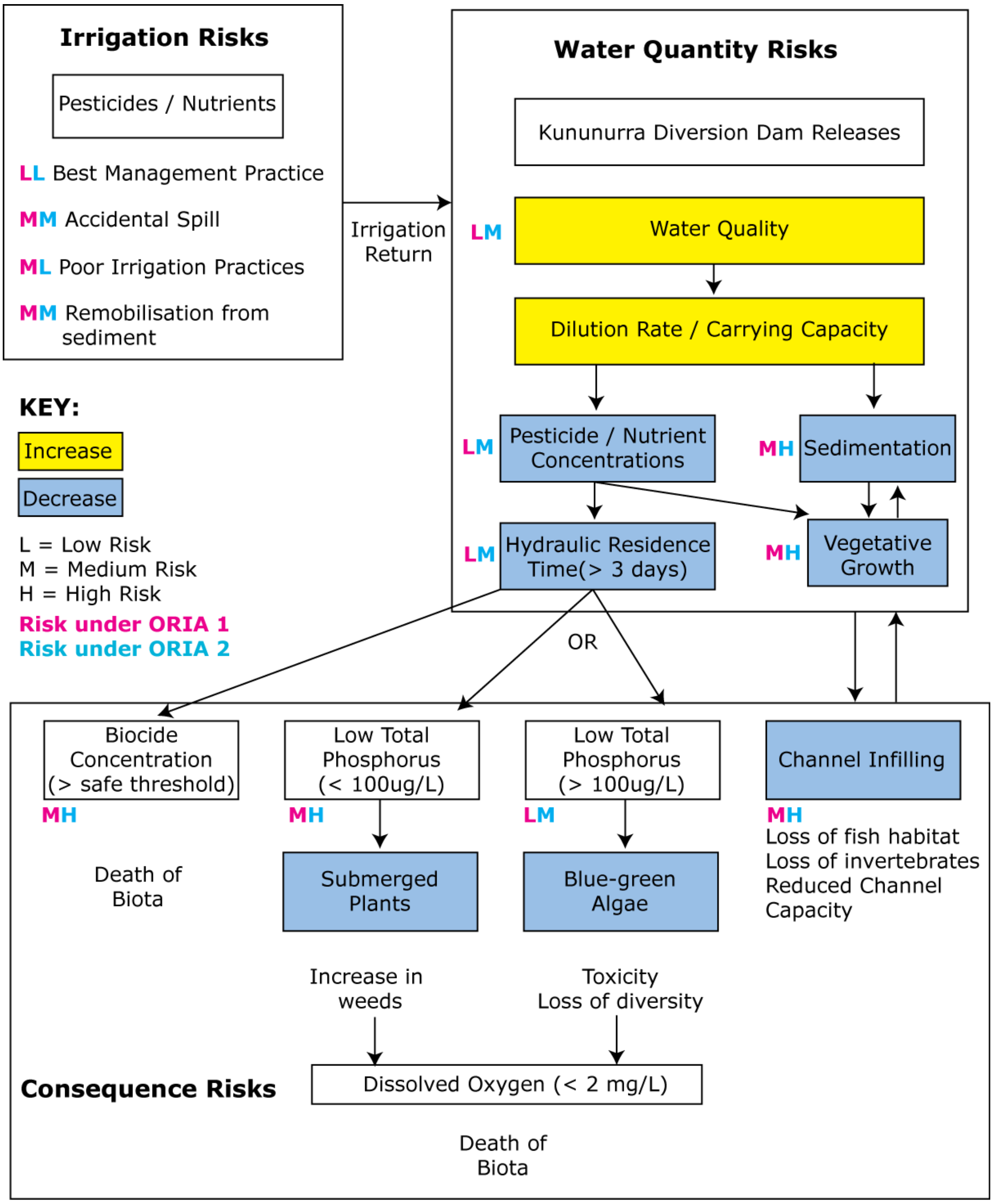


Figure 49: Conceptual model of the risks to the lower Ord River from the Ord River Irrigation Areas (ORIA) 1 and 2 (Lund and McCrea 2001).

6.3 Commercial and recreational fishing

Cambridge Gulf and the lower Ord River are important recreational and commercial fisheries. However, the areas upstream and downstream of the Ramsar site are the most popular for these activities (West et al. 1996) and commercial fishing is no longer permitted upstream of Adolphus Island (Fisheries WA, unpublished). The most commonly caught fish are Barramundi (commercial and recreational), Bream (recreational) and Threadfin Salmon (commercial). The only quantitative data is that collected by Fisheries WA (2003 – 2007) and as there are fewer than 5 commercial licences catch per unit effort is not reported. This makes it difficult to determine if fish stocks are being impacted, as raw catch data does not provide information on populations.

Fisheries WA (2007) reported that at the last stock assessment in Cambridge Gulf (2002) the Barramundi populations in this area were being harvested at a sustainable level. No assessment of Threadfin Salmon has been undertaken. Fisheries WA (2007) also state that there are low habitat effects of the commercial fishery as:

"*The fishing gear has minimal impact on the habitat. The area and habitat fished is subject to extreme tidal currents and associated effects.*"

However, food chain effects have not been assessed. In addition, there is evidence that the fishing equipment (i.e. gill nets) can impact on other fish species. Of particular concern is the potential impact of commercial and recreational fishing on the endangered Northern River Shark and the vulnerable Freshwater Sawfish and Green Sawfish. Stevens et al. (2005) cite commercial gill net fishing and recreational fishing using live and dead bait as significant threats to these three species. There are records from other systems of all of these species being caught in commercial gill net equipment. In addition, the five specimens of the Northern River Shark recorded in the Ord River were all caught by a recreational fisherman. Although in these instances the fish were released alive, it is expected that other individuals would be retained or discarded dead.

6.4 Introduced species

There is little published information on introduced species within the Ord River Floodplain Ramsar site. Weed infestations of "sleeper" weeds such as *Leucaena leucocephala* and *Jatropha gossypiifolia* have been recorded elsewhere in the lower Ord River riparian zones (Start 2000) but the presence or threat to the Ramsar site is unknown. A quarantine area has been established in the Ord River Floodplain for Noogoora Burr (*Xanthium occidentale*). However, perhaps the most serious weed threat, however, is from the shrub Parkinsonia (*Parkinsonia aculeate*), which has formed extensive stands in riparian and floodplain areas (CALM 1998)

Grazing by feral donkeys and cattle of the wetlands and floodplains of Parry Lagoons was a serious threat, but has since been controlled. However, uncontrolled stock grazing continues in the False Mouths of the Ord. Given the inaccessibility and large area covered by the Ramsar site in this area, fencing the entire site is not considered to be feasible. However, areas within the False Mouths of the Ord, such as freshwater springs have been targeted by local agencies to manage stock (Department of Water, pers. comm.).

Redclaw Crayfish (*Cherax quadricarinatus*) have been recorded in Lake Kununurra (Doupe et al. 2004) and the Lower Ord River. Although the origins of this "wild" population are uncertain, there are no endemic freshwater crayfish in the Kimberley and the population is the result of either escapes from aquaculture facilities or from release by fisherman who commonly use this species for bait (Doupe et al. 2004). The impact of this species on the ecology of the Lower Ord River and Ramsar site is not known. However, Doupe et al. (2004) indicate potential impacts as: food web alterations via predation and grazing pressure, habitat alterations, and disease introductions.

Arguably, the greatest potential threat from an introduced species is from future expansion of the range of Cane Toads (*Bufo marinus*). Although not yet found in Western Australia, the predicted range of this pest species includes the northern Kimberley and the Lower Ord

River. A preliminary risk assessment for the effects of cane toads in Kakadu (Northern Territory), where cane toads were first recorded in 2001, provides some indication of the potential impacts to the Ord River Floodplain site, were this species to invade. van Dam et al. (2002) listed the potential effects of cane toads as:

- Poisoning of predator species (e.g. birds, freshwater crocodile);
- Decreasing abundance and diversity of prey (invertebrates);
- Competing with native amphibian species; and
- Contaminating water supplies.

6.5 Recreation

The majority of the recreational activities the site offers are considered passive (e.g. bird watching, bush walking). However, there is the potential for impacts to the ecological character of the site from more active recreational activities.

CALM (1998) indicates that the driving of four-wheel drive vehicles off designated tracks and roads is a major problem within the Parry Lagoons. This has resulted in compaction of the soil, trampling of native vegetation and unsightly tracks. In addition it has provided access for the illegal collection of wildlife from the site. The extent of other recreation activities within the Ramsar site (e.g. boating, camping) and their effects on the ecological character are not known.

