NSW GOVERNMENT
Environment, Climate Change & Water

Paroo River Wetlands Ramsar site

Ecological character description

This publication has been supported supported by the Australian Government through the Ramsar Management Planning Program.

Citation: Kingsford, R.T. and Lee, E. 2010. *Ecological character description of the Paroo River Wetlands Ramsar site*. Department of Environment, Climate Change and Water NSW, Sydney.

The contribution of Kate Brandis from the University of New South Wales and of Laura Torrible is acknowledged.

Published by:

Department of Environment, Climate Change and Water
59–61 Goulburn Street, Sydney
PO Box A290, Sydney South 1323

Phone: (02) 9995 5000 (switchboard)
131 555 (environment information and publications requests)
1300 361 967 (national parks, climate change and energy efficiency information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DECCW 2010/213
ISBN 978 1 74232 597 2
June 2010

Summary

The Paroo River Wetlands Ramsar site is in north-western New South Wales in the Paroo River catchment. The Ramsar site makes up about 2% of the land area and 2.4% of the wetland area in the Paroo River catchment, and consists of two main areas along the Paroo River: Nocoleche Nature Reserve and the Peery and Mandalay blocks in the Paroo–Darling National Park (the Peery and Mandalay blocks are referred to as Peery). The Paroo River is the last free-flowing river in the Murray–Darling Basin and hence is a unique example of a near-natural arid inland river system. It flows across two states, NSW and Queensland, which have agreed to the river's long term protection. There is a range of wetland types in the catchment, including claypans, canegrass swamps, river channels and waterholes, black box swamps, *Eleocharis* swamps, lignum swamps and overflow plains, freshwater lakes, salt lakes and mound springs. Nocoleche Nature Reserve has all of these except for freshwater lakes, salt lakes and mound springs. The Peery component includes freshwater lakes (Peery and Poloko lakes) and intermittent river channels and swamps. Peery Lake also contains several examples of active mound springs (natural discharge points from the Great Artesian Basin), the rarest landform in Australia, and these have significant conservation value as they form the largest active springs complex in NSW on a lake bed.

Wetlands in the Paroo River Wetlands Ramsar site support endangered flora and fauna of restricted distribution, support endangered ecological communities, support an abundance and diversity of waterbirds during critical stages of their life cycles, provide drought refuge for fauna, and are significant for native fish communities. Peery Lake and other associated overflow lakes depend predominantly on flows from the Paroo River and Kulkyne Creek, and the Warrego River also contributes flows through the Cuttaburra Creek system during large floods. Flooding and drying cycles of the Paroo River, which are driven by climate and affected by geomorphology, are critical in supporting the flora and fauna of the Paroo River Wetlands Ramsar site, as are the physicochemical environments.

Ecological components measured over a reasonably long period of time include waterbirds (species richness, abundance and breeding data), streamflow data and fish (species richness and abundance data). Information on the distribution and abundance of invertebrates, frogs, reptiles, mammals, terrestrial birds and threatened species in relation to flooding, the composition and distribution of vegetation communities over time, as well as on water quality, soil characteristics and geomorphology, is needed. Such data would improve knowledge of the ecological character of the Ramsar site, and could be used as indicators in future assessments of the ecological character of the site.

The key to maintaining the ecological character of the Paroo River Wetlands Ramsar site and wetlands in the catchment is to protect the Paroo River from alteration of river flows that have affected other regulated rivers around the world and in the Murray–Darling Basin. While the alteration of natural flows is currently not foreseeable in the immediate future because of the Paroo River Agreement protecting river flows, there are three potential threats. The first is the for construction of levee banks upstream of the Ramsar site for stock access or roads. Small levee banks can have major impacts on rivers and their inundation patterns in areas of low relief such as the Paroo River. The second potential impact is the increasing development of the Warrego River through further access to allocated water. This will affect flows down the Cuttaburra Creek system which supplies some water to the Paroo Overflow lakes, including Peery Lake. The third potential impact may occur when the Paroo Water Resource Plan for Queensland is reviewed, as the new plan may recommend further development on the Paroo River. The status of the Paroo River needs to be recognised under the basin plan to be developed by the Murray–Darling Basin Authority. At a local level, feral animals and weeds can impact on the ecological values of the Ramsar site.

There is an urgent need to identify any levee banks that may alter or interrupt flows in the river and to develop policies that restrict further development throughout the catchment. Ongoing monitoring of ecological indicators needs to continue, and new techniques for monitoring, such as the use of satellite imagery, should be explored in relation to flooding patterns.

Contents

Figures

Tables

1 Introduction

1.1 Site details

Table 1 provides introductory details about the Paroo River Wetlands Ramsar site and gives information on the preparation of this ecological character description. It also details the management authorities responsible for the maintenance of the Ramsar site and provides references for relevant management plans and the Ramsar Information Sheet.

Table 1: Ecological character description details for the Paroo River Wetlands Ramsar site

Site name	The Paroo River Wetlands
General location	The Paroo River Wetlands Ramsar site is in north-western New South Wales, south-eastern Australia, in the Paroo River catchment. The Ramsar site consists of two main areas along the Paroo River: the Nocoleche Nature Reserve and the Peery and Mandalay Blocks in the Paroo–Darling National Park (the latter area referred to as Peery). Nocoleche Nature Reserve is about 180 km west of Bourke, and Peery is about 240 km south-west of Bourke (Nocoleche Nature Reserve is 120 km north of Peery).
Location in coordinates	Nocoleche Nature Reserve: 144.156°E, 29.902°S (centroid) Peery: 143.528°E, 30.764°S (centroid)
Area	Nocoleche Nature Reserve: 71,133 ha; Peery: 67,134 ha Total: 138,267 ha
Date of listing of Ramsar Site	September 2007
Ramsar nomination criteria	1, 2, 3, 4, 5 and 7
Date for which the description of ecological character applies	The description is for the Ramsar site at the time of listing in 2007.
Management authorities	NSW National Parks and Wildlife Service, Far West Region Western Catchment Management Authority Murray–Darling Basin Authority Department of Environment, Climate Change and Water NSW Department of Environment and Resource Management Queensland
Status of description	This is the first description of the ecological character of the Paroo River Wetlands Ramsar site.
Names of compilers	Richard T. Kingsford and Enhua Lee Australian Wetlands and Rivers Centre School of Biological, Earth and Environmental Sciences University of NSW, Sydney, NSW 2052 richard.kingsford@unsw.edu.au
Compilation date	March 2007
Reference for Ramsar Information Sheet	Department of Environment and Conservation (2007). *Draft Ramsar Information Sheet for the Paroo River Wetlands*
References for management plans	NSW National Parks and Wildlife Service (2000). *Nocoleche Nature Reserve Plan of Management* NSW National Parks and Wildlife Service (2009). *Paroo–Darling National Park and State Recreation Area: Draft Plan of Management* Paroo River Agreement 2003 between NSW and Queensland

1.2 Statement of purpose

In accordance with the Ramsar Convention, appropriate management of Ramsar wetlands includes describing and maintaining the ecological character of the wetland and implementing planning processes that promote conservation and wise use (Ramsar Convention Secretariat 2007).

Describing the ecological character of a Ramsar site is a fundamental management tool for site managers and other parties, and should form the baseline or benchmark for management planning and action, including site monitoring to detect negative impacts.

The ecological character of a wetland is the 'combination of ecosystem components, processes and benefits/services that characterise the wetland at a given point in time (Ramsar Convention 2005, Resolution IX.1 Annex A) The given point is usually the time of Ramsar listing.[1] The description of the ecological character should identify its key elements and provide an assessment point for the monitoring and evaluation of the site, as well as guide policy and management.

The purpose of this description of the ecological character of the Paroo River Wetlands Ramsar site is described below (mostly following McGrath 2006):

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 (Cwlth):
   a) to describe and maintain the ecological character of declared Ramsar wetlands in Australia
   b) to formulate and implement planning that promotes:
      i. conservation of the wetland
      ii. implementing Australia's obligations under the Ramsar Convention, 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 meet Australia's obligations by enabling information to be provided as soon as possible about whether the ecological character of a Ramsar-listed Australian wetland 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 in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and 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 for the Environment and Water Resources in the Australian Government 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 for the Environment and Water Resources in the Australian Government under Part 7 of the EPBC Act for assessment and approval
6 to assist the NSW Government in its development of management and planning for the Paroo–Darling National Park and Nocoleche Nature Reserve and the supply of water from the Paroo River
7 to assist the management of the Paroo River
8 to provide direction for restoration targets and key indicators for the Paroo–Darling National Park and Nocoleche Nature Reserve

[1] www.ramsar.org/res/key_res_ix_index_e.htm

9 to consolidate current information about the Paroo–Darling National Park and Nocoleche Nature Reserve and their management in a publicly available document.

Ecological character descriptions need to relate to other planning and management documents relevant to Ramsar sites. The relationships among these documents are outlined for the Paroo–Darling National Park and Nocoleche Nature Reserve (Figure 1), adapted from the *National Framework and guidance for describing the ecological character of Australian Ramsar wetlands* (DEWHA 2008).

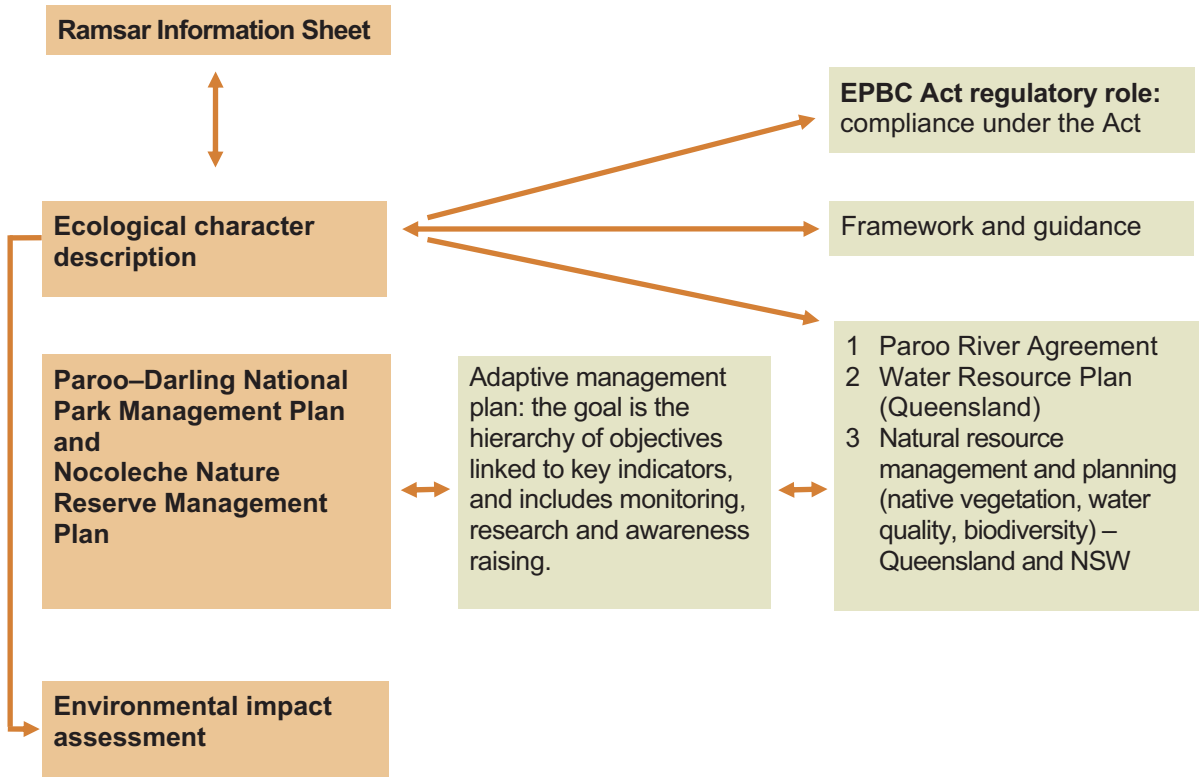

Figure 1: Relationship of this ecological character description to relevant planning, management and legislation

1.3 Relevant treaties, legislation and regulations

1.3.1 Ramsar Convention on Wetlands

The *Convention on Wetlands of International Importance Especially for Waterbird Habitat*, to which Australia is a signatory, was initially adopted in Ramsar, Iran, in 1971. Commonly known as the Ramsar Convention, this was the first modern intergovernmental treaty between nations with the aim of conserving natural resources.

The Convention's broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. This requires international cooperation, policy making, capacity building and technology transfer.

The Ramsar Convention encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity. Once designated, these sites are added to the Conventions List of Wetlands of International Importance and become known as Ramsar sites. In designating a wetland as a Ramsar site, countries agree to establish and oversee a management framework aimed at conserving the wetland and ensuring its wise use. Wise use under the Convention is broadly defined as maintaining the ecological character of a wetland. Wetlands can be included on the List of

Wetlands of International Importance because of their ecological, botanical, zoological, limnological or hydrological importance.

Australia was one of the first countries to sign the Ramsar Convention, and in 1974 designated the world's first Wetland of International Importance – Cobourg Peninsula in the Northern Territory.

1.3.2 Migratory bird agreements

There are many waterbirds that depend on the wetlands of the Paroo River, and some of these waterbirds are protected by international migratory bird agreements, including the:

- Japan–Australia Migratory Bird Agreement (JAMBA) 1974, between the Government of Australia and the Government of Japan for the protection of migratory birds in danger of extinction and their environment (see Appendix 1)
- China and Australia Migratory Bird Agreement (CAMBA) 1986, between the Government of Australia and the Government of China for the protection of migratory birds in danger of extinction and their environment (see Appendix 1)
- Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA) 2006, between the Government of Australia and the Government of the Republic of Korea for the protection of migratory birds in danger of extinction and their environment (see Appendix 1)
- Convention of Migratory Species of Wild Animals (Bonn 1983), which aims to conserve terrestrial, marine and avian migratory species throughout their range
- Partnership for the East Asian–Australasian Flyway (2006), which was formally the Asia–Pacific Migratory Waterbird Conservation Strategy (2001–2005) that in turn replaced the East Asian–Australasian Shorebird (or wading bird) Reserve Network (1996). This initiative aims to establish a network of the most important wetland sites used by migratory wading birds along the East–Asian Australian Flyway. This flyway, or migration path, stretches from non-breeding sites in New Zealand and Australia, through south-east Asia, China and Japan, to the main breeding sites in Siberia and Alaska.

The policy and legislative documents relevant to the Paroo River wetland sites (Paroo–Darling National Park and Nocoleche Nature Reserve) are listed in detail in Appendix 1 and are described briefly below.

1.3.3 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act[2] protects the environment, particularly matters of national environmental significance. It streamlines the national environmental assessment and approvals process, protects Australian biodiversity and integrates management of important natural and cultural places. Under the EPBC Act, approval is required for actions that are likely to have a significant impact on any matter of national environmental significance. For example, migratory waterbirds are considered a matter of national environmental significance.