6.6 Tidal power

There is a proposal for a tidal power station within the Ord River Floodplain Ramsar site. Although still in early stages, with no government approval to proceed, the project should still be considered a potential threat to the ecological character of the Ramsar site.

The proposal includes the construction of a rock barrage across the Lower Ord River within the Ramsar site, just south of Panton Island and a storage facility in the west bank of the Ord River (Figure 50). The river would be diverted through the power plant, which comprises a series of turbines designed to capture the energy from the macro tide of the system. There has yet to be an environmental impact assessment for this project. However, there is the potential for a serious effect to connectivity between the outer estuary and the upstream river affecting the movement of saltwater crocodiles and diadromous fish; including the EPBC listed species (Freshwater Sawfish, Green Sawfish and Northern River Shark). In addition, hydrological changes may affect sediment dynamics, nutrient cycling and inundation of upstream regions.

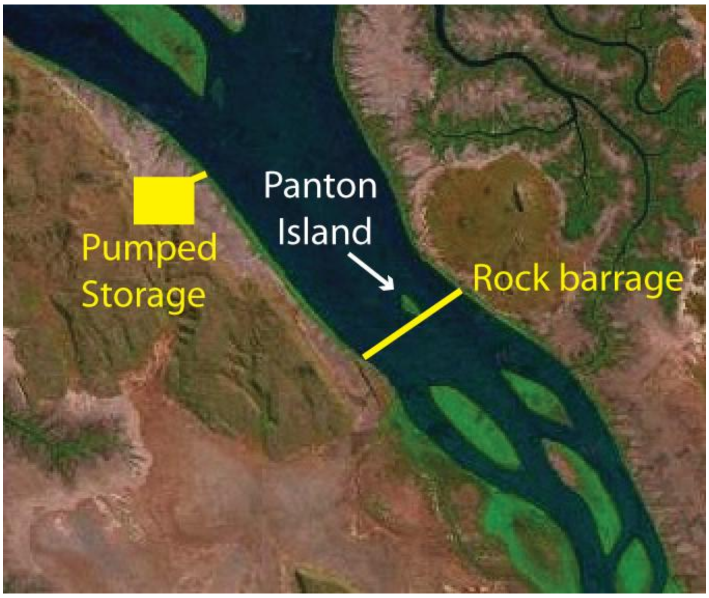


Figure 50: Location of the proposed tidal power facility on the Lower Ord River.

6.7 Fire

Fire regimes have changed over much of the bioregion since the disruption to traditional Aboriginal management, with generally fewer but more extensive and hotter fires. The summer wet season is a time of high productivity and rapid vegetation growth (particularly of non-woody plants). This high biomass subsequently cures during winter, resulting in a high fuel load by the late dry season (Williams 2002). Late dry season fires, particularly if between fire intervals have been long, can be very intense and have significant environmental impacts including tree death, change in species composition (with a loss of fire sensitive species), loss of nutrients from the soil and flow on effects to fauna from habitat and food source loss.

A fire management program has been developed for Parry Lagoons Nature reserve by the Department of Environment and Conservation and aerial control burning was undertaken within the Ramsar site for the first time in 2008 (Troy Sinclair, DEC, pers. com.).

6.8 Climate change

There are few published climate change predictions for the dry tropics. Hennessy et al. (2004) described potential climate change scenarios for the Northern Territory (Text Box 3). Which provide some indication of potential impacts to the Ord River Floodplain Ramsar site. The effect of these changes on a system that already has considerable natural disturbance (macro-tides, tropical cyclones) is unknown. It is predicted that climate change will impact on fire regimes in Australia. In the wet-dry tropics, there is a predicted increase in severe fires (Williams et al. 2001). This may have an effect on the vegetation of tropic savannahs and forests, with a shift to communities dominated by grasses and fire-tolerant trees and shrubs, at the expense of more sensitive species (Goldammer and Price 1998).

Summary of Northern Territory Climate Change

Average temperatures over the Northern Territory are projected to increase by 0.2 to 2.2°C by 2030, and 0.8 to 7.2°C by 2070, relative to 1990. Least warming is expected over the Top End and most warming in the south-west, especially in November to April. There would be associated increases in potential evaporation and heatwaves, and fewer frosts in the south during winter. Wet-season rainfall (Nov-Apr) is expected to decrease over most of the Territory (-16 to +8% by 2030, -40% to +20% by 2070), with little change in a 400-km-wide strip running from Darwin to Camooweal (±8% by 2030 and ±20% by 2070). Dry-season rainfall (May-Oct) is likely to decrease also (-20% to +8% by 2030, -60% to +20% by 2070), except near Darwin, which has a tendency for wetter condition (-8% to +20% by 2030, -20% to +60% by 2070). When rainfall changes are combined with increases in potential evaporation, a general decrease in available atmospheric moisture is projected. In Nov-Apr, the moisture balance south of Daly Waters declines 30-130 mm by 2030 and 90-400 mm by 2070, with smaller decreases in the north (mostly 10-80 mm by 2030 and 50-240 mm by 2070). In May-Oct, moisture balance declines 20- 100 mm by 2030 and 70-320 mm by 2070, with smaller decreases in the far south and Top End (10-80 mm by 2030 and 50-240 mm by 2070). Droughts are likely to become more frequent and more severe where moisture balance declines.

Since most climate impacts are due to extreme weather events, future changes in extreme events need to be considered. By 2030, the average number of days over 35°C at coastal sites is expected to rise by 1-51 days. Inland, the increase is likely to be 5-30 days in the south, 5-40 days in the north and 5-70 days in the centre. The intensity of tropical cyclones is likely to increase. This, combined with a sea-level rise 5-15 cm by 2030 and 10-50 cm by 2070, would increase coastal inundation due to storm surges. The frequency of heavy rainfall and inland flooding may also increase.

Text Box 3: Predicted climate change for the Northern Territory (Hennessy et al. 2004).

Regardless of the predicted impacts, climate change cannot be addressed at the site scale. However, increased knowledge of the potential impacts of climate change to this site, may lead to the identification of management activities that can be applied to help reduce impacts to ecological character.

7. Current Ecological Character and Changes to Ecological Character since the time of listing

The Ord River Floodplain Ramsar site was first listed under the Ramsar Convention as a wetland of international importance in 1990. At this point in time, the site had already been subject to significant hydrological alteration, as a result of water regulation and development as a part of the Ord River Irrigation Scheme, Phase 1. Since 1990, there has been further water related development on the Ord River, most significantly the increasing of the Ord River Dam wall by 6 metres and the commissioning of a hydroelectric power station.

DoW (2006) reported some hydrological parameters for pre and post increasing the dam wall and operation of the hydroelectric plant. However, there has been little difference in hydrology since the time of listing based on monthly mean flows (Figure 51) and variability.

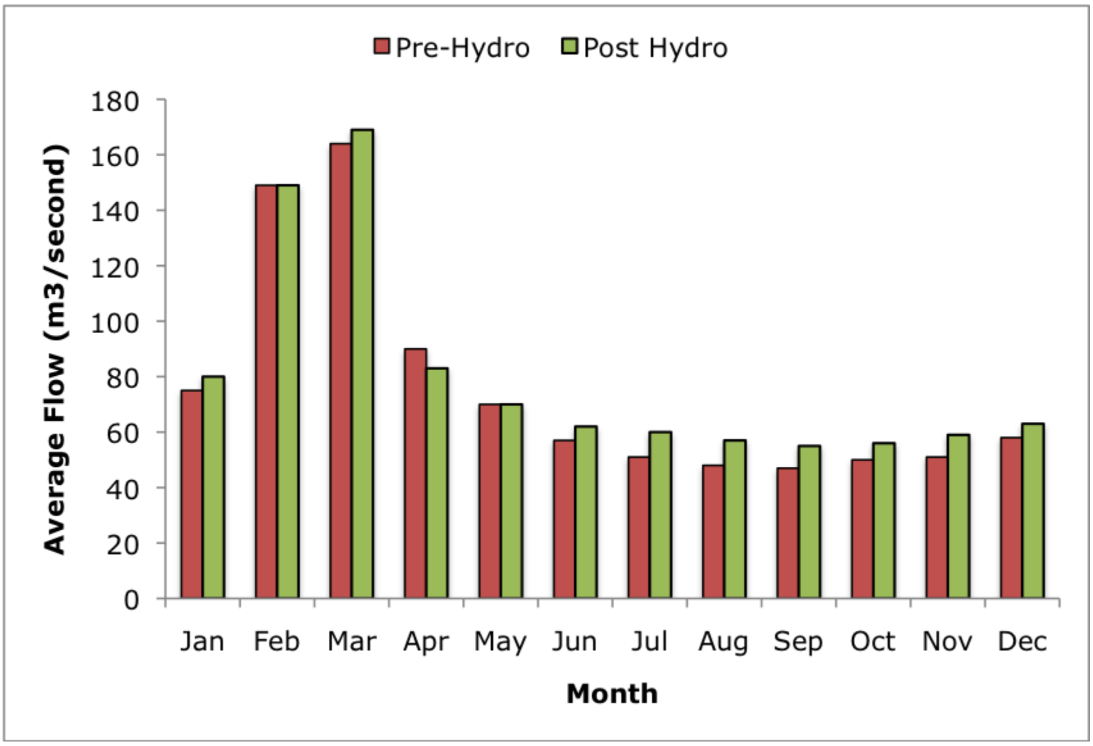


Figure 51: Mean monthly flow in the lower Ord River (below Dunham River) at the time of listing (pre-hydro) and current (post hydro). (Data from DoW 2006)

With the exception of hydrology described above, there is little quantitative data upon which to base potential changes in the ecological character of the Ramsar site since the time of listing. Anecdotal evidence suggests that the high rainfall in 2006 (> 1500mm) and the in the early part of 2008 (600 mm in February 2008) may have flushed the system and removed some of the deposited sediment at the estuary mouth. However, there is no data to support this.

Monitoring and survey results generally do not span the period of time 1990 to 2008, and the small amount of data available, indicates that there have not been significant changes in the site since the time of listing (e.g. crocodile populations, commercial fishing data).

There have, however, been significant changes in the hydrology and geomorphology of the site since European settlement, and in particular since the regulation of the Ord River with the construction of the two dams. As described in section 3 above the following significant changes have occurred in the Lower Ord River since regulation:

- A 35% decrease in total annual flow;
- A change in the seasonality with a 440% increase in average dry season flows (prior to regulation the Ord River dried to a series of pools with little or no flow during the dry season);
- A reduction in the variability of flows;
- A reduction in overbank flows and inundation of the Parry Lagoon area; and
- An increase in fine sediment accumulation in the Ord estuary as a result of decreased flushing flows.

The alteration of hydrological regimes is considered to be the most significant threat to be ecology of rivers and floodplain wetlands (Naiman et al. 1995). The potential effects of altered hydrology include (Bunn and Arthington 2002 and references within):

- Increased stability of baseflow and reduction of flow variability
    - Excessive growths of aquatic macrophytes
- Timing of rising flows
    - Loss of cues for fish spawning and migration
- Reduced frequency, duration and area of inundation of floodplain wetlands
    - Reduced spawning areas and/or recruitment success of lowland river fish
    - Decline in waterbird species richness and abundance
    - Loss of functions for waterbirds at critical stages of life cycle (breeding, migration stopover)
    - Decline in wetland vegetation

While many of these effects have been recorded in the lower Ord River upstream of the Ramsar site, the Ord Estuary continues to operate as a highly productive ecosystem with abundant top predators such as Barramundi and Crocodiles. Parslow et al. (2003) hypothesised that the Ord Estuary has been naturally subject to high levels of disturbance via high interannual changes in river flows and consequent large fluctuations in salinity, sediments and nutrients. They further suggested that the system had “adapted” to the new regime without significant effect on function.

Having said this, however, maintenance of function does not necessarily equate to maintenance of all ecological character. There may have been changes to species, communities and processes; there is however, no data upon which to determine these changes with few records prior to regulation.

8. Knowledge Gaps

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

The key knowledge gaps that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table 18, together with a brief description of the action required to address these gaps.

Table 18: Knowledge Gaps for the Ord River Floodplain Ramsar site

Component/Process	Knowledge Gap	Recommended Action
Hydrology	Arguably the most significant knowledge gap for this site is the role of Parry Creek in inundation of Parry Lagoons (and associate floodplain). Since regulation, it is likely that inundation from local catchments and Parry Creek is the most significant and regular pathway for flooding of the site. However, there is no data on timing, frequency, duration or extent of flooding.	A high resolution digital elevation model (compiled from Lidar data) exists for Parry Lagoons. This DEM could be used, together with hydrological monitoring in Parry Creek to develop a hydrological model of inundation of the floodplain.
	While the hydrology of the river upstream of the Ramsar site has been characterised, little is known of the hydrology within the site, especially in the estuary and False Mouths of the Ord.	Hydrological monitoring of the estuary (tide gauges) linked to water quality (see below).
Water Quality	Water quality information for the site is based on a single 15-month survey (Parslow et al. 2003). Little is known about interannual variability over long time scales	Regular water quality monitoring (salinity, nutrients and pH) at Parry Lagoons and within the estuary
Vegetation communities	With the exception of the extent of mangroves, there is no quantitative information on the extent and composition of vegetation communities within the Ramsar site	Mapping of extent of vegetation (remote sensing) and community composition (ground surveys in both wet and dry seasons) to set a baseline against which change can be assessed.
Mangrove communities	Apart from limited bird surveys there is no information on the species and communities that inhabit the mangrove creek systems such as those of the False Mouth of the Ord	Comprehensive ecological investigation of the False Mouths of the Ord
Fish	Current community composition and abundance of fish within the site. No surveys dedicated to the estuary could be found.	Annual fish surveys
Waterbirds	The abundance and species of waterbirds that regularly use Parry Lagoons in the wet season. Current knowledge is based on surveys in the 1980s, 1993 and a single survey in 2005.	Annual waterbird surveys, including both wet season (most critical) and dry seasons.
Threatened species	The site is thought to support four species listed under threatened species legislation (Freshwater Sawfish, Green Sawfish, Northern River Shark and Australian Painted Snipe). However, records for these species are based on isolated surveys.	Investigation into the status of these threatened species within the site.

9. Monitoring Needs

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

While there may be existing monitoring programs in place for components within the Ord River Floodplain Ramsar site, there is no over-arching monitoring program designed to detect and manage changes to the ecological character of the wetlands. A management plan is currently in preparation for the system, which will act as an overarching guide for decision makers and stakeholders in the region this will include monitoring actions.

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

9.1 Existing monitoring programs

There are few monitoring programs in the region that regularly measure components within the Ord River Ramsar site. Current (or recently completed) programs include:

Water quality and hydrology

Water quality and hydrology were measured monthly at “The Rocks” and a number of sites within the Ramsar site for the CSIRO Lower Ord River and Estuary Study (Robson et al. 2008). This included nutrients, chlorophyll *a*, turbidity and salinity as well as hydrological measures such as stage height. However, this project was completed in 2008 and sampling ceased in 2007. There are no plans to continue the CSIRO monitoring of water quality or hydrology within the Ramsar site (Duncan Palmer, Department of Water, pers. comm.).

There has been no regular water quality or hydrological monitoring at Parry Lagoons although isolated samples have been collected under a number of programs (e.g. Water and Rivers 2003a). An aerial electromagnetic survey and the acquisition of ground-truth data is currently being collected to determine salinity levels of groundwater within the Parry Lagoons area (DEC, pers. com.). A recent digital elevation model was completed for Parry Lagoons, by LIDAR. This information would be useful for developing a hydrological model of the system, but as yet there is no program in place to undertake this.

Biodiversity

Three sites (two terrestrial and one floodplain) within the Parry Lagoons are included in a Kimberley regional monitoring program. Vegetation surveys, invertebrates and fauna trapping are conducted together with photo-point monitoring at 50 m plots. The monitoring commenced n 2006, and repeat surveys are planned for every 2 – 5 years (Karin Carnes, DEC. pers. com.).

Frogs

A frog monitoring program using sophisticated bioacoustic monitoring equipment is planned for a number of sites in Western Australia under a joint Commonwealth Government and Department of Environment and Conservation funded project. Parry Lagoons has been identified as a potential site under this program and it is expected that frogs will be monitored from 2008 onwards (Gordon Grigg, University of Queensland).

Waterbirds

There is no regular on-going bird monitoring within the Ord River Floodplain Ramsar sites. There were surveys conducted in the 1980s, 1993 and 2005 at Parry Lagoons. However, there are no plans for continued monitoring at any sites within the Ramsar site.

Crocodiles
The crocodile management program in Western Australia involves monitoring of both Saltwater and Freshwater Crocodiles through helicopter and spotlight surveys in Cambridge Gulf, Lake Kununurra and Lake Argyle. Surveys in specific "monitoring" zones have been carried out annually since 1992 (Wildlife Management International 2008). The Cambridge Gulf monitoring zone includes areas within the Ramsar site within the lower Ord River.