1.3.4 Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act 1995* (TSC Act)[3] is designed to protect threatened species, communities and critical habitats in NSW. Species and populations are listed as threatened or endangered. In 2002, amendments recognised the importance of invertebrates and non-vascular plants. The TSC Act also provides a framework for planning for species recovery and the control of threatening processes. The purposes of the amended TSC Act (NPWS 2002) are to conserve biological diversity and promote ecologically sustainable development; prevent the extinction and promote the recovery of threatened species, populations and ecological communities; protect the critical habitat of those species, populations and ecological communities; eliminate or manage certain threatening processes;

[2] www.environment.gov.au/epbc/
[3] www.legislation.nsw.gov.au/viewtop/inforce/act+101+1995+FIRST+0+N

ensure proper assessment of activities impacting threatened species, populations and ecological communities; and encourage the conservation of threatened species, populations and ecological communities through cooperative management. The 'alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands' has been identified as a key threatening process because it is as a major factor contributing to the loss of biological diversity and ecological function in aquatic ecosystems, including floodplains.[4] Major causes of alteration of flows include the building of dams (including all dams, weirs and off-river storages), diversion of flows by structures or extraction, and alteration of flows on floodplains with levees and structures (including those on wetlands to allow water storage).

1.3.5 Nocoleche Nature Reserve Management Plan and Draft Paroo–Darling National Park Management Plan

These management plans aim to protect river flows and groundwater in the Paroo and Warrego reserve areas, manage wetlands within the reserves to avoid affecting flow patterns, protect waterbird breeding areas and protect cultural heritage. They also aim to protect all flora and fauna within the reserves, and to provide opportunities for scientific research, recreation, tourism and environmental education that are compatible with the conservation of the reserves under the NPW Act.

1.3.6 The Intergovernmental Agreement between Queensland and NSW for the Paroo River 2003

This agreement aims to protect the Paroo River and its water-related natural resources at the catchment level. In particular, it protects flows (quantity and variability) and respects the importance of river flows for downstream ecosystems, cultural heritage and pastoral activities that do not affect natural flow patterns.

1.3.7 Water Resource (Warrego, Paroo, Bulloo and Nebine) Plan 2003

This plan provides a framework for the allocation and sustainable management of surface and overland flow water in Queensland which includes about half of the catchment of the Paroo River. It provides for only 100 ML of water to be allocated for town water, ecosystem or other uses. The plan also provides for an allocated amount of water in the connecting Warrego River and another 8000 ML of unallocated water that can be extracted from the Warrego River. In 2007 the Queensland Government withdrew this unallocated water and subsequently gifted it to the Commonwealth Environmental Water Holder.

1.3.8 Western Catchment Management Plan

The Western Catchment Management Authority has developed a catchment management plan for improving and managing natural resources (land, vegetation, rivers, groundwater and biodiversity) in the western catchment, which includes the Paroo River catchment and the Paroo River Wetlands Ramsar site. The Western Catchment Management Plan was released in 2006 and is based on the Western Catchment Management Authority's 2003 Western Catchment Blueprint.[5] The Western Catchment Management Plan integrates and builds on the blueprint's management targets and sets the management direction for 10 years (WCMA 2005). Five catchment targets and 14 management targets have been formulated, and wetland management targets include:

- Management target 4: habitat improvement actions implemented on 20% of identified priority areas of stream, floodplain, wetland and riparian areas by 2016
- Management target 6: water sharing plans implemented for all priority streams by 2010
- Management target 7: water pressure stabilised in key regions of the Great Artesian Basin, as defined by NSW Great Artesian Basin Advisory Committee, by 2015.

[4] www.environment.nsw.gov.au/threatenedspecies/AlterationNaturalFlowKTPListing.htm
[5] www.western.cma.nsw.gov.au/Pages/Thewesterncatchmentplan.htm

1.3.9 Queensland Regional Natural Resource Plan

The Queensland Regional Natural Resource Management Plan is a framework to guide coordinated and holistic planning and on-ground action to improve the management and condition of natural resources across the Queensland Murray–Darling Basin and Bulloo Catchment (QMDC and SWNRM 2004). This management plan identifies resource condition targets and prioritises innovative management strategies to improve catchment health and protect regional assets. These management targets focus on:

- motivating changes in land use and in production and environmental management practices
- protecting and conserving regional and catchment environmental assets and values
- activities to arrest degradation and rehabilitate degraded areas as appropriate.

The Queensland Murray–Darling Committee Inc. is the designated regional body responsible for leading the planning and implementation of the Queensland Regional Natural Resource Management Plan in the Maranoa–Balonne part of the Condamine–Balonne–Maranoa Priority Investment Region and the Queensland section of the Border Rivers (Queensland–NSW) Priority Investment Region. The South West Natural Resource Management Group Inc. is the designated regional body responsible for planning and the implementation of the Queensland Regional Natural Resource Management Plan in the Warrego, Paroo, Bulloo and Nebine–Mungallala catchments.

1.3.10 National Water Initiative

In 2004, the Council of Australian Governments agreed to the National Water Initiative (NWI), with Tasmania and Western Australia becoming signatories in 2005 and 2006; the NWI will chart the future responsibilities and progress towards sustainable management of the nation's rivers and aquifers. The NWI is a comprehensive strategy driven by the Australian Government to improve water management across the country. It recognises that Australia's highly variable and often scarce water resources are crucial for economic, social and environmental wellbeing. Provisions in the intergovernmental agreement on the NWI commit the participating parties to identify, protect and manage high-conservation value rivers and aquifers and the ecosystems that depend on them, and return allocations to sustainable levels.[6]

1.3.11 Water Act 2007

The *Water Act 2007* (Cwlth) established an independent Murray–Darling Basin Authority with the support of an Intergovernmental Agreement signed by all six basin jurisdictions. The Murray–Darling Basin Authority is responsible for managing the water resources of the Murray–Darling Basin and it is charged with preparing a Basin Plan by 2011.

The Basin Plan provides for the integrated management of the water resources of the Murray–Darling Basin in a way that promotes the objects of the *Water Act 2007*. The mechanisms for achieving this include the setting of long-term average sustainable diversion limits for the basin water resources, a water quality and salinity management plan and identification of risks to the basin's water resources (such as climate change) and strategies to manage those risks. In addition the Basin Plan must include an environmental watering plan the objects of which are to protect and restore the wetland and environmental assets of the basin and to protect biodiversity dependent on the basin water resources. The Act also provides for local water resource plans which will be consistent with the Basin Plan. The Basin Plan and water resource plans under the Act will be special measures and must address the threats to the basin water resources and promote conservation of declared Ramsar wetlands within the Murray–Darling Basin and take into consideration the ecological character descriptions of all Ramsar wetlands in the basin (*Water Act 2007* s.21 (3)).

[6] www.nwc.gov.au/www/html/117-national-water-initiative.asp

2 General information

2.1 Site details and location

The Paroo River Wetlands Ramsar site is in the Mulga Lands biogeographic region in the Western Division of NSW (IBRA)[7] along the middle and lower sections of the Paroo River. It consists of two separate parts: the floodplains and channels of the Paroo River and Cuttaburra and Kulkyne creeks in Nocoleche Nature Reserve, and Peery and Poloko lakes in Paroo–Darling National Park (Figure 2), which will be referred to as Peery. Nocoleche Nature Reserve covers 71,133 ha across the floodplain of the Paroo River and Cuttaburra and Kulkyne creeks (Figure 3), and the Paroo–Darling National Park covers 67,134 ha (Figure 4). Nocoleche Nature Reserve is about 180 km west of Bourke, Peery is about 240 km south-west of Bourke, and Nocoleche Nature Reserve is 120 km north of Peery. The Paroo River Wetlands Ramsar site makes up 1.9% (74,128 km^2) of the land area of the Paroo River catchment (Kingsford et al. 2004; RIS 2007), and 2.4% (Nocoleche Nature Reserve: 11,485 ha; Peery: 8,544 ha; Paroo River catchment: 830,596 ha) of the wetland area in the Paroo River catchment (Kingsford et al. 2004).

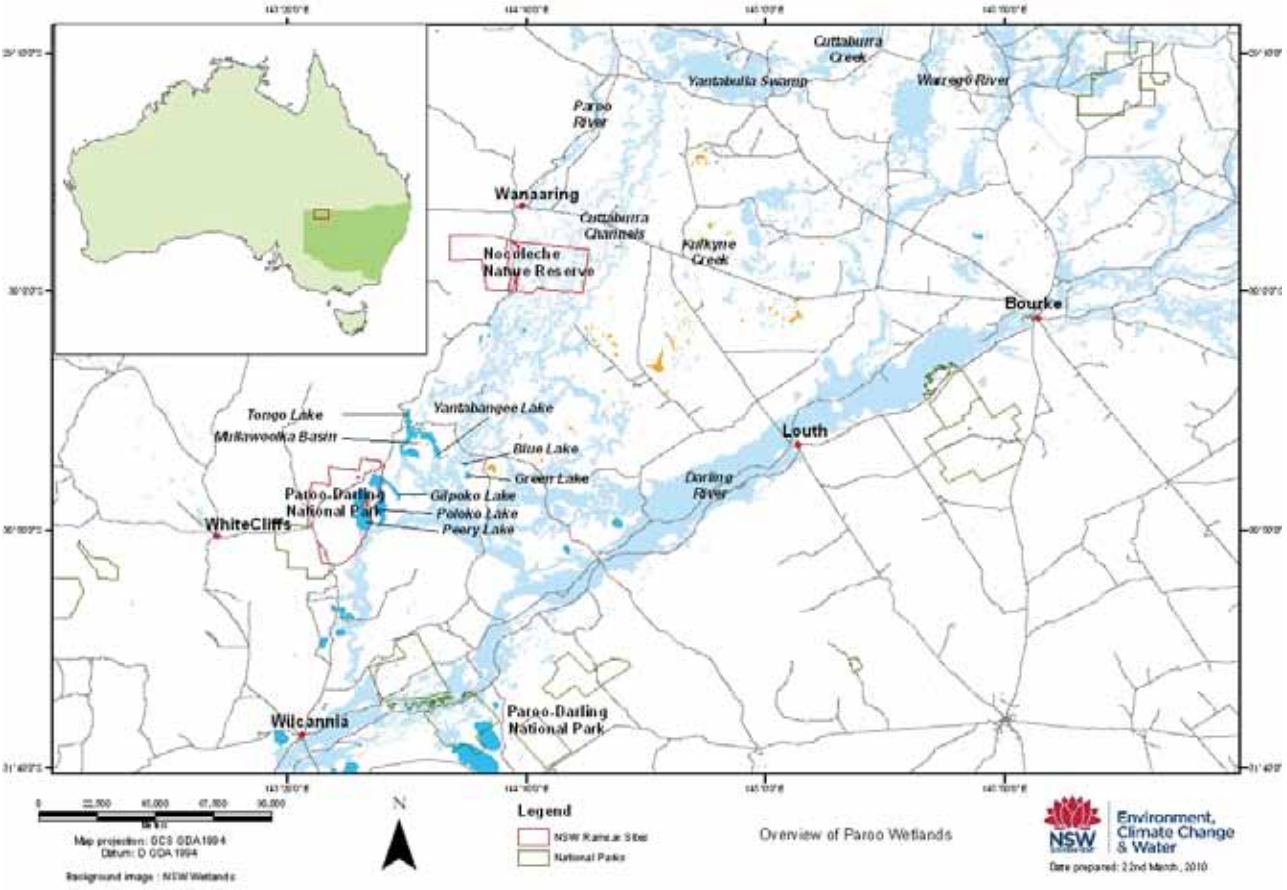

Figure 2: Location of the Paroo River Wetlands Ramsar site

[7] www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html

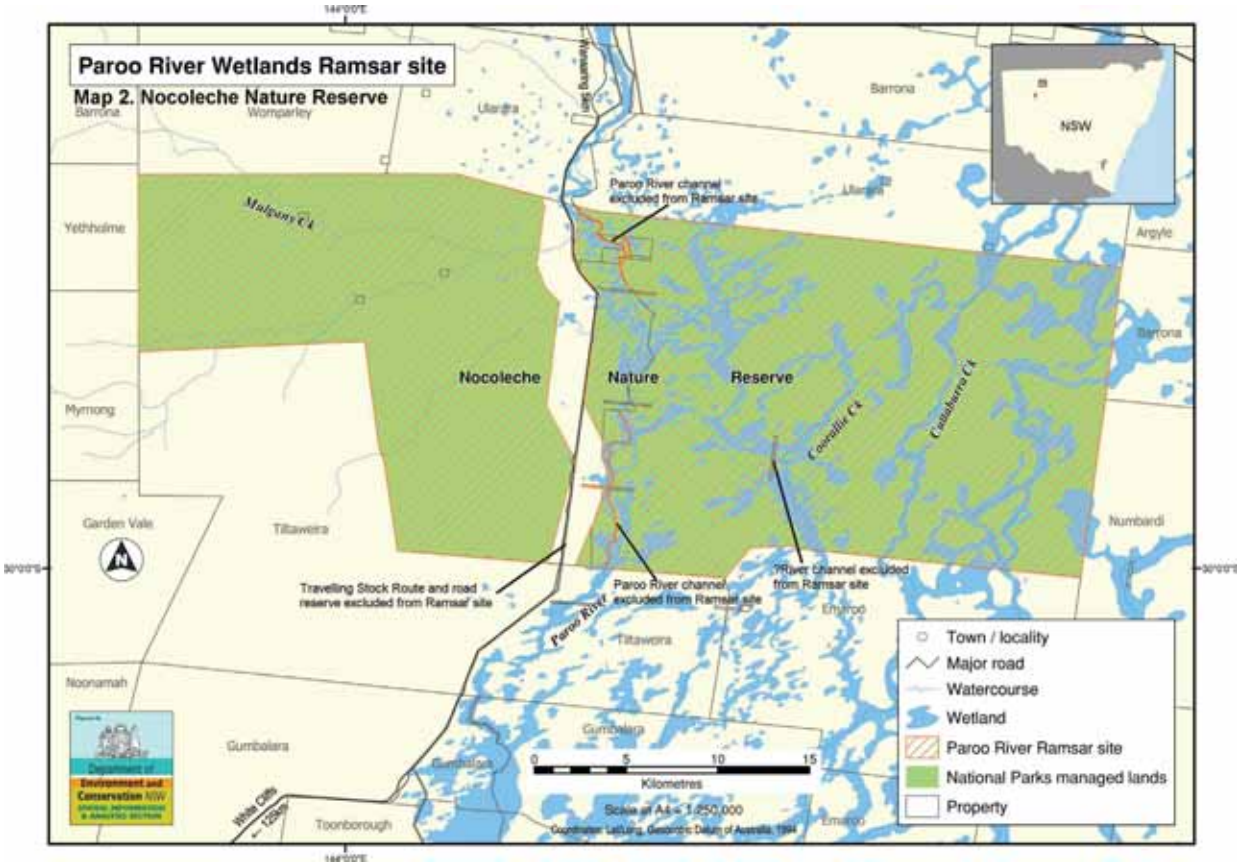

Figure 3: Fine scale map of the Paroo River Wetlands Ramsar site in Nocoleche Nature Reserve