9.2 Monitoring of Ecological Character

The recommended monitoring to meet the obligations under Ramsar and the EPBC Act (1999) with respect to the Ord River Floodplain Ramsar site are provided in Table 19. There are few current programs in place and so much of this represents establishing new monitoring initiatives. In recognition that there will be limited funds for monitoring, a priority has been assigned to each component.

Detailed monitoring design is essential to ensure that appropriate and useful data is collected. Although a detailed monitoring program design for each of these components is beyond the scope of an ecological character description, it is recommended that the Ramsar framework for monitoring wetlands be used as a guide in developing monitoring programs (Text Box 2).

Finlayson (2001) describes the difference between monitoring and surveillance:

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

While there has been a number of scientific research projects and some ad hoc surveys, there has been little "monitoring" (as defined above) conducted in the Ord River Floodplain Ramsar site. The exceptions to this are hydrology, water quality and the annual crocodile surveys of the lower Ord River and estuary. The need for co-ordinated, purpose designed, objective driven monitoring of ecological character in the Ord River Floodplain system must be emphasised.

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

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

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

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

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

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

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

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

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

Text Box 2: Ramsar framework for monitoring wetlands (Annexure to Resolution VI.1: http://www.ramsar.org/res/key_res_vi.1.htm)

Table 19: Monitoring needs for the Ord River Floodplain Ramsar site

Component/Process	Purpose	Indicator	Locations	Frequency	Priority
Hydrology	Establishment of baseline and then detection of change	Inundation frequency and extent of Parry Lagoons Flow (m^3/s) at Parry Creek	Across Parry Lagoons and Floodplain	Flow – continuous Inundation - annual	Highest
	Detection of change	Flow (m^3/s) Stage height (metres AHD)	Existing monitoring locations in the Ord Estuary and Cambridge Gulf (Robson et al. 2008)	Continuous	High
Geomorphology	Detection of change	Cross-channel profile	Estuarine reach of the Ord River at locations of Wolanski et al. (2001)	Annual	Moderate
Water Quality - general	Establishment of baseline and then detection of change	Nutrients (total nitrogen, ammonium, nitrate-nitrite, total phosphorus, orthophosphate); salinity, dissolved oxygen, suspended sediments	At hydrological monitoring points	Optimum – event based Monthly - minimum	High
Water Quality - toxicants	Detection of change	Agrochemicals including Endosulphan and Atrazine	Existing monitoring locations	Monthly	High
Vegetation - extent	Establishment of baseline and then detection of change	Extent of broad vegetation types (remote sensing)	Entire Ramsar site	Every 5 years	High
Vegetation -community composition	Establishment of baseline and then detection of change	Community composition of vegetation types (field surveys)	Entire Ramsar site	Every 5 years	High
Weeds	Determination of impact	Location, extent, species	Parry Lagoons	Annual	Low
Macroinvertebrates	Establishment of baseline and then detection of change	Abundance, community composition	Mudflats and shallow wetland areas	Annual	Low
Fish - species	Establishment of baseline and then detection of change	Community composition	Parry Lagoon, Ord Estuary	Annual	Moderate
Fish - abundance	Establishment of baseline and then detection of change	Abundance of key species such as Barramundi	Parry Lagoon, Ord Estuary	Annual	High
Waterbirds	Establishment of baseline and then detection of change	Counts and species identifications, breeding observations	Parry Lagoon	Seasonal	High
Mangrove birds	Establishment of baseline and then detection of change	Species identifications and breeding observations	Ord Estuary and False Mouths of the Ord	Annual	Low
Crocodiles	Detection of change	Population estimates	Existing survey locations (CALM 2003)	Annual	High

10. Communication and Education Messages

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

A management plan for the Ord River Floodplain Ramsar site is currently under development. This will include consideration of CEPA activities and a range of communication and education messages and actions. Following on from the identified threats to the ecological character of the Ord River Floodplain Ramsar site (see Section 6, above), there are a number of communication and education messages that could be given priority. These include:

- Identification of threatened fish species (Freshwater Sawfish, Green Sawfish and Northern River Shark) for recreational and commercial fishermen - this may help to minimise the number of these species taken and / or released dead and could help to improve records for these rare fish;

- Effect of disturbance on migratory birds – the importance of energy conservation for migratory birds and steps the community can take to minimise shorebird disturbance by walking, boating and recreational vehicles;

- Connectivity between fresh and marine waters – community education for locals and visitors on the importance of both marine and freshwater environments to crocodiles and native fish and the potential impacts of barriers to this connectivity such as reduced floodplain inundation and physical barriers within the river and estuary; and

- The uniqueness of the Ord River Floodplain Ramsar site and its potential role in tourism for the region – in addition to the bird hide and interpretative signs at Parry Lagoons, a broader campaign to inform the community and local tourist operators of the existence of the Ramsar site and the natural values of the system.

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Appendix A: Method

A.1 Approach

The method for compiling this ECD comprised of the following tasks:

Project Inception:
Consultant team leader Jennifer Hale met with the Western Australian Department of Environment and Conservation (DEC) project manager to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted.

Task 1: Review and compilation of available data
The consultant team undertook a thorough desktop review of existing information on the ecology of the Ord River Floodplain. This task also involved the consultant team leader travelling to Kununurra to gather local data and information sources. The consultant met with the local DEC staff that will be responsible for developing the management plan for the site to align the ECD process with the management planning process.

Task 2: Stakeholder engagement and consultation
DEC formed a Technical Advisory Group (TAG) specifically for the Ord River Floodplain Ramsar site ECD. This group was comprised of the following stakeholders with an interest in the ECD and management planning process:

Mr Michael Coote, Department of Environment and Conservation, Perth
Mr Robert Cossart, Department of Water, Kununurra
Ms Sarah Greenwood, Department of Environment and Conservation, Kununurra
Ms Jennifer Higbid, Department of Environment and Conservation, Perth
Mr Ben Malseed, Department of Water, Perth
Mr Daryl Moncrieff, Department of Environment and Conservation, Kununurra
Mr Troy Sinclair, Department of Environment and Conservation, Kununurra
Dr Clare Taylor, CSIRO
Mr Gareth Watkins, Department of Environment and Conservation, Perth

The TAG met in Perth on the 22nd of July to discuss the components, processes, services and benefits of the Ord River Floodplain Ramsar site. In addition, members of the TAG provided written comments on drafts of the ECD.

A community presentation of the ECD and management planning process is to be undertaken in Kununurra later in 2008.

Task 3: Development of a draft ECD
Consistent with the national guidance and framework (2008) the following steps were undertaken to describe the ecological character of the Ord River Floodplain Ramsar site.

Steps from the national draft (2008) framework	Activities
1. Document introductory details	Prepare basic details: site details, purpose, legislation
2. Describe the site	Based on the Ramsar RIS and the above literature review describe the site in terms of: location, land tenure, Ramsar criteria, wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services	Identify all possible components, services and benefits. Identify and describe the critical components, services and benefits responsible for determining ecological character
4. Develop a conceptual model of the system.	Two types of models were developed for the system: A series of control models that describe important aspects of the ecology of the site, including feedback loops. Aiding in the understanding of the system and its ecological functions. A stressor model that highlights the threats and their effects on ecological components and processes. Aiding in understanding management of the system.

Steps from the national draft (2008) framework	Activities
5. Set Limits of Acceptable Change	For each critical component process and service, establish the limits of acceptable change.
6. Identify threats to the site	This process identified both actual and potential future threats to the ecological character of the wetland system.
7. Describe changes to ecological character since the time of listing	This section describes in quantitative terms (where possible) changes to the wetlands since the initial listing in 1990 and the expansion to the site in 2001
8. Summarise knowledge gaps	This identifies the knowledge gaps for not only the ecological character description, but also for its management.
9. Identify site monitoring needs	Based on the identification of knowledge gaps above, recommendations for future monitoring are described.
10. Identify communication, education and public awareness messages	Following the identification of threats, management actions and incorporating stakeholder comments, a general description of the broad communication / education messages are described.

Task 4: Revision of the Ramsar Information Sheet (RIS)
The information collated during Task 1, together with the draft Ecological Character Description was used to produce a revised RIS in the standard format provided by Ramsar.

Task 5 Finalising the ECD and RIS
The draft ECD and RIS were submitted to DEC, the TAG and the Department of Environment, Water Heritage and the Arts (DEWHA) for review. Comments from agencies and stakeholders were incorporated to produce revised ECD and RIS documents. DEC contributed to the updating of the boundary information for the RIS and finalised both documents.

A.2 Consultant Team

Jennifer Hale (team leader)
Jennifer has over eighteen years experience in the water industry having started her career with the State Water Laboratory in Victoria. Jennifer is an aquatic ecologist with expertise in wetland, riverine and estuarine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for the Peel-Yalgorup, the Coorong, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites. Jennifer also has a solid knowledge and understanding of estuarine systems.

Roger Jaensch
Roger Jaensch is a waterbird expert of national and international repute. He has extensive on-ground experience on a range of wetlands across Australia, including the Ord River Floodplain. He has been working in the field of wetlands and waterbirds for over 25 years and has extensive experience in the description, management and nomination of Ramsar sites. He is currently a senior program officer with Wetlands International, and has held high level positions with Birds Australia and the Asian Wetland Bureau here and overseas. He has not only an understanding of the site and extensive knowledge on waterbirds, but also a sound background in the Ramsar Convention and its application to the management of Australian Wetlands.

David Morgan
David Morgan is a fish biologist specialising in zoogeography of fishes, habitat and environmental associations of fishes, biology of fishes, ontogenetic changes in diet of fishes, parasitism of fishes, impacts of introduced fishes and habitat modification on native fishes, utilisation of fishways and ethnobiology. He is a lecturer at Murdoch University and a member of the Centre for Fish and Fisheries Research. He is the Western Australian representative on

the Exotic Fishes Committee of the Australian Society for Fish Biology and a member of the Western Australian Recreational Freshwater Fisheries Stakeholder Sub-committee. He has extensive experience with the fish of the Kimberley region and the Ord River system.

Halina Kobryn

Dr Halina Kobryn has over fifteen years of experience in applications of GIS and remote sensing in environmental applications. She is a GIS and remote sensing expert, specialising in natural resource assessment. Dr Kobryn has a BSc in Physical Geography and Cartography, Graduate Diploma in Surveying and Mapping and a PhD which explored impacts of stormwater on an urban wetland and explored GIS methods for such applications. She has worked at a university as a lecturer for over 15 years and taught many subjects including GIS, remote sensing, environmental monitoring and management of aquatic systems. She has developed the first course in Australia (at a graduate level) on Environmental Monitoring. She has been involved in many research and consulting projects and her cv outlines the breadth of her expertise. She has also supervised over 20 research students (honours, Masters and PhD). She has worked in Indonesia, Malaysia (Sarawak) and East Timor on projects related to water quality and river health.

Mark Lund

Associate Professor Mark Lund is a wetland ecologist with 20 years of experience in Western Australian Wetland systems. He is a lecturer and Head of School for Natural Sciences at Edith Cowan University. Mark is a generalist wetland ecologist with experience and skills in a wide range of fields including macroinvertebrates, water quality and wetland rehabilitation. Mark has extensive experience in the Ord River Floodplain and has been the lead author on a number of seminal papers on the effects of altered hydrology on the ecology of the lower Ord River and estuary.

Eric Paling

Associate Professor Eric Paling is an ecologist with over 20 years experience in mangrove ecology and impact assessment. He is a lecturer at Murdoch University and the director of the Marine and Freshwater Research Laboratory. He has produced 34 refereed book chapters or journal articles and 110 technical reports and is Australia's foremost expert in mangrove impact assessment. Eric has extensive experience in mangrove and seagrass nutrient relationships and the impact of water quality on benthic plant communities. His research covers research covers seagrass growth and photodynamics, mangrove biology and impact assessment, macro-algal distribution and nutrient dynamics along with marine, estuarine and lake water quality.

Appendix B: Fish Species

Based on species either recorded or predicted to occur within the Ramsar site from Water and Rivers Commission (2003a), Gehrke (2008) and Stevens et al. (2005).

Life cycle category based on Storey (2003) and FishBase (2007)- Am – Amphidromous, An-Anadromous, C-Catadromous, E- Breeds in estuaries, F- Fresh water, MO - marine estuarine-opportunist

Environment and biological information sourced from FishBase (Froese, R. and D. Pauly. Editors. 2007.FishBase. World Wide Web electronic publication.www.fishbase.org , version (05/2007) (original references not cited).

Family	Species	Common Name	Life cycle	Habitat	Listing		Occurrence		
					IUCN	EPBC	Parry Lagoons	Estuary	Freshwater / Tidal
Ambassidae	*Ambassis macleayi*	Macleay's Glassfish	F	Demersal			Recorded		Predicted
	Ambassis muelleri	Mueller's Glassfish	F	Demersal			Recorded		Predicted
	Ambassis vachelli	Vachelli's Glass Perchlet	MO	Demersal				Predicted	
	Parambassis gulliveri	Giant Glassfish	F	Demersal					Predicted
Anguillidae	*Anguilla bicolor*	Northern Eel	C	Demersal					Predicted
Apogonidae	*Glossamia aprion*	Mouth Almighty	F	Benthopelagic					Predicted
Ariidae	*Arius graeffei*	Lesser Salmon Catfish	F, E, MO	Demersal				Predicted	Predicted
	Arius leptaspis	Triangular Shield Catfish	F, E, MO	Demersal					Predicted
	Arius midgleyi	Silver Cobbler	F, E, MO	Demersal					Recorded
Atherinidae	*Craterocephalus stramineus*	Blackmast	F	Benthopelagic					Recorded
Belonidae	*Strongylura krefftii*	Longtom	F	Pelagic					
Carcharhinidae	*Carcharhinus leucas*	Bull Shark	C	Pelagic	NT			Observed	Observed
	Glyphis sp. C	Northern River Shark	Am? MO, E	Pelagic	CE	E		Recorded	Recorded
Clupeidae	*Nematalosa come*	Mud Herring	MO	Pelagic				Recorded	
	Nematalosa erebi	Bony Bream	F	Pelagic					Predicted

Family	Species	Common Name	Life cycle	Habitat	Listing		Occurrence		
					IUCN	EPBC	Parry Lagoons	Estuary	Freshwater / Tidal
Dasyatidae	*Dasyatis* sp.	Stingrays						Recorded	
	Himantura chaophraya	Freshwater Whipray	F, E	Demersal				Predicted	Predicted
Eleotridae	*Hypseleotris compressa*	Empire Gudgeon	F, E	Demersal			Recorded		Predicted
Elopidae	*Elops hawaiensis*	Hawaiian Giant Herring	MO	Pelagic				Predicted	
Gobiidae	*Glossogobius giuris*	Tank Goby	F, Am	Benthopelagic			Recorded	Predicted	Predicted
	Periophthalmus spp.	Mudskippers	E	Demersal				Observed	
Hemiramphidae	*Arrhamphus sclerolepis*	Northern snub-nosed Garfish	MO	Pelagic				Predicted	Predicted
Kurtidae	*Kurtus gulliveri*	Nurseryfish	E	Benthopelagic				Recorded	Predicted
Latidae	*Lates calcarifer*	Barramundi	C	Demersal			Recorded	Recorded	Recorded
Leiognathidae	*Leiognathus equulus*	Common Ponyfish	MO	Demersal				Predicted	Predicted
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack	MO, C	Reef-associate				Recorded	Predicted
	Lutjanus johnii	Golden Snapper	MO	Reef-associate				Recorded	
Megalopidae	*Megalops cyprinoides*	Oxeye Herring	Am, MO	Benthopelagic			Recorded		Observed
Melanotaeniidae	*Melanotaenia australis*	Western Rainbowfish	F	Pelagic			Recorded		Predicted
Mugilidae	*Liza subviridis*	Greenback mullet	C	Demersal				Predicted	Predicted
	Liza vaigiensis	Diamondscale mullet	C	Reef-associated				Predicted	Predicted
	Mugil cephalus	Sea Mullet	C	Benthopelagic				Predicted	Predicted
	Rhinomugil nasutus	Popeye Mullet	E	Benthopelagic				Observed	
Platycephalidae	*Platycephalus arenarius*	Fan-tailed Flathead	MO	Demersal				Predicted	
Polynemidae	*Eleutheronema tetradactylum*	Blue threadfin salmon	E	Pelagic				Recorded	
	Polydactylus macrochir	Giant threadfin Salmon	MO, E	Demersal				Recorded	