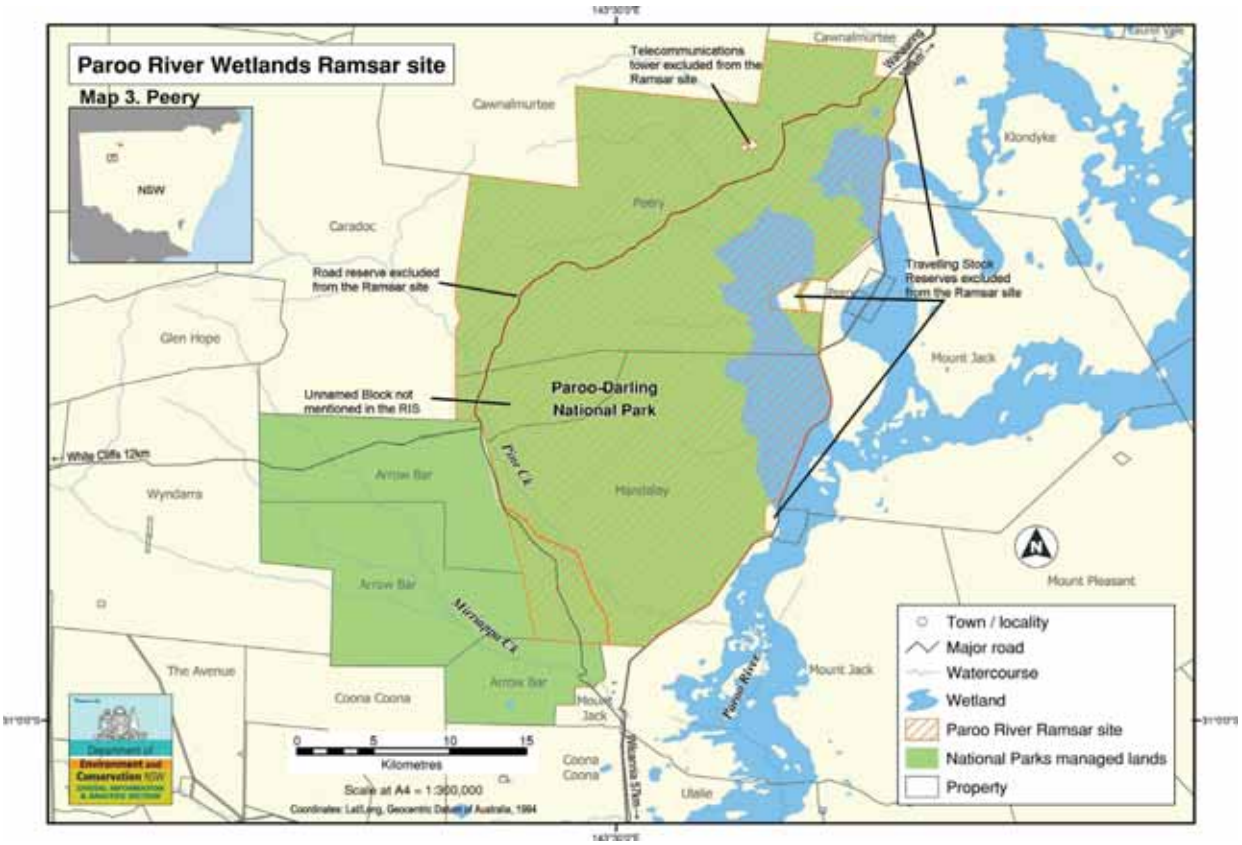

Figure 4: Fine scale map of the Paroo River Wetlands Ramsar site in Paroo–Darling National Park

2.2 Paroo River

The Paroo River catchment extends from central Queensland into far western NSW (Figure 5). The Paroo River originates in south-western Queensland with water flows from the Warrego, Willies and Walters ranges (Kingsford et al. 1994). Flows may eventually reach the Darling River. The first major wetlands on the Paroo River are Currawinya Lakes in Queensland, another Ramsar site. The river fills Lake Numalla and, during particularly high flows, water reaches Lake Wyara (Timms 1999). The Paroo River flows south, flooding areas of canegrass and lignum on the floodplain, including Nocoleche Nature Reserve, before reaching an extensive area of freshwater lakes and lignum known as the Paroo Overflow Lakes (Mullawoolka Basin and Blue, Gilpoko, Poloko, Peery, Tongo and Yantabangee lakes). This is the site of the southern part of the Paroo River Wetlands Ramsar site. During large floods water flows through a series of lakes (Coona Coona Lake, East Coona Lake, Nine Mile Lake, Lake Dick, Copago Lake, Salt Lake and Nine Mile Lagoon) south of Peery Lake to reach the Darling River.

The Warrego River catchment further to the east connects with the Paroo River catchment through Cuttaburra Creek. The Warrego River originates in south-western Queensland with flows from Warrego Range, near Blackall and Chesterton Range, north-west of Augathella. South of Cunnamulla, water flows down the effluent Cuttaburra Creek during large floods and continues south (Figure 5). After filling Yantabulla Swamp (Cuttaburra Basin), a large lignum and sedge wetland, water floods down the Cuttaburra Channels and Kulkyne Creek and joins the Paroo River before flowing further south to the Paroo Overflow Lakes.

2.3 Wetland types

Based on the Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of the Contracting Parties, there are six wetland types in the Ramsar site (Table 2). Four of these wetland types are in Nocoleche Nature Reserve and four are in Peery, and all wetlands are inland wetlands. Alphabetic codes for wetland types do not represent particular aspects of the wetlands. Representative photographs illustrating some of the wetland types in the Paroo River Wetlands Ramsar site are shown in Figures 6–10.

Table 2: Wetland types in order of most common wetland type

Ramsar code for wetland type	Wetland type according to the Ramsar classification system for wetland type	Examples from Nocoleche Nature Reserve	Examples from Peery
Ts	Seasonal, intermittent freshwater marshes, pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	Nocoleche claypans, *Eleocharis* and canegrass swamps	N/A
N	Seasonal, intermittent, irregular rivers, streams, creeks, channels	Paroo River, Cuttaburra Creek, Kulkyne Creek	Peery Creek
W	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	Lignum swamps, black box swamps (Momba swamp)	Lignum areas in Poloko Lake and the southern part of Peery Lake
P	Seasonal, intermittent freshwater lakes (over 8 ha); includes floodplain lakes	N/A	Peery and Poloko lakes
Tp	Permanent freshwater waterholes	Paroo River waterholes (for example King Charlie Waterhole)	N/A
Y	Freshwater springs; oases	N/A	Mound springs on the bed of Peery Lake

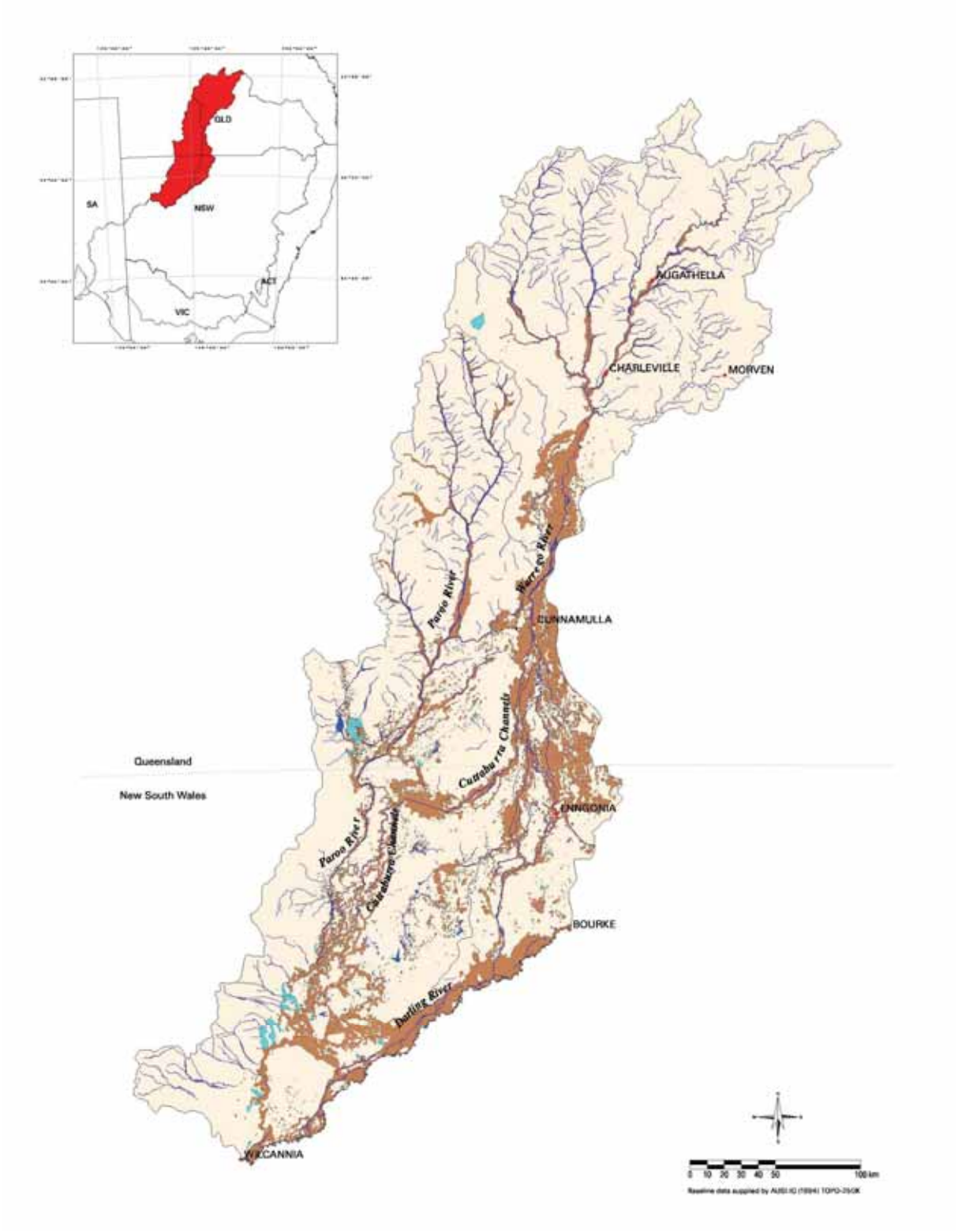

Figure 5: The Paroo and Warrego river catchments

The wetland types found in the Ramsar site can be described in more detail (Table 3). Descriptions and classifications of wetlands can sometimes hide the diversity of wetlands and give a false impression of discreteness which ignores ecological variability (Kingsford and Porter 1999). However, they are useful for providing a 'picture' of the wetlands.

The differences among wetlands determine the composition of the biota. Claypans and canegrass swamps are dominated by canegrass (*Eragrostis australasica*), nardoo (*Marsilea drummondii*), stoneworts and mud colonisers such as waterfire (*Bergia trimera*). River channels and waterholes are mostly comprised of fringing floodplain eucalypts, such as river red gum (*Eucalyptus camaldulensis*), black box (*E. largiflorens*), coolibah (*E. coolabah*) and yapunyah (*E. ochrophloia*), and may have an understorey of river cooba (*Acacia stenophylla*), lignum (*Muehlenbeckia florulenta*), grasses and herbs. Black box swamps are dominated by black box and bimble box (*E. populnea*), with a ground cover of sedges, grasses and herbs, and submerged water plants.

Eleocharis swamps are dominated by sedges and grasses and have occasional shrubs such as lignum, spiny lignum or nitre goosefoot. Lignum swamps are mostly filled with lignum and sedges and may be sparsely fringed by black box, bimble box and river cooba. Claypans, permanent waterholes in river channels, black box swamps and *Eleocharis* swamps are only found in the Nocoleche Nature Reserve component of the Ramsar site.

Figure 6: Flooded claypans in Nocoleche Nature Reserve
Photo: R.T. Kingsford

Table 3: Main wetland types in the Paroo River Wetlands Ramsar site

Wetland type	Vegetation	Geomorphology*	Hydrology
Claypans and canegrass swamps Example: Nocoleche claypans	Treeless margins, with chenopod shrubs or grasses fringing; low to extensive cover of canegrass (*Eragrostis australasica*); nardoo (*Marsilea drummondii*), stoneworts (*Nitella* spp. and *Chara* spp.) and mud colonisers such as waterwort (*Elatine gratioloides*), mudworts (*Limosella* spp.) and matted pratia (*Pratia darlingensis*) may appear after flooding.	Shallow wind-formed pans with heavy non-cracking clays. Often small in area and flat-bottomed.	Freshwater, highly turbid. Fill rapidly from local runoff, and dry quickly.
River channels and waterholes Examples: Paroo River King Charlie Waterhole Coorallie Waterhole	Fringing river red gum (*Eucalyptus camaldulensis*), blackbox (*E. largiflorens*), coolibah (*E. coolabah*), yapunyah (*E. ochrophloia*) and river cooba (*Acacia stenophylla*). Sparse to moderately dense shrub understorey of lignum (*Muehlenbeckia florulenta*), occasional canegrass (*Eragrostis australasica*), flowering lignum (*Eremophila polyclada*) and spreading emubush (*E. divaricata*). Grasses and annual herbs include warrego grass (*Paspalidium jubiflorum*), native millet (*Panicum decompositum*), channel millet (*Echinochloa inundatus*), couch (*Sporobolus mitchelli*), Jersey cudweed (*Gnaphalium luteo-album*), saffron thistle (*Carthamus lanatus***), *Goodenia* spp., common verbena (*Verbena officinalis*) and sedges (*Eleocharis acuta* and *Juncus* spp.). Water primrose (*Ludwidgia peploides* ssp. *montevidensis*) and duckweed (*Lemna* spp.) may be found in the water.	Shallow to deep river channels and impoundments formed by moving water and sediment deposition of major streams and waterways. Deep cracking grey clays with sandy deposits on higher ground.	Freshwater, highly turbid. Fill from local and regional rainfall in extensive catchment area. 'Blackwater' flows may occur after drought and are caused by concentration of tannins from leaf litter and debris. Many waterholes are semi-permanent and capable of holding water for prolonged periods.
Black box swamps Example: Momba swamp	Fringing black box (*Eucalyptus largiflorens*) and bimble box (*Eucalyptus populnea* ssp. *bimbil*) trees are typical. Ground cover of grasses include neverfail (*Eragrostis setifolia*), sedges (*Eleocharis acuta, E.pallens*, *Juncus aridicola*) and the herbs carpetweed (*Glinus lotioides*), monkey flower (*Mimulus repens*), blue rod (*Stemodia florulenta*), matted pratia (*Pratia darlingensis*), eryngo (*Eryngium plantagineum*), heliotrope (*Heliotropum europaeum,*** *H.supinum***), buttercups (*Ranunculus* spp.), sneezeweed (*Centipeda cunninghamii*), knotweed (*Polygonum plebeium*) and nardoo (*Marsilea angustifolia*, *M. drummondii*). If the water clears, the submergent plants milfoil (*Myriophyllum verrucosum*), water nymph (*Najas tenuifolia*) and stoneworts (*Chara australis* and *Nitella* spp.) may be found.	Small to large shallow or moderately deep basins. Grey or brown cracking clays, often with hummocks and potholes caused by expansion and contraction of the clays. May be formed on the edge of river floodplains or in sandplains away from major streams.	Fresh to moderately brackish water, moderate to low turbidity. Fill from local runoff, stream inflows and river floods.

Wetland type	Vegetation	Geomorphology*	Hydrology
Eleocharis swamps	Mostly treeless margins with occasional shrubs including lignum (*Muehlenbeckia florulenta*), spiny lignum (*M. horrida*) or nitre goosefoot (*Chenopodium nitrariaceum*) with extensive cover of sedges (*Eleocharis acuta*, *E.pallens*, *Fimbristylis dichotoma*, *Juncus aridicola*), grasses, including canegrass (*Eragrostis australasica*), Warrego grass (*Paspalidium jubiflorum*), native millet (*Panicum decompositum*), couch (*Sporobolus mitchelli*), beetle grass (*Diplachne fusca*), spike grass (*Elytrophorus spicatus*) and umbrella canegrass (*Leptochloa digitata*). Typical herbs are river mint (*Mentha australis*), joyweed (*Alternanthera denticulata*), knotweed (*Polygonum plebeium*), buttercups (*Ranunculus* spp.) and nardoo (*Marsilea angustifolia*, *M. drummondii*) after flooding.	Shallow to moderate depth basins in sandplains with flat or hummocky base and potholes. Cracking grey and brown clays. Larger basins may have an extensive catchment.	Fresh to moderately brackish water, moderate to low turbidity. Fill from local runoff, stream inflows and river floods.
Lignum swamps and overflow plains Example: Cuttaburra channels	May be sparsely fringed by floodplain eucalypts: black box (*Eucalyptus largiflorens*), bimble box (*E. populnea* ssp. *bimbil*) and river cooba (*Acacia stenophylla*). Moderate to dense shrub cover of lignum (*Muehlenbeckia florulenta*) and sometimes nitre goosefoot (*Chenopodium nitrariaceum*) or dillon bush (*Nitraria billardieri*). Dense cover of grasses; spear grasses (*Stipa* spp.), Warrego grass (*Paspalidium jubiflorum*), native millet (*Panicum decompositum*), channel millet (*Echinochloa inundata*), couch (*Sporobolus mitchelli*), umbrella canegrass (*Leptochloa digitata*) and sedges (*Eleocharis acuta*, *Juncus* spp.). Herbs such as milfoil (*Myriophyllum verrucosum*), duckweed (*Lemna* spp.) and nardoo (*Marsilea* spp.) appear after flooding.	Small to large basins and alluvial plains with shallow distributary channels. Grey and brown cracking clays often forming potholes and hummocks.	Fresh to moderately brackish water, moderate to low turbidity. Fill from local runoff, stream inflows and river floods. Moderate to large catchments.
Freshwater lakes Examples: Peery Lake Poloko Lake	Around margins and channels river red gum (*Eucalyptus camaldulensis*), black box (*E. largiflorens*), bimble box (*E. populnea* ssp. *bimbil*) and river cooba (*Acacia stenophylla*) occur. Ground cover at the margins is often a dense growth of sedges: spiny sedge (*Cyperus gymnocaulos*), couch (*Sporobolus mitchelli*), Warrego grass (*Paspalidium jubiflorum*), umbrella canegrass (*Leptochloa digitata*) and beetle grass (*Diplachne fusca*). Herbs such as milfoil (*Myriophyllum verrucosum*) are common. When drying back the lake bed may be colonised by carpetweed (*Glinus lotioides*), native liquorice (*Glycyrrhiza acanthocarpa*) and heliotropes (*Heliotropum europaeum,*** *H.supinum*****).	Terminal basins of old stream carved or blocked channel systems, may be large (>5 km^2) and deep (>2 m). Heavy cracking clays becoming increasingly sandy away from the centre of the lake.	Freshwater highly turbid lakes which can become moderately brackish when drying. Shallow to deep basins, intermittent to semi-permanent. Fill from local catchment and/or river inflows.
Artesian mound springs Example: Artesian mound springs on the bed of Peery Lake	Moderate to dense cover of sedges: *Cyperus gymnocaulos*, *C. laevigatus*, downs nutgrass (*C. bifax*), dirty dora (*C. difformis*), *C. gilesii*, *C. iria*, dwarf sedge (*C. pygmaeus*), bearded-flat sedge (*C. squarrosus*), common spike rush (*Eleocharis acuta*) and pale spike rush (*E. pallens*). Also includes the salt pipewort (*Eriocaulon carsonii*) and *Utricularia dichotoma.*	Mounds of accumulated mud and evaporate ranging from mounds up to 2 m high and 4 m in diameter to muddy depressions. Water flows from springs from the hydraulic pressure of the Great Artesian Basin	Freshwater, low turbidity. Muddy depressions to 2-m high mounds. Groundwater supplies water. Water flows permanently.

Source: Kingsland and Porter (1999) * Based on Goodrick (1984) ** Introduced species

Figure 7: A waterhole on the Paroo River in Nocoleche Nature Reserve
Photo: E. Lee, April 2006

Figure 8: Momba Swamp in the Nocoleche Nature Reserve, surrounded by black box
Photo: J. Winter/DECCW, 1998

Figure 9: Peery Lake
Photo: E. Lee, April 2006

Figure 10: Artesian mound springs on the bed of Peery Lake
Photo: E. Lee, April 2006

The margins of freshwater lakes are mostly fringed by river red gum, black box, bimble box and river cooba, with an understorey of sedges, grasses and herbs. Artesian mound springs (vents for the natural discharge of artesian water which occur on the margins of the Great Artesian Basin and are considered to be the rarest landform in Australia – McMahon et al. 2005) are dominated by sedges and samphires. Freshwater lakes and artesian mound springs are found only in the Peery component of the Ramsar site. There are two distinct sets of artesian mound springs on the eastern and western sides of Peery Lake, and together these comprise the largest active springs complex in NSW. These mound springs, the only known mound springs on lake beds in NSW, are formed from accumulated mud and evaporite (Ponder 1986, 1999) which can contain carbonates, clastic material and salts (McMahon et al. 2005) and are thus highly variable, ranging from mounds up to two metres high and four metres in diameter, to muddy depressions with little surface expression in the bed of Peery Lake (McMahon et al. 2005; Figure 10). Both Nocoleche Nature Reserve and Peery contain intermittent river channels and lignum swamps.

2.4 Land tenure

As the Paroo River Wetlands Ramsar site includes Nocoleche Nature Reserve and part of the Paroo–Darling National Park, it is gazetted under the *National Parks and Wildlife Act 1974* (Nocoleche Nature Reserve was gazetted in 1979 and Peery, which is in Paroo–Darling National Park, was gazetted in April 2000). The Nocoleche Nature Reserve component is managed under the Nocoleche Nature Reserve Management Plan (NPWS 2000), while the Peery component is managed under the Paroo–Darling National Park Management Plan (NPWS 2009) (see Appendix 1 for details of management plans). The lands surrounding both components are leased to pastoralists for grazing under Western Lands Leases. The travelling stock routes which bisect Nocoleche Nature Reserve and adjoin Peery are Crown land administered by the local Livestock Health and Pest Authority. The road that bisects Peery is a shire main road and is maintained by the Wilcannia Central Darling Shire (RIS 2007).

2.5 Criteria for listing

The Paroo River Wetlands Ramsar site was designated based on meeting six of the nine Ramsar criteria (1, 2, 3, 4, 5 and 7):

1 … contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
2 … supports vulnerable, endangered or critically endangered species or threatened ecological communities.
3 … supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
4 … supports plant and/or animal species at a critical stage of their life cycles, or provides refuge during adverse conditions.
5 … regularly supports 20,000 or more waterbirds.
7 … supports a significant proportion of indigenous fish subspecies, species or families, life history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

3 Ecosystem components, processes, services and benefits

The complex interactions among the biological, physical and chemical components of a wetland make it difficult to clearly distinguish among the components and their interactions, and the products, functions and attributes of a wetland (Figure 11). Components may be biological, physical or chemical and can serve as indicators of the ecological character of a wetland. The different components of an ecosystem are closely linked through ecological processes. The ecological character is defined as the sum of its components and processes. The ecosystem services can be thought of as a subset of components and processes of the ecological character that specifically provide benefits to people.

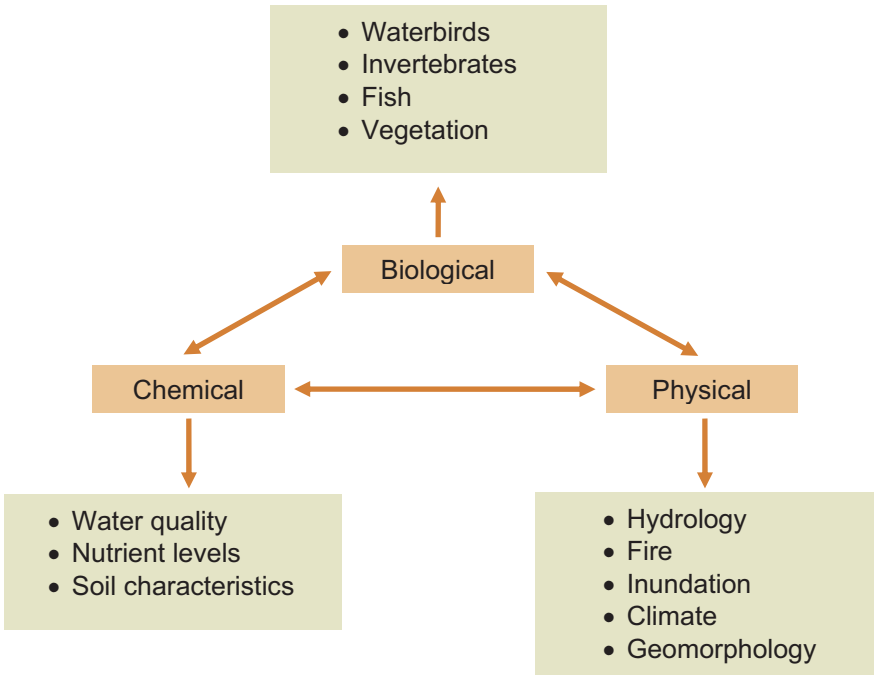

Figure 11: Interactions among the chemical, physical and biological components of a wetland and examples of different categories

3.1 Ecosystem components

The major ecological components for any wetland such as the Paroo River Wetlands Ramsar site are listed in Table 4. These broad categories provide a hierarchy into which most components that can be measured at a range of different spatial and temporal scales fall.

There are many potential ecosystem components that could be presented. The specific focus is on components for which some data exist and which are likely to be useful for management and policy for the ecological health of the wetland. To be useful for management and decision-making, data for a component should identify particular changes that may be of interest.

Wetlands of the Paroo River and their associated plants and animals are unusually diverse because of enormous variations in the water regime (driven by unpredictable rainfall), geomorphology and physicochemical environments (Timms and Boulton 2001; Roshier et al. 2002; Brock et al. 2006; Young and Kingsford 2006). Floods and droughts are unpredictable (Roshier et al. 2002; Young and Kingsford 2006), with surface water expanding and contracting across the landscape and altering the size, shape and connectivity of aquatic

habitats (Brock et al. 2006); these variations provide essential conditions for aquatic organisms (McComb and Qiu 1998; Boulton et al. 2006; Kingsford et al. 2006). Many plants and animals in the Paroo River Wetlands Ramsar site use the ecosystems throughout the Paroo River catchment and sometimes beyond for their survival and reproduction. These wetlands therefore need to be considered as part of the Paroo River catchment.

Table 4: Major ecosystem components

Component type	Examples
Biological	Species (genes, individuals and populations) Flora and fauna communities (community assemblages) Exotic species (weeds and feral animals) Other biota (for example bacteria, fungi, community assemblages) Habitats Habitat connectivity
Physical	Geomorphology Soils (sediment composition) Fire regime Climate (local, catchment rainfall, evaporation) Size (area of wetland when fully inundated) Morphology (length, width, shape, depth) Connectivity of surface waters (distributary creeks) Water source (surface water and/or groundwater) Substrate or soil type Light reaching the wetland (openness or shading) Light attenuation in water Water temperature Water turbidity Wetland buffer zone
Chemical	Dissolved gases (hydrogen, nitrogen, oxygen, carbon dioxide and methane) Water salinity Redox potential of water and sediments Nutrients (for example, phosphorus, nitrogen, potassium, sodium, magnesium, calcium, and trace elements such as iron, manganese, copper, zinc and silicon) Dissolved organic carbon

Source: DSE (2005)

3.1.1 Biological components

Biodiversity

Wetlands in the Paroo River catchment support high biodiversity at the species, genetic and ecosystem levels (Watts 1999; Table 5). Understanding of the biodiversity at each of these levels is limited, but several studies have demonstrated the existence of unique biodiversity in the Paroo River catchment. For example, plant species endemic to the Paroo region (such as yapunyah (*Eucalyptus ochrophloia*), starfruit (*Damsonium minus*), *Nitella partita*, *Aponogeton queenslandicus* and salt pipewort), newly identified species of plants and animals (aquatic plants and crustacean and reptile species, which are probably endemic to the Paroo region), and a breeding population of golden perch have been found in wetlands in the Paroo River catchment (Watts 1999).

Endemic plant species that are supported in the Paroo River Wetlands Ramsar site include large stands of yapunyah, a medium-sized (~15 m high) floodplain tree with rough, hard yellowish bark and a high tolerance for drought and extremes of temperature (Brooker and Kleinig 1990; Figure 12) that is found on the braided floodplain of Nocoleche Nature Reserve. Nocoleche Nature Reserve also supports starfruit (*Dentella minutissima*) and the

charophyte algal species *Nitella partita*, and has the only known NSW record for the aquatic plant *Aponogeton queenslandicus* (these species are all threatened in NSW and listed under the TSC Act). Peery supports the nationally threatened salt pipewort.

Several new plant species have been found in the Ramsar site. These are the aquatic plants *Nitella* 'parooensis' (charophyte algae) and *Goodenia* sp. 'Nocoleche' (a small yellow-flowered aquatic herb) in Nocoleche Nature Reserve (Pellow and Porter 2005) and a new species of *Utricularia* spp. at Peery Lake (Westbrooke et al. 2003). Newly identified fauna that are supported in the Ramsar site, which may also be endemic to the Paroo region, include crustacean and reptile species (RIS 2007). Two new crustacean species in the genus *Branchinella* (fairy shrimp) – *Branchinella budjiti* and *B. campbelli* – a new genus in the family Branchipodidae and a new species of *Parastreptocephalus* (Streptocephalidae) were discovered in Nocoleche Nature Reserve (Timms 2001); these fairy shrimp are not found in Peery due to predation by fish (RIS 2007). Two new species of reptiles (genera *Ctenotus* and *Tympanocryptis*, which are striped skinks and small earless dragons, respectively) were found at Peery Lake (RIS 2007).

Besides new and endemic species, wetlands in the Paroo River catchment (which probably include wetlands in the Ramsar site) support a genetically distinct and separate breeding population of golden perch (*Macquaria ambigua*) (Keenan et al. 1996, 1998).