Family	Species	Common Name	Life cycle	Habitat	Listing		Occurrence		
					IUCN	EPBC	Parry Lagoons	Estuary	Freshwater / Tidal
Pristidae	*Pristis microdon*	Freshwater Sawfish	C	Demersal	CE	V		Predicted	Recorded
	Pristis zijsron	Green Sawfish	MO	Demersal	CE	V		Predicted	Recorded
Scatophagidae	*Scatophagus argus*	Spotted scat	MO	Reef-associated				Observed	Observed
Sciaenidae	*Nibea squamosa*	Scaly Jewfish	E, MO	Benthopelagic				Predicted	
	Protonibea diacanthus	Black Jewfish	MO	Demersal					Predicted
Scombridae	*Scomberomorus semifasciatus*	Grey Mackerel	MO	Pelagic					Predicted
Serranidae	*Epinephelus coioides*	Estuary Groper	E	Benthopelagic				Predicted	
	Epinephelus lanceolatus	Queensland Groper	MO	Demersal	V			Predicted	
	Epinephelus malabaricus	Malabar Cod	Am	Benthopelagic				Predicted	
Siganidae	*Siganus sp.*	Happy Moments	E, MO					Predicted	
Sillaginidae	*Sillago sihama*	Northern Whiting	Am, E	Benthopelagic				Predicted	
Teraponidae	*Amniataba percoides*	Barred Grunter	F	Benthopelagic				Predicted	Predicted
	Hephaestus jenkinsi	Black Bream	F	Benthopelagic					Predicted
	Leiopotherapon unicolor	Spangled Perch	F	Demersal			Recorded		Predicted
	Syncomistes butleri	Butler's grunter	F	Benthopelagic					Predicted
	Terapon jarbua	Crescent perch	E	Demersal				Predicted	
Tetraodontidae	*Chelonodon pafoka*	Milk-spotted Puffer	MO	Reef-associated				Observed	
	Marilyna meraukensis	Merauke toadfish	MO	Demersal				Predicted	Observed
Toxotidae	*Toxotes chatareus*	Seven-spotted Archerfish	F	Pelagic					Observed

Appendix C: Waterbirds and mangrove birds recorded in the Ord River Floodplain Ramsar Site

Location: PL= Parry Lagoon; FMO = False Mouths of Ord; ORE = Ord River Estuary. Blank indicates the species is listed in CALM 1998 or in the Birds Australia Atlas, but the location within the Ramsar site is not recorded

X = present; B = breeding

Species listing: ME = Listed as migratory or marine under the EPBC Act; J = JAMBA; C= CAMBA; R = ROKAMBA,; V = Vulnerable under the EPBC Act (Australian Painted Snipe)

Species list compiled from CALM 1998; Jaensch 1986; Hassel et al. 2006; and Johnstone 1990

Common Name	Species Name	Location			Listing
		PL	FMO	ORE	
Ducks and Allies					
Australasian Shoveler	*Anas rhynchotis*	X			ME
Australian Wood Duck	*Chenonetta jubata*	X			ME
Black Swan	*Cygnus atratus*	X			ME
Chestnut Teal	*Anas castanea*	X			ME
Freckled Duck	*Stictonetta naevosa*	X			ME
Garganey Teal	*Anas querquedula*	X			ME, C, J, R
Green Pygmy-goose	*Nettapus pulchellus*	X			ME
Grey Teal	*Anas gracilis*	X			ME
Hardhead	*Aythya australis*	X			ME
Magpie Goose	*Anseranas semipalmata*	B			ME
Pacific Black Duck	*Anas superciliosa*	X			ME
Pink-eared Duck	*Malacorhynchus membranaceus*	X			ME
Plumed Whistling-Duck	*Dendrocygna eytoni*	X			ME
Radjah Shelduck	*Tadorna radjah*	X			ME
Wandering Whistling-Duck	*Dendrocygna arcuata*	X			ME
Grebes					
Australasian Grebe	*Tachybaptus novaehollandiae*	B			
Great Crested Grebe	*Podiceps cristatus*				
Hoary-headed Grebe	*Poliocephalus poliocephalus*				
Pelicans, Cormorants and Darters					
Australian Pelican	*Pelecanus conspicillatus*	X			ME
Darter	*Anhinga melanogaster*	B			
Great Cormorant	*Phalacrocorax carbo*				
Little Black Cormorant	*Phalacrocorax sulcirostris*	X			
Little Pied Cormorant	*Phalacrocorax melanoleucos*	X			
Pied Cormorant	*Phalacrocorax varius*	X			
Herons, Ibis, Egrets and Spoonbills					
Australian White Ibis	*Threskiornis molucca*	X			ME, J
Black Bittern	*Ixobrychus flavicollis*	X			
Black-necked Stork	*Ephippiorhynchus asiaticus*	X	X		
Cattle Egret	*Ardea ibis*				ME, C, J
Glossy Ibis	*Plegadis falcinellus*	X			ME, C, J
Great Egret	*Ardea alba*	X	X		ME, C, J
Intermediate Egret	*Ardea intermedia*	B			ME
Little Egret	*Egretta garzetta*	B			ME
Mangrove Heron	*Butorides striatus*			X	
Nankeen Night Heron	*Nycticorax caledonicus*	X			ME

Pied Heron	*Ardea picata*	X			
Royal Spoonbill	*Platalea regia*	X			
Straw-necked Ibis	*Threskiornis spinicollis*	X			
White-faced Heron	*Egretta novaehollandiae*	X			
White-necked Heron	*Ardea pacifica*	X			
Yellow-billed Spoonbill	*Platalea flavipes*	X			
Hawks, Eagles and Falcons					
Osprey	*Pandion haliaetus*				ME
Swamp Harrier	*Circus approximans*	X			ME
White-bellied Sea Eagle	*Haliaeetus leucogaster*	X			ME, C
Cranes, Crakes and Rails					
Australian Crake	*Porzana fluminea*	X			
Black-tailed Native-hen	*Gallinula ventralis*	B			
Brolga	*Grus rubicunda*	X			
Buff-banded Rail	*Gallirallus philippensis*	X			
Chestnut Rail	*Eulabeornis castaneoventris*			B	
Eurasian Coot	*Fulica atra*	B			
Purple Swamphen	*Porphyrio porphyrio*	B			
White-browed Crake	*Porzana cinerea*	X			
Comb-crested Jacana	*Irediparra gallinacea*	B			
Shorebirds					
Australian Pratincole	*Stiltia isabella*	X			ME
Banded Lapwing	*Vanellus tricolor*				
Bar-tailed Godwit	*Limosa lapponica*			X	ME, C, J, R
Beach-Stone Curlew	*Esacus neglectus*		X	X	ME
Black-fronted Dotterel	*Elseyornis melanops*	X			
Black-tailed Godwit	*Limosa limosa*	X		X	ME, C, J, R
Black-winged Stilt	*Himantopus himantopus*	X			ME
Bush-Stone-curlew	*Burhinus grallarius*	X			
Common Greenshank	*Tringa nebularia*	X			ME, C, J, R
Common Sandpiper	*Actitis hypoleucos*	X			ME, C, J, R
Curlew Sandpiper	*Calidris ferruginea*	X			ME, C, J, R
Eastern Curlew	*Numenius madagascariensis*		X	X	ME, C, J, R
Great Knot	*Calidris tenuirostris*				ME, C, J, R
Greater Sand Plover	*Charadrius leschenaultii*				ME, C, J, R
Grey Plover	*Pluvialis squatarola*				ME, C, J, R
Grey-tailed Tattler	*Heteroscelus brevipes*			X	ME, C, J, R
Little Curlew	*Numenius minutus*	X			ME, C, J, R
Long-toed Stint	*Calidris subminuta*				ME, C, J, R
Marsh Sandpiper	*Tringa stagnatilis*	X			ME, C, J, R
Masked Lapwing	*Vanellus miles*	X			
Oriental Plover	*Charadrius veredus*				ME, J, R
Oriental Pratincole	*Glareola maldivarum*	X			
Pacific Golden Plover	*Pluvialis fulva*	X			ME, C, J, R
Painted Snipe	*Rostratula australis*	X			ME, V, C
Pectoral Sandpiper	*Calidris melanotos*	X			ME, J, R
Red-capped Plover	*Charadrius ruficapillus*	X			ME
Red-kneed Dotterel	*Erythrogonys cinctus*	X			
Red-necked Avocet	*Recurvirostra novaehollandiae*	X			ME

Red-necked Stint	*Calidris ruficollis*	X			ME, C, J, R
Ruddy Turnstone	*Arenaria interpres*				ME, C, J, R
Ruff	*Philomachus pugnax*				ME, C, J, R
Sharp-tailed Sandpiper	*Calidris acuminata*	X			ME, C, J, R
Swinhoe's Snipe	*Gallinago megala*	X			ME, C, J, R
Terek Sandpiper	*Tringa terek*		X	X	ME, C, J, R
Whimbrel	*Numenius phaeopus*			X	ME, C, J, R
Wood Sandpiper	*Tringa glareola*	X			ME, C, J, R
Gulls and Terns					
Caspian Tern	*Sterna caspia*	X			ME, C, J
Crested Tern	*Sterna bergii*			X	ME
Gull-billed Tern	*Sterna nilotica*	X	X	X	ME
Little Tern	*Sterna albifrons*				ME, C, J, R
Silver Gull	*Larus novaehollandiae*	X	X	X	ME
Whiskered Tern	*Chlidonias hybridus*	X		X	ME
White-winged Black Tern	*Chlidonias leucopterus*	X			ME, C, J, R
Mangrove Birds					
Bar-shouldered Dove	*Geopelia humeralis*			X	
Black Butcherbird	*Cracticus quoyi*		X	B	
Chestnut Rail*	*Eulabeornis castaneoventris*			B	
Lemon-breasted Flycatcher	*Microeca flavigaster*			X	
Mangrove Flycatcher	*Gerygone levigaster*			X	
Mangrove Golden Whistler	*Pachycephala melanura*			X	
Mangrove Grey Fan-tail	*Rhipidura phasiana*		X	X	
Mangrove Heron*	*Butorides striatus*			X	
Mangrove Kingfisher	*Halcyon chloris*			B	
Mangrove Robin	*Eopsaltria pulverulenta*			X	
White-breasted Whistler	*Pachycephala laniodes*			X	
White-breasted wood Swallow	*Artamus leucorynchus*			X	
Other Birds					
Yellow Chat	*Ephthianura crocea*	B			
Zitting Cisticola	*Cisticola juncidis*	B			
Clamorous Reed-Warbler	*Acrocephalus stentoreus*	X			

*Considered both mangrove dependant as well as waterbirds

Waterbird feeding and guilds.

Feeding Guilds: F1= dense inundated vegetation; **F2** = Shallows (<0.5m) &/or mud; **F3=** Deep water (>1m); **F4** = Away from wetland habitats
Dietary Guilds: D1= Plants and animals; **D2** = Mostly plants; **D3=** Mostly animals; **D4** = Fish
X = Common or usual, O = Occasional

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Ducks and Allies								
Australasian Shoveler		X	X		X			
Australian Wood Duck				X	X			
Black Swan		X	X	X		X		
Chestnut Teal		X	X		X			
Freckled Duck		X	X		X			
Garganey Teal		X	X		X			
Green Pygmy-goose		X	X			X		
Grey Teal		X	X		X			
Hardhead		X	X		X			O
Magpie Goose		X				X		
Pacific Black Duck		X	X	X	X			
Pink-eared Duck		X	X		X			
Plumed Whistling-Duck		X	X		X			
Radjah Shelduck		X	X		X			
Wandering Whistling-Duck		X	X		X			
Grebes								
Australasian Grebe		X	X				X	X
Great Crested Grebe			X			O	X	X
Hoary-headed Grebe		X	X				X	X
Pelicans, Cormorants and Darters								
Australian Pelican			X				X	X
Darter			X		X			X
Great Cormorant			X				X	X
Little Black Cormorant			X				X	X
Little Pied Cormorant		X	X				X	X
Pied Cormorant			X				X	X
Herons, Ibis, Egrets and Spoonbills								
Australian White Ibis		X		X			X	X
Black Bittern	X	X					X	X
Cattle Egret		X		X		X	X	X
Glossy Ibis		X				X	O	X
Great Egret		X		X		X	X	X
Intermediate		X		X		X	X	X
Little Egret		X				X	X	X
Mangrove Heron	X	X					X	X
Nankeen Night Heron	X	X		X		X	X	X
Pied Heron	X	X					X	X
Royal Spoonbill		X			O	X	X	X
Straw-necked Ibis		X		X		X		X
White-faced Heron		X		X		X	X	X
White-necked Heron		X				X	X	X
Yellow-billed Spoonbill		X				X	X	X
Hawks, Eagles and Falcons								
Osprey			X				X	X
Swamp Harrier	X	X		X			X	X
White-bellied Sea-Eagle		X	X	X			X	X
Cranes, Crakes and Rails								
Australian Crake	X	X			X			
Black-tailed Native-hen	X	X		X	X			
Buff-banded Rail	X	X		X	X			
Chestnut Rail	X	X			X			
Dusky Moorhen	X	X		X	X			
Eurasian Coot		X	X		X			

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Purple Swamphen	X	X		X	X			
White-browed Crake	X	X		X	X			
Comb-crested Jacana				X	X			
Shorebirds								
Australian Painted Snipe		X			X			
Australian Pratincole		X					X	
Banded Lapwing				X	X			
Bar-tailed Godwit		X			X		X	
Beach-Stone Curlew		X			X			
Black-fronted Dotterel		X		X	X			
Black-tailed Godwit		X				O	X	
Black-winged Stilt		X				O	X	O
Common Greenshank		X			X			
Common Sandpiper		X			X			
Curlew Sandpiper		X					X	
Eastern Curlew		X					X	
Great Knot		X					X	
Greater Sand Plover		X					X	
Grey Plover		X					X	
Grey-tailed Tattler		X					X	
Little Curlew		X			X			
Long-toed Stint		X					X	
Marsh Sandpiper		X					X	
Masked Lapwing		X					X	
Oriental Plover		X		X			X	
Oriental Pratincole				X			X	
Pacific Golden Plover		X		X	X		X	
Pectoral Sandpiper		X			X			
Red-capped Plover		X		X	X			
Red-kneed Dotterel		X			X			
Red-necked Avocet		X				O	X	O
Red-necked Stint		X			X			
Ruddy Turnstone		X					X	
Ruff		X					X	
Sharp-tailed Sandpiper		X			X			
Swinhoe's Snipe							X	
Terek Sandpiper		X					X	
Whimbrel		X					X	
Wood Sandpiper		X			X			
Gulls and Terns								
Caspian Tern			X				X	X
Crested Tern			X				X	X
Gull-billed Tern		X	X	X			X	X
Little Tern			X				X	X
Silver Gull		X	X	X	X			X
Whiskered Tern		X	X				X	X
White-winged Tern	X	X	X				X	

Appendix D: Native flora recorded within the Ord River Floodplain Ramsar site

Flora species and families as contained in CALM (1998)

Family	Species name	Family	Species name
Psilotaceae	*Psilotum nudum*	Onagraceae	*Ludwigia perennis*
Seiaginellaceae	*Selaginella ciliaris*	Combretaceae	*Lumnitzera racemosa*
Platyzomataceae	*Platyzoma microphyllum*		*Terminalia arostrata*
Adiantaceae	*Cheilanthes brownii*		*T. bursarina*
	C. pumilia		*T. canescens*
Pteridaceae	*Acrastichum speciasum*	Combretaceae	*Terminalia ferdinandiana*
Thelypteridaceae	*Cyclosorus interruptus*		*T. hadleyana*
Marsileaceae	*Marsilea spp.*		*T. platyphylla*
	M. mutica		*T. platyptera*
Lauraceae	*Cassytha spp.*	Rhizophoraceae	*Bruguiera exaristata*
	C. jilifarmis		*B. parviflora*
Hernandiaceae	*Gyracarpus americanus*		*Ceriops tagal*
Nymphaeaceae	*Nymphaea gigantea*		*Rhizophora stylosa*
Ceratophylaceae	*Ceratophyllum demersum*	Santalaceae	*Exocarpos latifolius*
Menispermaceae	*Tinospora smilacina*		*Santalum lanceolatum*
Ulmaceae	*Celtis philippensis*	Loranthaceae	*Amyema sanguineum*
Moraceae	*Fatoua pilosa*		*Decaisnina petiolata*
	Ficus coronulata		*Dendrophthoe acacioides*
	F. leucotricha		*Lysiana spathulata*
	F. opposita	Euphorbiaceae	*Bridelia tomentosa*
	F. platypoda		*Euphorbia comans*
	F. scobina		*E. hirta*
	F. virens		*Excoecaria agallocha*
Urticaceae	*Laportea interrupta*		*E. parvifolia*
Nyctaginaceae	*Boerhavia dominii*		*Flueggea virosa*
	B. paludosa		*Petalostigma pubescens*
Chenopodiaceae	*Chenopodium auricomum*		*Phyllanthus reticulatus*
	Halosarcia indica		*P. virgatus*
	Tecticornia verrucosa	Vitaceae	*Ampelocissus acetosa*
Amaranthaceae	*Achyranthes aspera*		*Cayratia trifolia*
	Alternanthera nodiflora		*Cissus adnata*
	Amaranthus interruptus	Sapindaceae	*Atalaya hemiglauca*
	A. pallidiflorus		*A. variifolia*
	Gomphrena brachystylis	Sapindaceae	*Distichostemon hispidulus*
	G. canescens	Burseraceae	*Canarium australianum*
	G. conica	Anacardiaceae	*Buchanania obovata*
	Hemichroa diandra	Simaroubaceae	*Brucea javanica*