Table 5: Species, genetic and ecosystem diversity

Biodiversity attribute	Nocoleche Nature Reserve (NPWS 2000)	Peery (NPWS 2009)
Species diversity		
Waterbirds	63 species (Kingsford and Porter 1999)	Lake Peery: 42 species Lake Poloko: 35 species (Kingsford and Porter 1999)
Other birds	117 species	237 species
Vegetation	304 species	378 species in Paroo–Darling National Park from a 2003 survey following rain, with an extra 46 species from a drier survey (Westbrooke et al. 2003)
Reptiles	37 species	67 species. An additional survey in 1999 of Lake Peery identified 41 species
Frog	15 species	14 species
Fish	8 species (Gehrke et al. 1999)	11 species in the lakes of the Paroo (Gehrke et al. 1999)
Mammals	26 species	26 species
Aquatic invertebrates	23 families of aquatic macroinvertebrates (B. Grey 2005, pers. comm.)	17 families of aquatic macroinvertebrates (B. Grey 2005, pers. comm.)
Genetic diversity		
Fish	Golden perch in the Paroo River form a single breeding population (Keenan et al. 1996, 1998)	
Ecosystem diversity		
Ecosystem	Floodplain wetlands: claypans, river channels and waterholes, *Eleocharis* swamps, lignum swamps and black box swamps	Freshwater lakes that turn brackish from evaporation. Artesian mound spring at Lake Peery supports the Artesian springs ecological community The Peery Lake mound spring is one of the few places where permanent water occurs away from the Darling River in far-western NSW

Source: RIS (2007) adapted from NPWS (2000) unless otherwise stated

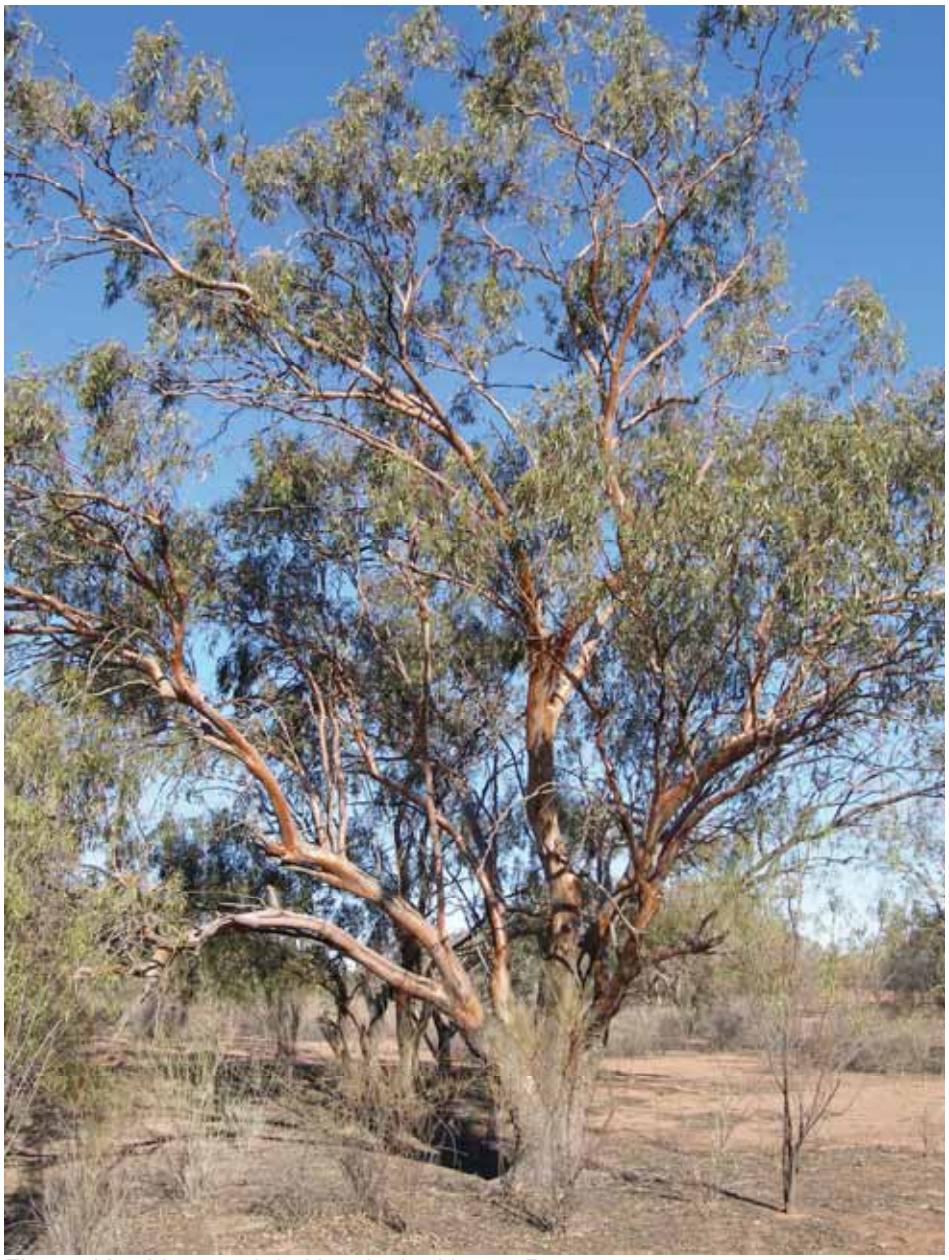

Figure 12: Yapunyah in Nocoleche Nature Reserve
Photo: J. Porter, April 2006

Waterbirds

Knowledge of fauna is greatest for waterbirds as a result of surveys of waterbird species using the Ramsar site and other sites between 1987 and 1990 (Kingsford et al. 1994) and waterbird surveys in parts of the Paroo River catchment from 1984 to 2005.

Migratory waterbirds

Migratory shorebirds visit Australia during their non-breeding season (August–April) and return to sites in Siberia and Alaska to breed (Kingsford 1998). The Paroo River wetlands are important for migratory shorebirds and other waterbirds listed under international bird agreements (JAMBA, CAMBA and ROKAMBA). Fifteen species of waterbirds covered by migratory bird agreements have been recorded in the Paroo River Wetlands Ramsar site (RIS 2007; Table 6) of which 10 are migratory shorebirds, including godwits, sandpipers and stints.

Table 6: Migratory bird species listed under international agreements

Family	Species	Common name
Ardeidae	*Ardea alba*	Great egret
Plataleidae	*Plegadis falcinellus*	Glossy ibis
Scolopacidae	*Limosa lapponica*	Bar-tailed godwit*
	Limosa limosa	Black-tailed godwit*
	Actitis hypoleucos	Common sandpiper*
	Calidris acuminata	Sharp-tailed sandpiper*
	Calidris ferruginea	Curlew sandpiper*
	Calidris ruficollis	Red-necked stint*
	Calidris subminuta	Long-toed stint*
	Tringa glareola	Wood sandpiper*
	Tringa nebularia	Common greenshank*
	Tringa stagnatilis	Marsh sandpiper*
Rostratulidae	*Rostratula benghalensis*	Painted snipe
Laridae	*Chlidonias leucoptera*	White-winged black tern
Laridae	*Sterna caspia*	Caspian tern

* Migratory shorebirds
Source: RIS (2007); DFAT (2006)

Waterbird abundance

The Paroo River Wetlands Ramsar site and surrounding wetlands in the Paroo River catchment support large concentrations of waterbirds. The maximum number of waterbirds in a single survey for Peery Lake, obtained from aerial surveys conducted every three months from 1987 to 1990, with an additional survey conducted in March 1993, with four counts per survey (Kingsford et al. 1994; Kingsford and Porter 1999), was estimated to be 35,900 in March 1990 and 38,000 in March 1993 (Kingsford and Porter 1999). For Poloko Lake, the maximum waterbird number was estimated at 28,000 in December 1990. Temporal patterns of waterbird abundance at Peery and Poloko lakes are shown in Figure 13 (mean abundances over four counts per survey period). No abundance data are available for Nocoleche Nature Reserve.

Common species (those with more than 1000 individuals) recorded at Peery Lake during the three-year survey were pink-eared duck (*Malacorhynchus membranaceus*), grey teal (*Anas gracilis*), red-necked avocet (*Recurvirostra novaehollandiae*), hardhead (*Aythya australis*), eurasian coot (*Fulica atra*) freckled duck (*Stictonetta naevosa*), black swan (*Cygnus atratus*) and Australian wood duck (*Chenonetta jubata*). For pink-eared duck and grey teal, maximum numbers estimated in a single survey exceeded 10,000. Common species at Poloko Lake (those which numbered more than 1000 individuals in a single survey) were grey teal, pink-eared duck, black-tailed native-hen (*Gallinula ventralis*), red-necked avocet, black swan and Pacific black duck (*Anas superciliosa*) (Kingsford and Porter 1999). Detailed data for the remaining species surveyed and numbers counted for Peery and Poloko lakes are provided in Appendices 4 and 5, respectively. Other less common species may have been underestimated by as much as 50% (Kingsford and Porter 1994).

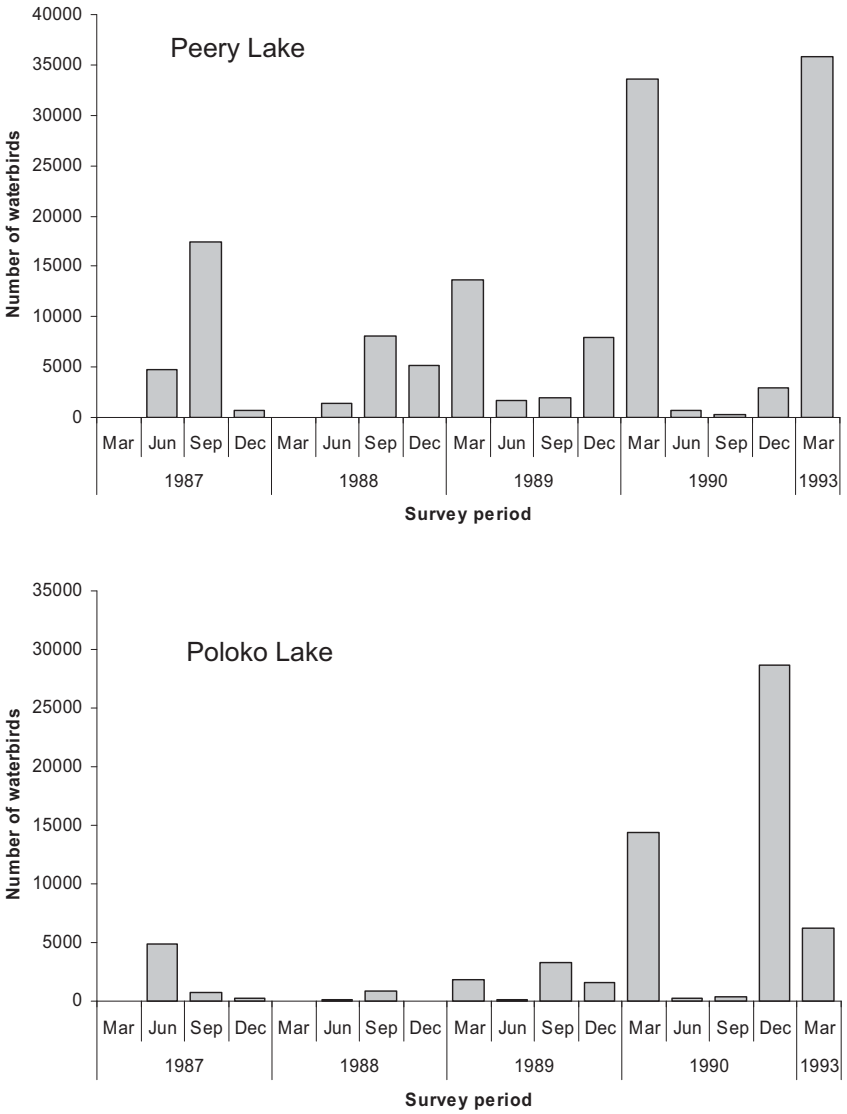

Figure 13: Temporal variation in the estimated mean abundance of waterbird species over four counts

Waterbird diversity

Highly diverse waterbird assemblages are supported in the Paroo River Wetlands Ramsar site. Some short-term temporal data from aerial surveys conducted every three months from 1987 to 1990, with an additional survey in March 1993, are available for the numbers of waterbird species (Kingsford et al. 1994; Kingsford and Porter 1999).

Data show that the number of species has varied over time, but that a maximum of 30 and 28 waterbird species have been counted during single surveys for Peery and Poloko lakes respectively (Figure 14), although the total number of species recorded over the three-year survey period for Peery and Poloko lakes was 42 and 35 species (Table 5). The actual number of species will be higher because small numbers of waterbirds are often missed in aerial surveys (Kingsford and Porter 1994)

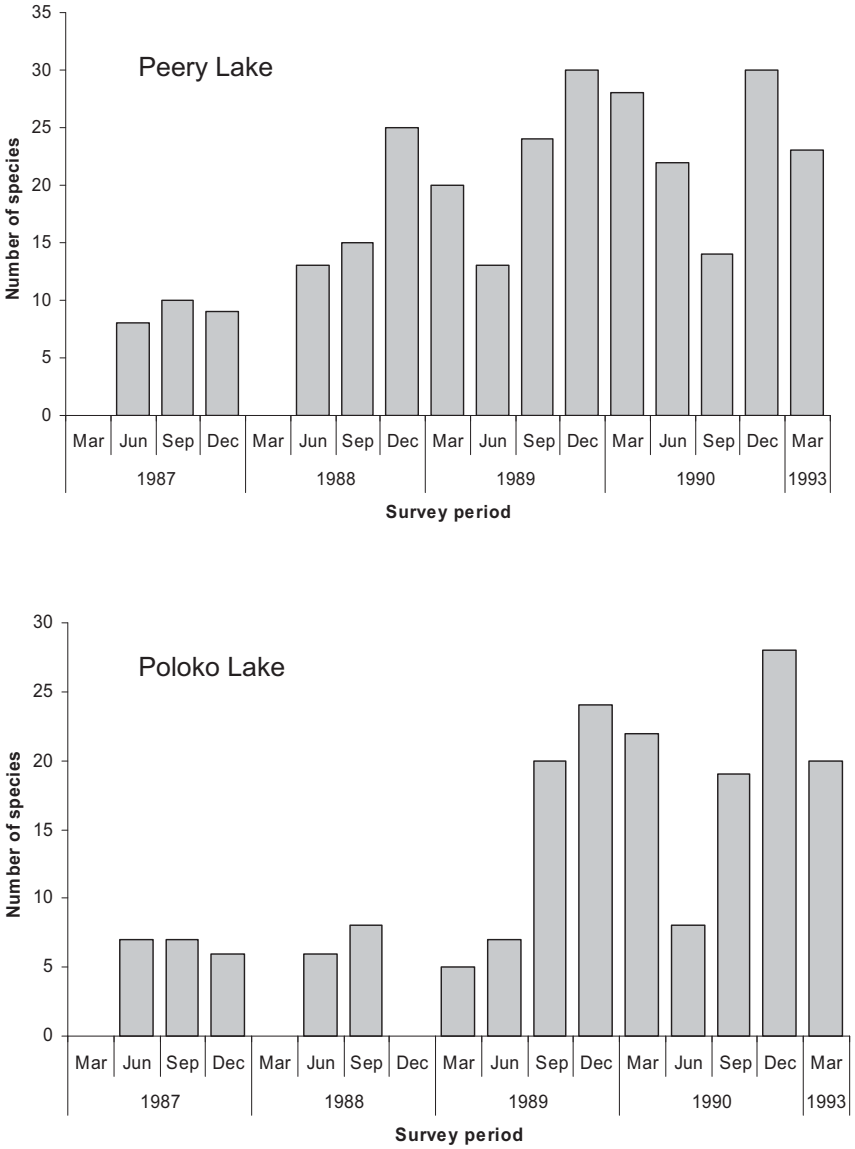

Figure 14: Temporal variation in numbers of waterbird species recorded at Peery and Poloko lakes
Data: R.T. Kingsford

Variability in the number of waterbird species over time is usual in the wetlands in the Paroo River catchment (Kingsford and Porter 1999). In wetlands outside of the Ramsar site, waterbird data collected annually are available not only from between 1987 and 1990 but also from 1983 to 2005. While wetland types will affect the species of waterbirds visiting wetlands (Kingsford et al. 1994), averages taken over five freshwater lakes similar to Peery and Poloko lakes (Tongo Lake, Mullawoolka Basin, Yantabangee Lake, Blue Lake and Green Lake), as well as over the seven lakes (to include datasets for Peery and Poloko lakes between 1987 and 1990) show this natural variability (Figure 15). Since 1983, the average number of waterbird species has ranged from two in 2005 to approximately 23 in December 1989 and December 1990. In 2002 and 2003 the wetlands were dry.