Family	Species name	Family	Species name
	Ptilotus conicus	Meliaceae	*Melia azedarach*
	P. exaltatus		*Owenia reticulata*
	P. polystachyu		*O. vernicosa*
Portulacaceae	*Calandrinia strophiolata*		*Xylocarpus moluccensis*
Caryophyllaceae	*Polycarpaea spp.*	Rutaceae	*Boronia lanuginosa*
	P. arida	Zygophyllaceae	*Tribulopis angustifolia*
Plumbaginaceae	*Aegialitis annulata*	Loganiaceae	*Mitrasacme exserta*
	Plumbago zeylanica		*Strychnos lucida*
Tiliaceae	*Corchorus aestuans*	Gentianaceae	*Canscora diffusa*
	C. sidoides	Apocynaceae	*Carissa lanceolata*
	C. tridens		*Wrightia saligna*
	Grewia breviflora	Asclepiadaceae	*Cynanchum jloribundum*
	G. retusifolia		*Gymnanthera spp.*
	Triumfetta plumigera	Solanaceae	*Physalis minima*
Sterculiaceae	*Brachychiton diversifolius*		*Solanum dioicum*
	B. jitzgeraldianus		*S. lucani*
	B. incanus	Convolvulaceae	*Cressa cretica*
	B. viscidulus		*Ipomoea coptica*
	Melochia corchorifolia		*I. diamantinensis*
	Sterculia holtzei		*I. pes-caprae*
	Waltheria indica		*Operculina aequisepala*
Bombacaceae	*Adansonia gregorii*		*Xenostegia tridentata*
	Camptostemon shultzii	Menyanthaceae	*Nymphoides aurantiaca*
Malvaceae	*Abutilon indicum*		*N. crenata*
	Gossypium pilosum		*N. indica*
	Hibiscus coatesii	Boraginaceae	*Coldenia procumbens*
	H. leptocladus		*Heliotropium cunninghamii*
	H. meraukensis		*Ehretia saligna*
	Urena lobata		*Tournefortia mollis*
Lecythidaceae	*Barringtonia acutangula*		*Trichodesma zeylanicum*
	Planchonia careya	Verbenaceae	*Premna acuminata*
Droseraceae	*Drosera ordensis*		*Vitex glabrata*
Bixaceae	*Cochlospermum fraseri*	Avicenniaceae	*Avicennia marina*
Violaceae	*Hybanthus aurantiacu*	Lamiaceae	*Anisomeles malabarica*
Cucurbitaceae	*Cucumis melo*		*Basalicum polystachyon*
	Diplocyclos palmatus	Oleaceae	*Jasminum didymum*
	Mukia maderaspatana		*J. molle*
	Trichosanthes cucumerina	Scrophulariaceae	*Stemodia viscosa*
Capparaceae	*Capparis jacobsii*	Acanthaceae	*Dicliptera armata*
	C. cleomoides		*Nelsonia campestris*
	C. tetrandra		*Rostellularia adscendens*

Family	Species name	Family	Species name
	C. viscosa	Bignoniaceae	*Dolichandrone filiformis*
Myrsinaceae	*Aegiceras corniculatu*		*D. heterophylla*
Mimosaceae	*Acacia adoxa*	Lentibulariaceae	*Utricularia antennifera*
	A. aulacocarpa		*U. aurea*
	A. colei		*U. gibba*
	A. dunnii		*U. stellaris*
	A. lycopodifolia	Stylidiaceae	*Stylidium spp.*
	A. lysiphloia	Goodeniaceae	*Goodenia sepalosa*
	A. platycarpa		*G. lamprosperma*
	A. plectocarpa	Rubiaceae	*Canthium spp.*
	A. stigmatophylla		*Gardenia megasperma*
	A. translucens		*Nauclea orientalis*
	A. tumida		*Spermacoce exserta*
	Cathormion umbellatum	Asteraceae	*Blumea axillaris*
	Neptunia dimorphantha		*B. diffusa*
Caesalpiniaceae	*Erythrophleum chlorostachys*		*B. sp.A.*
	Lysiphyllum cunninghamii		*Pluchea rubelliflora*
	Senna goniodes		*Pterocaulon spp.*
	S. notabilis		*P. serrulatum*
	S. oligoclada		*P. sphacelatum*
	S. venusta		*P. sphaeranthoides*
Papilionaceae	*Abrus precatorius*		*Streptoglossa macrocephala*
	Aeschynomene indica	Lemnaceae	*Wolffia angusta*
	Crotalaria alala	Taccaceae	*Tacca leontopetaloides*
	C. cunninghamii	Asparagaceae	*Protasparagus racemosus*
	C. goreensis	Amaryllidaceae	*Crinum angustifolium*
	C. medicaginea	Orchidaceae	*Cymbidium canaliculatum*
	C. montana	Ponterderiaceae	*Monochoria cyanea*
	Desmodium filiforme	Typhaceae	*Typha domingensis*
	D. trichostachyum	Commelinaceae	*Cartonema parviflorum*
	Erythrina vespertilio		*Commelina ciliata*
	Indigofera colutea	Eriocaulaceae	*Eriocaulon cinereum*
	I. hirsuta	Cyperaceae	*Bulbostylis barbata*
	Jacksonia forrestii		*Crosslandia setifolia*
	Mucuna gigantea		*Cyperus bulbosus*
	Psoralea spp.		*C. haspan*
	Rhynchosia minima		*C. microcephalus*
	Sesbania cannabina		*C. squarrosus*
	S. erubescens		*C. zollingeri*
	S. formosa		*Eleocharis brassii*
	Tephrosia rosea		*E. dulcis*

Family	Species name	Family	Species name
Proteaceae	*Grevillea agrifolia*		*Fimbristylis afflittoralis*
	G. dryandri		*F. depauperata*
	G. pteridifolia		*F. rara*
	G. pyramidalis		*Scleria polycarpa*
	G. refracta		*S. rugosa*
	G. striata	Poaceae	*Acrachne racemosa*
	G. velutinella		*Aristida holathera*
	Hakea arborescens		*A. inaequiglumis*
	H. suberea		*A. ingrata*
	Persoonia falcata		*Bothriochloa bladhii*
Haloragaceae	*Gonocarpus implexus*		*Brachyachne convergens*
Sonneratiaceae	*Sonneratia alba*		*Chloris pumilia*
Lythraceae	*Rotala occutiflora*		*Dactyloctenium radulans*
Myrtaceae	*Calytrix achaeta*		*Dicanthium fecundum*
	C. brownii		*D. sericeum*
	C. exstipulata		*Digitaria papposa*
	Corymbia aspera		*Dimeria ornithopoda*
	C. bella		*Diplachne parviflora*
	C. byrnesii		*Eragrostis tenellula*
	C. confertiflora		*Eriachne melicacea*
	C. drysdalensis		*Eriochloa australiensis*
	C. ferruginea		*Heteropogon contortus*
	C. grandifolia		*Iseilema vaginiflorum*
	C. polycarpa		*Leptochloa neesii*
	C. ptychocarpa		*Oryza australiensis*
	Eucalyptus bigalerita		*Panicum mindanaense*
	E. camaldulensis		*P. trachyrhachis*
	E. chlorophylla		*P. trichoides*
	E. leptalea		*Perotis rara*
	E. microtheca		*Phragmites karka*
	E. miniata		*Sehima nervosum*
	E. pruinosa		*Setaria apiculata*
	E. tectifica		*Sorghum australiense*
	E. tetrodonta		*S. stipoideum*
	Lophostemon grandiflorus		*Spinifex longifolius*
	Melaleuca acacioides		*Sporobolus australasicus*
	M. argentea		*S. virginicus*
	M. dealbata		*Thaumastochloa major*
	M. leucadendra		*Themeda triandra*
	M. minutifolia		*Triodia spp.*
	M. sericea		*Urochloa reptans*

Family	Species name	Family	Species name
	M. viridiflora		*Whiteochloa biciliata*
	Osbornia octodonta		*Xerochloa imberbis*
	Verticordia cunninghamii		*Yakirra majuscula*
	Xanthostemon psidioides	Arecaceae	*Livistona spp.*
Pandanaceae	*Pandanus aquaticus*		
	P. spiralis		