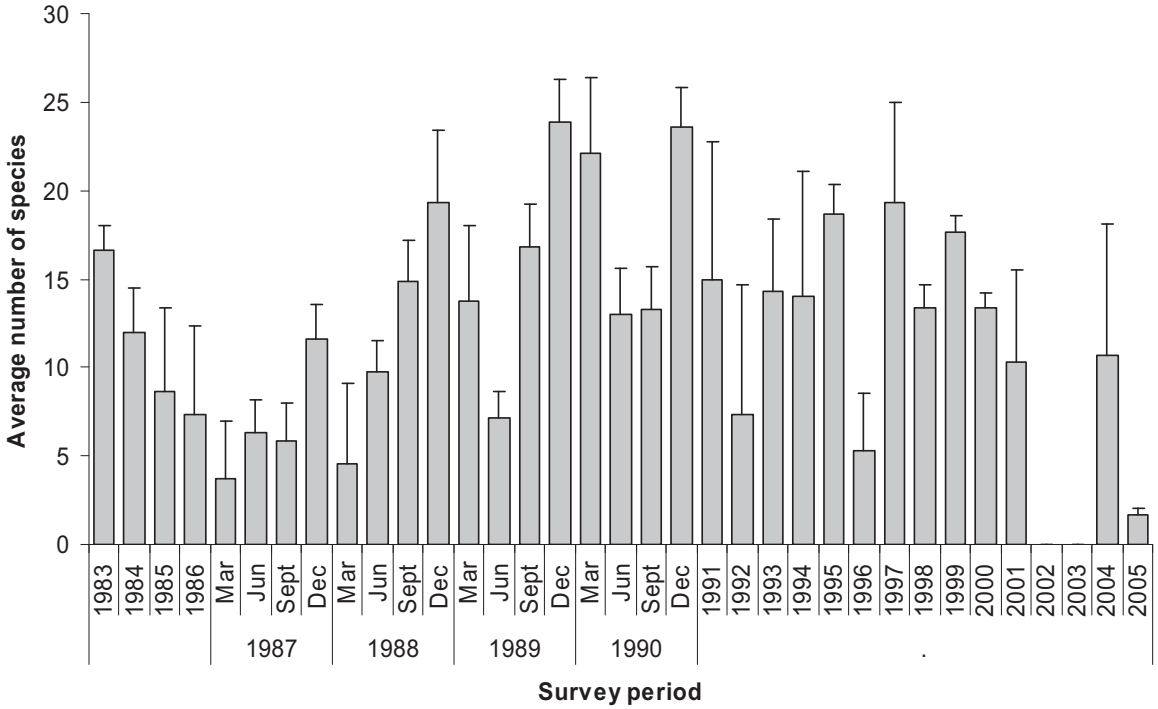

Figure 15: Temporal variation in the average number of waterbird species

Note: Error bars for years show standard errors calculated from the five lakes near Peery and Poloko lakes, while error bars for months between 1987 and 1990 show standard errors calculated from all seven lakes.

Data: R.T. Kingsford

Fish

Wetlands in the Paroo River catchment support a significant native fish community. Data collected from four habitat types in the Paroo Overflow (lake, river, creek, floodplain) at Mullawoolka Basin, Paroo River, Tongo Creek and Mustang Flat (six sample times between July 1992 and July 1995) show that 10 fish species are present in this part of the Paroo River catchment (Gehrke et al. 1999), although a total of 12 fish species has been recorded in the Ramsar site (Harris and Gehrke 1997; Appendix 3). Comparisons of the number of species found in the different habitats sampled reveal that lake habitats supported the highest number of species (10 species – seven native and three exotic), followed by creek and river habitats (eight species each – five native and three exotic), and then floodplain habitats (six species – three native and three exotic) (Table 7). In terms of supporting large numbers of fish, however, river habitats ranked highest, followed by lake, creek and floodplain habitats. The fish community in this part of the Paroo River catchment was dominated by native species (seven native compared to three exotic species: Gehrke et al. 1999). Bony bream (*Nematolosa erebi*), a native species, comprised almost half the fish population. Populations of the next most abundant native species, spangled perch (*Leiopotherapon unicolour*) and golden perch (*Macquarie ambigua*), together comprised almost a quarter of the fish population. Bony bream and golden perch are common in remnant waters in the Paroo River catchment during the dry season (Boulton 1999). Although there is little specific research, the Paroo River Wetlands Ramsar site probably provides important habitat for the fish populations of the Paroo River.

Table 7: Total captures of fish species in four habitats

Fish species	Creek	Floodplain	Lake	River	Total
Silver perch	0	0	1	0	1
Spangled perch	158	128	150	298	734
Golden perch	136	76	130	235	577
Crimson-spotted rainbowfish	0	0	1	0	1
Bony bream	1,148	558	1,906	480	4,092
Hyrtl's tandan	37	0	21	43	101
Australian smelt	3	0	18	1	22
Goldfish	16	3	17	90	126
Carp	387	283	179	1,661	2,510
Gambusia	9	5	29	8	51
Total	**1,894**	**1,053**	**2,452**	**2,816**	**8,215**

Note: Samples were taken between July 1992 and July 1995.
Source: Gehrke et al. (1999)

Other vertebrates

The Ramsar site supports other vertebrate fauna such as amphibians, reptiles, small mammals and arid desert birds (Kingsford and Porter 1999). Little is known of such fauna in terms of their abundances and use of wetlands in the Ramsar site. However, the occurrence of some species is known, and the number of species per fauna group are shown in Table 5. Some of the faunal species are threatened or of conservation concern in western NSW.

Many of the fauna are likely to be significantly affected by the flooding and drying patterns of the Paroo River wetlands. The 15 species of frogs recorded in the Paroo River Wetlands Ramsar site are adapted to surviving long dry periods, and during floods they emerge and breed (Kingsford and Porter 1999). The Murray turtle (*Emydura macquarii*) is affected by the availability of water, and during dry periods is likely to be restricted to permanent waterholes in Nocoleche Nature Reserve. Small mammals, such as the water rat (*Hydromys chrysogaster*), have life histories significantly affected by flooding and drying patterns of rivers (Briggs 1992). Arid-zone rivers provide valuable areas for terrestrial birds, and an estimated 40% of Australian desert land birds are thought to be water-dependent (Fisher et al. 1972). The Paroo River Wetlands Ramsar site is known to support 120 species of terrestrial birds and many of these birds either drink from the wetlands or rely on floodplain eucalypts for habitat. Flooding is probably an important stimulus for flowering of vegetation which provides food for honeyeaters (Kingsford and Porter 1999).

Vegetation

The Paroo River Wetlands Ramsar site supports over 300 plant species. In Nocoleche Nature Reserve alone, 317 species have been recorded (Kingsford and Porter 1999; Porter and Kingsford, unpublished data). The exact number of plant species supported by Peery is unknown, although Westbrooke et al. (2003) estimated that 378 species of plants were supported in Paroo–Darling National Park.

Vegetation communities have not been mapped for the whole of the Ramsar site. However, vegetation is generally related to wetland type, with some overlap between wetland types (Kingsford and Porter 1999). As wetland types in the Ramsar site and the vegetation associated with wetland types in the Paroo River catchment are known, it is possible to infer dominant vegetation and vegetation communities in the wetlands of the Ramsar site (Table 3). Dominant vegetation for wetland types is given in Table 8, and a list of plant species for the Ramsar site is given in Appendix 2.

Table 8: Dominant vegetation

Wetland type	Vegetation
Claypans and canegrass swamps	Canegrass (*Eragrostis australasica*) Nardoo (*Marsilea drummondii*) Stoneworts (*Nitella* spp. and *Chara* spp.) Mud colonisers, for example waterfire (*Bergia trimera*)
River channels and waterholes	River red gum (*Eucalyptus camaldulensis*) Black box (*E. largiflorens*) Coolibah (*E. coolabah*) Yapunyah (*E. ochrophloia*) River cooba (*Acacia stenophylla*) Lignum (*Muehlenbeckia florulenta*) Grasses and herbs
Black box swamps	Black box (*E. largiflorens*) Bimble box (*E. populnea*) Ground cover of sedges, grasses, herbs and submerged water plants
Eleocharis swamps	Lignum (*Muehlenbeckia florulenta*) Spiny lignum (*M. horrida*) Nitre goosefoot (*Chenopodium nitrariaceum*) Sedges, such as *Eleocharis acuta* and *E. pallens*, and grasses and herbs
Lignum swamps	Lignum (*M. florulenta*) Sedges, grasses and herbs Some scattered black box (*Eucalyptus largiflorens*) Some scattered bimble box (*E. populnea*) Some scattered river cooba (*Acacia stenophylla*)
Freshwater lakes	Sedges, grasses and herbs River red gum (*E. camaldulensis*) Black box (*E. largiflorens*) Bimble box (*E. populnea*) River cooba (*Acacia stenophylla*)
Artesian springs	Sedges (*Eleocharis* or *Cyperus* spp.) Samphires Salt pipewort (*Eriocaulon carsonii*)

Source: Kingsford and Porter (1999)

Some plants found in the Paroo River Wetlands Ramsar site are endemic to the Paroo River catchment. Nocoleche Nature Reserve supports large stands of yapunyah (*Eucalyptus ochrophloia*) which mainly grows in floodplain areas close to the main river channel (Brooker and Kleinig 1990; Figure 12). Nocoleche Nature Reserve also supports starfruit (*Dentella minutissima*) and the charophyte algal species *Nitella partita*, and has the only known NSW record for the aquatic plant *Aponogeton queenslandicus* (these species are all threatened in NSW and listed under the TSC Act). Peery supports the nationally threatened salt pipewort.

In Paroo–Darling National Park, which includes the Peery component of the Paroo River Wetlands Ramsar site, vegetation has been surveyed and mapped, and approximate areas of each vegetation community type have been documented (Westbrooke et al. 2003; Figure 16). Twenty vegetation communities have been identified. The most widespread community (making up 33% of the area around Peery Lake) is *Acacia aneura* tall shrubland, and the next most common vegetation communities are *Eremophila – Dodonaea – Acacia* open shrubland and *Maireana pyramidata* low open shrubland, making up 14.2% and 13% of the area around Peery Lake, respectively (Figure 16).

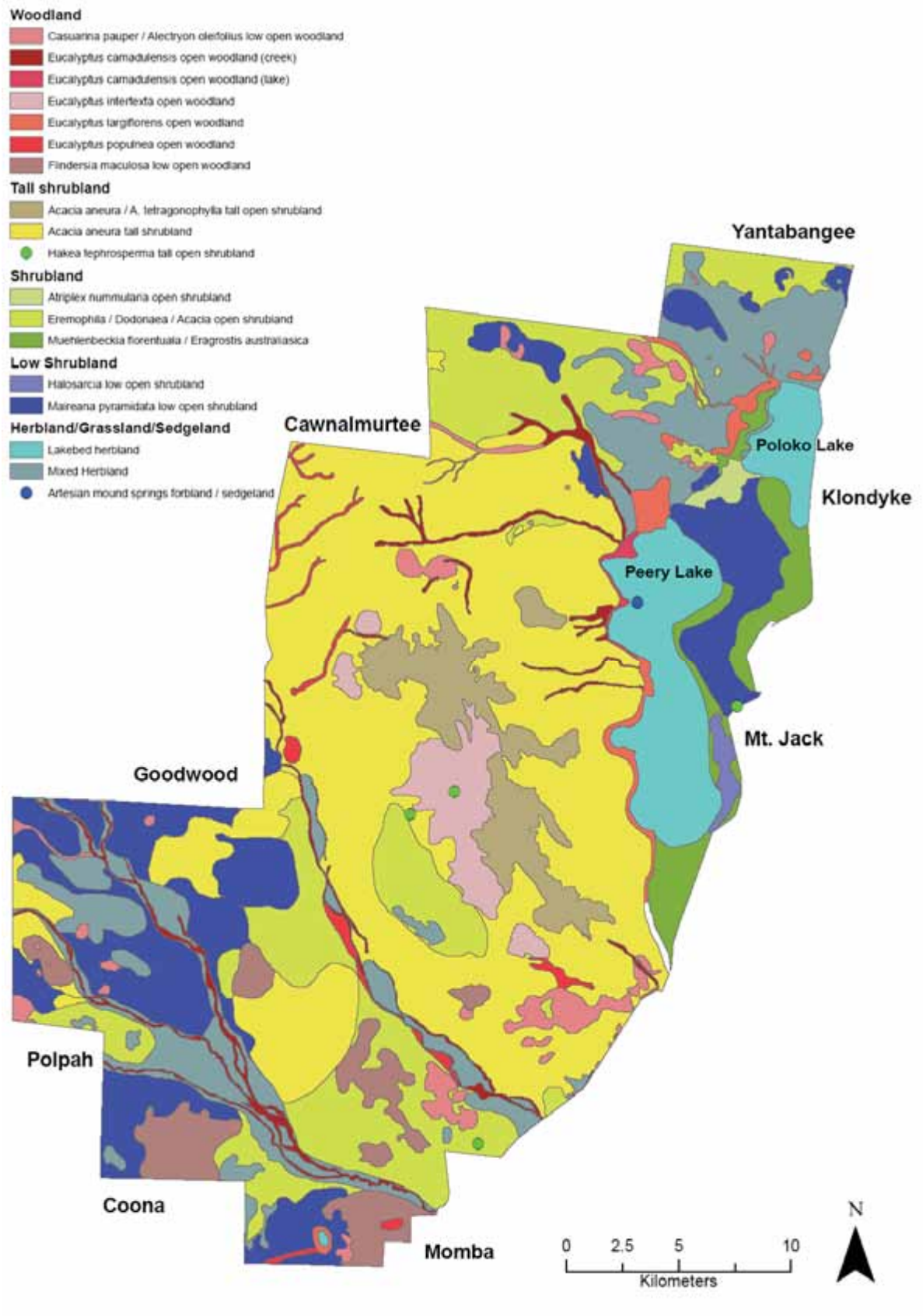

Figure 16: Vegetation communities in the Peery Lake area

Source: Westbrooke et al. (2003)

Note: Vegetation communities represented by circles are too small to be mapped at this scale. Names of surrounding areas are given as points of reference.

A vegetation community of particular interest in Peery is the sedgeland community on the mound springs of Peery Lake. This community is dominated by *Cyperus gymnocaulos* and *C. laevigatus* and includes the salt pipewort (*Eriocaulon carsonii*) which is endangered at the national level because it is endemic to and dependent on rare active mound springs. Although it is known from mound springs in Queensland, NSW and South Australia, it has only been recorded at two springs in NSW, and since the early 1900s has been found only on a single spring on the western side of Peery Lake (RIS 2007).

Vegetation in the Paroo River Wetlands Ramsar site provides food and habitat for fauna and hence strongly determines faunal community structure. The primary productivity of plants is the basis of all wetland food webs (Casanova 1999; Bunn et al. 2006). Some of the primary productivity in wetlands also comes from aquatic phytoplankton on which zooplankton feed. Other aquatic plants along with terrestrial plants form vegetation communities (Brock et al. 2006), and these communities provide both food and habitat for fauna, as well as nesting material and nesting sites (Casanova 1999). Vegetation is itself affected by hydrology, geomorphology, climate, physicochemical environment and biota.

Threatened species

The Paroo River Wetlands Ramsar site supports one nationally threatened plant species, the salt pipewort (*Eriocaulon carsonii*), which is listed as endangered under the EPBC Act, and six threatened plant species which are listed as endangered under the TSC Act (Table 9). The salt pipewort and *Aponogeton queenslandicus* are also listed as rare or threatened plants (Leigh et al. 1981). Spikegrass (*Elytrophorus spicatus*) is of particular conservation concern in western NSW (Bowen and Pressey 1993; RIS 2007).

In addition, the site supports 19 NSW threatened fauna species (13 bird, three mammal, two reptile and one fish species) two of which, the fat-tailed gecko (*Diplodactylus conspicillatus*) and the Australian bustard (*Ardeotis australis*), are listed as endangered under the TSC Act (Table 10). Many other fauna species that are of particular conservation concern in western NSW are also supported by the Paroo River Wetlands Ramsar site (Dickman et al. 1993; Smith et al. 1995*;* Saddlier et al. 1996) (Table 11).

Table 9: Threatened flora species listed under the EPBC Act and the TSC Act

Family	Species	Common name	Status under EPBC Act	Status under TSC Act
Characeae	*Nitella partita*			Endangered
Aponogetonaceae	*Aponogeton queenslandicus*			Endangered
Chenopodiaceae	*Dysphania platycarpa*			Endangered
Eriocaulaceae	*Eriocaulon carsonii*	Salt pipewort	Endangered	Endangered
Goodeniaceae	*Goodenia* sp. 'Nocoleche'			Endangered
Rubiaceae	*Dentella minutissima*	Starfruit		Endangered

Table 10: Threatened fauna species listed under the TSC Act and Fisheries Management Act 1994

Family	Species	Common name	Status
Reptiles			
Gekkonidae	*Diplodactylus conspicillatus*	Fat-tailed gecko	Endangered
Elapidae	*Simoselaps fasciolatus*	Narrow-banded snake	Vulnerable
Mammals			
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied sheathtail-bat	Vulnerable
Vespertilionidae	*Chalinolobus picatus*	Little pied bat	Vulnerable
	Vespadelus baverstocki	Inland forest bat	Vulnerable
Birds			
Anatidae	*Oxyura australis*	Blue-billed duck	Vulnerable
	Stictonetta naevosa	Freckled duck	Vulnerable
Accipitridae	*Hamirostra melanosternon*	Black-breasted buzzard	Vulnerable
	Lophoictinia isura	Square-tailed kite	Vulnerable
Falconidae	*Falco hypoleucos*	Grey falcon	Vulnerable
Gruidae	*Grus rubicunda*	Brolga	Vulnerable
Otididae	*Ardeotis australis*	Australian bustard	Endangered
Scolopacidae	*Limosa limosa*	Black-tailed godwit	Vulnerable
Rostratulidae	*Rostratula benghalensis*	Painted snipe	Vulnerable
Cacatuidae	*Cacatua leadbeateri*	Major Mitchell's cockatoo	Vulnerable
Climacteridae	*Climacteris picumnus*	Brown treecreeper	Vulnerable
Meliphagidae	*Certhionyx variegatus*	Pied honeyeater	Vulnerable
Pomatostomidae	*Pomatostomus halli*	Hall’s babbler	Vulnerable
Fish			
Terapontidae	*Bidyanus bidyanus*	Silver perch	Vulnerable

Table 11: Fauna species of conservation concern in western NSW that are supported by the Paroo River Wetlands Ramsar site

Family	Species	Common name
Amphibians		
Hylidae	*Cyclorana verrucosa*	Rough frog, warty water-holding frog
	Litoria alboguttata	Striped burrowing frog
Myobatrachidae	*Crinia deserticola*	Brown toadlet
	Crinia parinsignifera	Eastern sign-bearing froglet, plains froglet
Reptiles		
Gekkonidae	*Diplodactylus conspicillatus*	Fat-tailed gecko
	Gehyra dubia	Northern dtella
Scincidae	*Ctenotus strauchii*	Eastern wedgesnout ctenotus
Boidae	*Morelia spilota variegata*	Carpet python

Mammals		
Muridae	*Hydromys chrysogaster*	Water rat
Birds		
Phasianidae	*Coturnix ypsilophora*	Brown quail
Podicipedidae	*Podiceps cristatus*	Great crested grebe
Anhingidae	*Anhinga melanogaster*	Darter
Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant
	Phalacrocorax varius	Pied cormorant
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican
Ardeidae	*Ardea alba*	Great egret
	Ardea intermedia	Intermediate egret
Plataleidae	*Platalea regia*	Royal spoonbill
	Plegadis falcinellus	Glossy ibis
	Threskiornis molucca	Australian white ibis
	Threskiornis spinicollis	Straw-necked ibis
Laridae	*Larus novaehollandiae*	Silver gull
	Sterna caspia	Caspian tern
Pardalotidae	*Acanthiza reguloides*	Buff-rumped thornbill
Meliphagidae	*Melithreptus gularis*	Black-chinned honeyeater
Cinclosomatidae	*Cindosoma costaneothorax*	Chestnut-breasted quail thrush

Source: RIS 2007

Threatened ecological community

The Paroo River Wetlands Ramsar site supports the threatened Artesian Springs Ecological Community. It is listed as endangered under both the EPBC Act and the TSC Act due to the unique community of native species dependent on the natural discharge of groundwater from the Great Artesian Basin and the rarity of the mound spring landform in Australia. There are two distinct sets of artesian mound springs on the eastern and western sides of Peery Lake. The dominant vegetation of the mound springs is sedges (*Eleocharis* spp. or *Cyperus* spp.) and samphires (also known as glassworts), with the threatened salt pipewort a key component of the ecological community. A new species of *Utricularia* has been found on the mound springs of Peery Lake (Westbrooke et al. 2003; RIS 2007).

3.1.2 Physical components

Hydrology

Flow of the Paroo River

The Paroo River originates in south-western Queensland and flows through extensive floodplains before reaching the network of channels and wetlands known as the Paroo Overflow. Wetlands in the lower sections of the Paroo River catchment can receive flows from the neighbouring Warrego River via the distributary Cuttaburra Creek. During high flows (980,000 ML), and depending on antecedent conditions, the Paroo River can join the Darling River. Occasionally, high flows in the Darling River can move into the Paroo River (Kingsford and Porter 1999; Young 1999; Kingsford et al. 2001).

Filling patterns

Wetlands in the Paroo River Wetlands Ramsar site fill in different ways. Floodplain wetlands in Nocoleche Nature Reserve depend mainly on flows from the Paroo River and small stream inflows, but supplementary flows from the Warrego River may also enter the eastern section of the nature reserve through Cuttaburra and Kulkyne creeks (and hence development along the Warrego River in the Warrego catchment may affect wetlands in the Paroo River catchment). Other small wetlands (1–50 ha) away from the floodplain (the Nocoleche Pans) depend on local rainfall (Lawler and Briggs 1991; NPWS 2000). Both Peery and Poloko lakes rely predominantly on flows from the Paroo River from the north-east, and fill after other overflow lakes further north (Tongo Lake, Mullawoolka Basin and Yantabangee Lake) are flooded. Anecdotal records indicate the Darling River may flow into Peery Lake in extremely large floods (twice in 75 years). Besides flows from the Paroo River, Peery Lake can also fill from local rainfall – in 1971 the lake filled after 254–279 mm of local rainfall (Kingsford 1999b). The rain fills creeks flowing into the lake from the Peery Hills on the western border of the lake.

Geomorphology

The Paroo River Wetlands Ramsar site is 110–150 m above sea level and is in the Great Artesian Basin and the Mulga Lands Bioregion. The Mulga Lands Bioregion is dominated by horizontal Cretaceous sandstones and claystones deposited in an inland sea about 100 million years ago. The Cretaceous sediments vary in thickness across the basement rocks and form the main water-bearing strata of the Great Australian Basin.[8] On the surface of the bioregion, alluvial sediments (sand and clay) and silcrete pebbles and boulders dominate.

As the Paroo River Wetlands Ramsar site lies in two separate areas in the Mulga Lands Bioregion, the site is geomorphologically diverse. The wetlands of Nocoleche Nature Reserve comprise undulating sandplains and dunes, a reticulate system of broad, shallow, flat-bottomed distributary channels, floodplains and small lakes of the Paroo River and Cuttaburra and Kulkyne creeks. Soils are dominated by sandy red earths and grey cracking clays. The Peery component contains sandstone hills surrounded by stony plains, parallel dunes with swales, claypans and two overflow lakes, Peery and Poloko, which are terminal playa lakes. Peery Lake contains active artesian mound springs in its northern basin. These overflow lakes are the result of channel systems being blocked by ranges of Palaeozoic bedrock. Soils are dominated by reddish clay sands (RIS 2007).

The geomorphological features of the Ramsar site greatly affect the types of wetlands that form. This is because differences in topography, shapes of wetlands, sediment loads, rates of rainfall runoff and underlying bedrock influence the formation of wetland types and determine water permanence (Kingsford et al. 2006; Thoms et al. 2006).

Peery and Poloko lakes are deep freshwater lakes during floods or heavy local rainfall since underlying bedrock prevents floodwater or rainwater from infiltrating the ground, and runoff from surrounding sandstone hills channels rainwater into the lakes. Water can only leave the system through evaporation or when it overflows. Claypans form shallow wetlands, holding water as they are comprised of heavy, non-cracking clays that seal at the surface on wetting. However, they do not hold water for long as pans are usually small, shallow and flat-bottomed, and water is quickly lost through evaporation (Kingsford and Porter 1999). Artesian springs occur on the margins of the Great Artesian Basin where water moves from aquifer rocks through fault lines in the overlying rock to the surface (McMahon et al. 2005). Water flows from these springs are a result of the hydraulic pressure of the underlying Great Artesian Basin. Table 3 summarises the geomorphology of wetlands in the Paroo River Wetlands Ramsar site.

[8] www.environment.nsw.gov.au/bioregions/MulgaLands-Landform.htm

3.1.3 Chemical components

General characteristics of water quality for the wetland types in the Paroo River Wetlands Ramsar site are known (Table 12). According to Timms (1999) there is low, medium and high turbidity (<100 FTU, >100 FTU, and >1000 FTU respectively), low and moderate salinity (<2000 µS/cm and ~5000 µS/cm respectively) and water that is neutral and alkaline (pH of 7 and >7 respectively).

Table 12: Water quality characteristics

Wetland type	Turbidity	Salinity	pH
Claypans	High	Low	Close to neutral
River channels and waterholes	High	Low	Close to neutral
Black box, *Eleocharis*, lignum swamps	Moderate to low	Moderate	Weakly alkaline
Freshwater lakes	High	Low, but increases on drying	Alkaline
Artesian springs	Low	Low	Weakly alkaline

Source: Adapted from Kingsford and Porter (1999) and Timms (1999)

The physicochemical environment exerts a major influence on plant and animal communities in arid-zone wetlands (Bailey et al. 2006; Bunn et al. 2006) including wetlands in the Paroo River Wetlands Ramsar site (Brock et al. 2006). Generally, low salinity levels increase aquatic plant species diversity and seed bank density and diversity (Brock et al. 2006). Low salinity can also allow bacterial and fungal growth on leaf detritus and increase decomposition rates (Bailey et al. 2006; Bunn et al. 2006). However, low salinity can decrease the abundance of invertebrates which provide food for waterbirds (Kingsford and Porter 1999). Most wetlands in the Paroo River Wetlands Ramsar site are low in salinity, although Peery and Poloko lakes become brackish as they dry up (Table 12). Thus, plants and animals of the Ramsar site are influenced by high salinity at Peery and Poloko lakes during drying periods. During these periods, waterbird abundance has been found to increase in response to increases in food (Kingsford et al. 1997) but decreases as the wetlands become hypersaline.

Salinity can markedly affect other water quality variables and can thus affect the composition and production of plants, food webs and waterbirds through its effects on other measures of water quality (Kingsford and Porter 1994; Bunn et al. 2006). For example, salinity can affect turbidity (through flocculation of fine particles), dissolved oxygen levels and pH (increases in salinity decrease dissolved oxygen levels and pH) (Bailey et al. 2006). Turbidity in wetlands in the Paroo River Wetlands Ramsar site determines the depth distribution of plant species through its affect on light penetration. Aquatic plants in the wetlands of the Ramsar site are likely to be restricted to shallow littoral margins as they are in arid wetlands of Cooper Creek (Bunn et al. 2006).

The physicochemical environment of the Paroo River Wetlands Ramsar site is affected by hydrology, climate, geomorphology, habitat and biota as these components and processes affect water quality. For example, terrestrial plants such as red gum (*Eucalyptus camaldulensis*) and yapunyah (*E. ochrophloia*) filter runoff and reduce turbidity (Casanova 1999), and invertebrates such as mosquito larvae, some zooplankton and aquatic worms improve water quality (Boulton 1999).

3.2 Ecosystem processes

3.2.1 Biological processes

Breeding waterbirds

Many waterbird species use inland wetlands in Australia to breed. Breeding usually occurs when food supply is high and when suitable habitat is available (usually after flooding); thus there may be years when many species do not breed, and this may affect the long-term survival of waterbird species (Young and Kingsford 2006).

Short-term temporal data available for the Paroo River Wetlands Ramsar site (Kingsford et al. 1994; Kingsford and Porter 1999) show that 10 waterbird species have bred on Peery Lake (Table 13). This will be an underestimate by more than 50% because of the bias in estimating abundance for birds in small numbers during aerial surveys (Kingsford et al. 1994). During the three-year survey, the number of breeding waterbirds was highest for Australian pelicans (*Pelecanus conspicillatus*) (although data at three-monthly intervals are not available for this species) with 100 breeding records, followed by Australian white ibises (*Threskiornis molucca*) (41 records), black swans (*Cygnus atratus*) (12 records) and yellow-billed and royal spoonbills (*Platalea flavipes* and *P. regial*) (10 records each). Most breeding occurred in the spring and summer months.

Only five species of waterbirds were recorded breeding on Poloko Lake, two of which have not been recorded as breeding on Peery Lake: red-necked avocet (*Recurvirostra novaehollandiae*) and freckled duck (*Stictonetta naevosa*) (Table 14). Royal spoonbills had the highest number of breeding records on Poloko Lake during the three-year study (24 records). Although no numbers are available for freckled ducks, this vulnerable species has bred on Poloko Lake (Maher 1991). The pattern of spring breeding was not as pronounced on Poloko Lake as it was on Peery Lake. Even so, more waterbird species bred in the spring of 1990 than at other periods when breeding records were confined to only one waterbird species per period. Besides records from the three-year survey period, records from the

Table 13: Number of breeding waterbirds on Peery Lake

Species	September 1988	September 1989	December 1989	September 1990	December 1990	Total no. breeding
Black swan	2	4	3	1	2	**12**
Grey teal	1	1		1		**3**
Pink-eared duck	1	1				**2**
Hardhead		1				**1**
Eurasian coot		1				**1**
Australian white ibis			1		40	**41**
Pacific black duck			1			**1**
Yellow-billed spoonbill					10	**10**
Royal spoonbill					10	**10**
Australian pelican	These were recorded breeding, but nests, broods, and breeding pairs were not individually counted.					**100**

Note: Numbers are estimated from aerial counts conducted every three months between March 1987 and December 1990, with an additional count conducted in March 1993. Survey periods in which no waterbirds bred are not presented. Numbers represent the number of broods, nests or breeding pairs.

Source: Adapted from Maher (1991) and Kingsford and Porter (1999)

1970s and 1980s show that silver gulls (*Larus novaehollandiae*) and whiskered terns (*Chlidonias hybridus*) have bred on Poloko Lake following large floods (Kingsford and Porter 1999). There are no breeding records for waterbirds in Nocoleche Nature Reserve.

Breeding records for waterbirds on similar wetlands outside the Paroo River Wetlands Ramsar site indicate that more waterbird species could potentially use the Ramsar site to breed. On five wetlands similar to Peery and Poloko lakes slightly to the north (Tongo Lake, Mullawoolka Basin, Yantabangee Lake, Blue Lake and Green Lake; Kingsford et al. 1994), at least 17 waterbird species have been recorded breeding (data from aerial surveys collected at three-monthly intervals between 1987 and 1990, with an additional survey in March 1993, as well as annually from 1983 to 2005) (Table 15). Eight of these waterbird species – Australasian shoveler (*Anas rhynchotis*), Australian wood duck (*Chenonetta jubata*), masked lapwing (*Vanellus miles*), Australian white ibis (*Threskiornis aethiopicus*), straw-necked ibis (*Threskiornis spinicollis*), glossy ibis (*Plegadis falcinellus*), caspian tern (*Sterna caspia*) and egret species – have not been recorded as breeding on either Peery Lake or Poloko Lake but they may do so in some years.

Table 14: Number of breeding waterbirds on Poloko Lake

Species	June 1990	September 1990	March 1993	Total no. breeding
Black swan	1	3		**4**
Pink-eared duck		1		**1**
Red-necked avocet		1		**1**
Royal spoonbill			24	**24**
Freckled duck	These have been recorded breeding on this lake.			

Note: Numbers are estimated from aerial counts conducted every three months between March 1987 and December 1990, with an additional count conducted in March 1993. Surveys periods in which no waterbirds bred are not presented. Numbers represent the number of broods, nests or breeding pairs.

Source: Adapted from Maher (1991) and Kingsford and Porter (1999)

Table 15: Waterbird species recorded breeding on five freshwater lakes near Peery and Poloko lakes

Waterbird species	
Grey teal	Yellow-billed spoonbill
Australasian shoveler	Royal spoonbill
Pacific black duck	Glossy ibis
Hardhead	Straw-necked ibis
Australian wood duck	Australian white ibis
Black swan	Eurasian coot
Pink-eared duck	Masked lapwing
Freckled duck	Caspian tern
Egret species	

Note: The lakes are Tongo Lake, Mullawoolka Basin, Yantabangee Lake, Blue Lake and Green Lake. Data were from aerial surveys conducted every three months between March 1987 and December 1990, with an additional count in March 1993, as well as surveys conducted annually from 1983 to 2005.

Source: R.T. Kingsford

Feeding habitat for waterbirds and other fauna

The Paroo River Wetlands and, in particular, Peery and Poloko lakes, constitute a key feeding habitat in arid NSW (Morton et al. 1995). After filling, Peery Lake may hold water for 36 months, while Poloko Lake may hold water for up to 22 months (Kingsford et al. 1994). Peery and Poloko lakes are freshwater lakes that become more brackish as floodwaters recede. Generally, salt lakes support higher numbers of waterbirds, and Peery and Poloko lakes have been found to support their greatest numbers when drying up and slightly saline (Kingsford et al. 1997). As Peery Lake is large and can hold water for many months, it is able to maintain considerable populations of many waterbird species for up to 15 months after the end of a flood cycle when all other wetlands in the area have dried up or receded (RIS 2007).

Climate

Like all arid-zone wetlands, wetlands in the Paroo River catchment are characterised by high temperatures and evaporation rates, as well as low annual rainfall which is both spatially and temporally variable (Kingsford and Thompson 2006; Figure 17). The variable and extreme climate, along with geomorphology, drives the diversity of wetland types in the Paroo River catchment (Kingsford and Porter 1999) and largely determines the distribution of flora and fauna and thus community composition in the Paroo River Wetlands Ramsar site. This is because climate drives floods that define the temporal sequences of habitat availability for different species and successional processes (Brock et al. 2006; Young and Kingsford 2006).

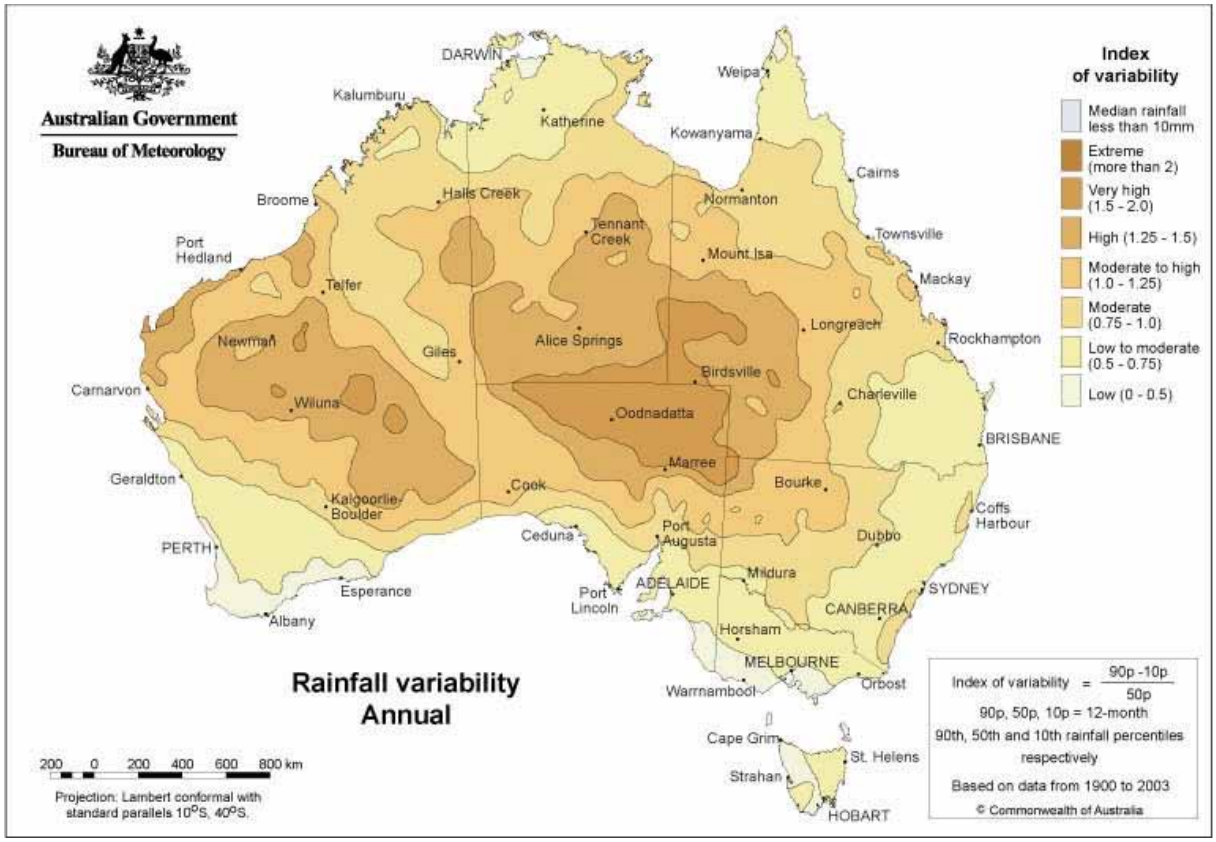

Figure 17: Rainfall variability map for Australia
Note: The Paroo River Wetlands Ramsar Site is in a zone of moderate to high variability.
Source: Bureau of Meteorology, www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/variability.cgi

The average maximum temperatures for the Ramsar site are 18°C in winter and 36°C in summer, while average minimum temperatures are 4.5°C and 21°C; average annual rainfall is 250 mm (RIS 2007). Most climate information for the Paroo River Wetlands Ramsar site, particularly information on temporal changes in climate, is provided from data measured in areas surrounding the Ramsar site. Wanaaring is near the Nocoleche Nature Reserve component of the Ramsar site and White Cliffs is near the Peery component.

Rainfall records from the Wanaaring Post Office weather station are available from 1884 to 2006 and reveal high temporal variability (Figure 18). Dry and wet periods are clearly shown. Annual rainfall has oscillated from a maximum of 35 mm in 1972 to a minimum of 747 mm in 1976. High rainfall years show 18 instances between 1884 and 2006 where over 150 mm of rain fell in a month (Table 16). On a seasonal basis, rainfall is generally highest during the summer months, with an average of 27 mm, 34 mm and 34 mm during December, January and February, compared with winter months (19 mm, 18 mm and 15 mm in June, July and August) (Figure 19).

Table 16: Months when more than 150 mm of rain fell at Wanaaring Post Office weather station 1884–2006

Year	Month	Total rainfall (mm)
1887	March	229.1
1890	January	218.5
1891	January	166.9
1896	February	166.3
1907	January	212.5
1926	March	196.8
1928	February	155.7
1936	March	200.4
1949	March	210.3
1956	March	209.5
1962	December	227.6
1974	January	183.6
1976	January	237.0
1976	February	353.8
1984	January	168.4
1987	December	159.8
1995	January	226.6
2000	February	173.4

Note: Some data are missing for 1970 and parts of 1884, 1885, 1903, 1971, 1987 and 2002.
Source: BoM (2006)

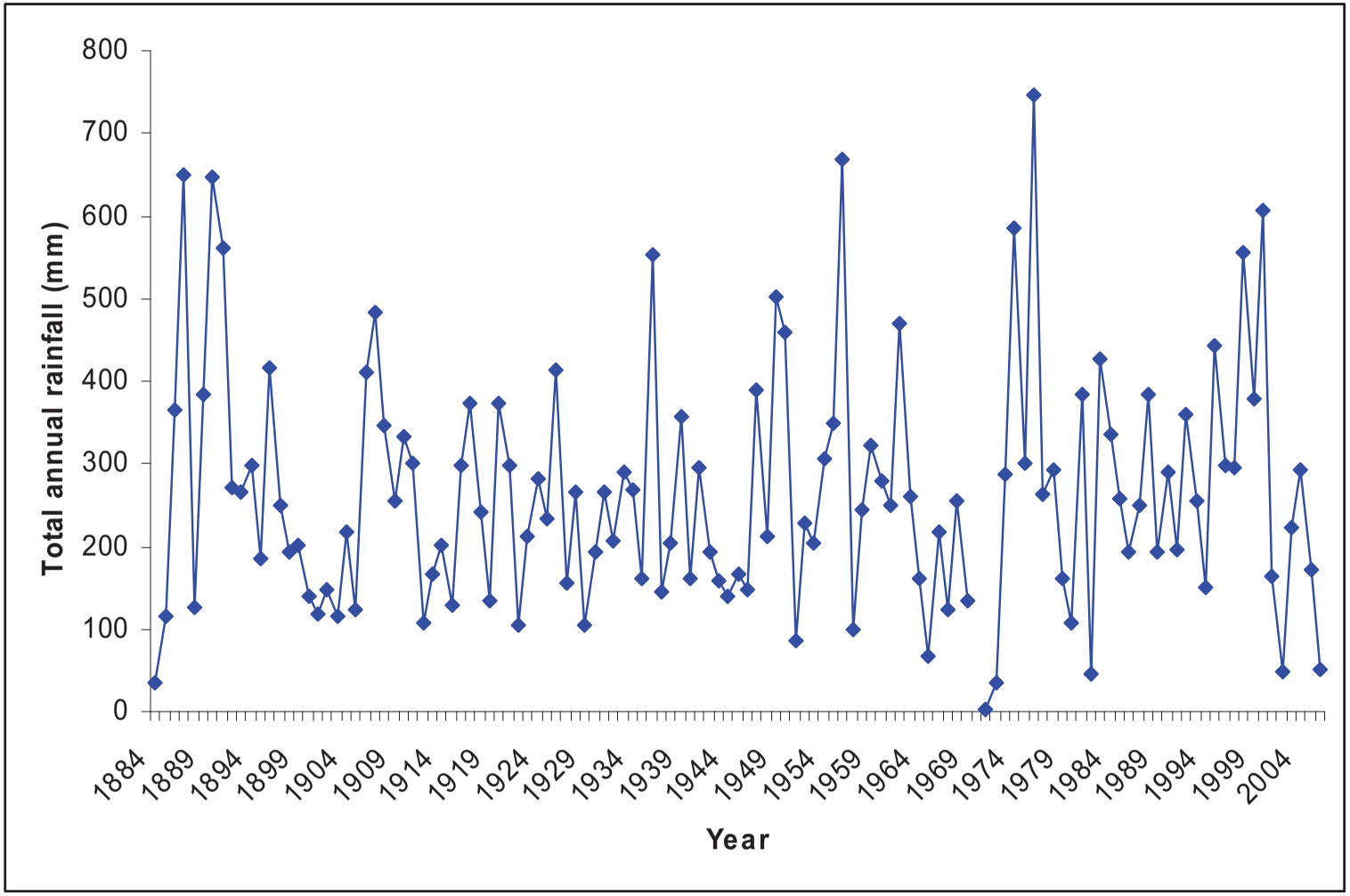

Figure 18: Annual rainfall at Wanaaring Post Office weather station between 1884 and 2006
Note: Some data are missing for 1970 and parts of 1884, 1885, 1903, 1971, 1987 and 2002.
Source: BoM (2006)

Records from the White Cliffs Post Office weather station near Peery Lake also show variable temporal patterns for temperature and rainfall. Records are available for 1901–2004 and show seasonal rainfall patterns, with more rain in summer months (Figure 20). Temperature ranges at the height of summer (January) are 21–36°C and drop to 4–17°C in winter (July).

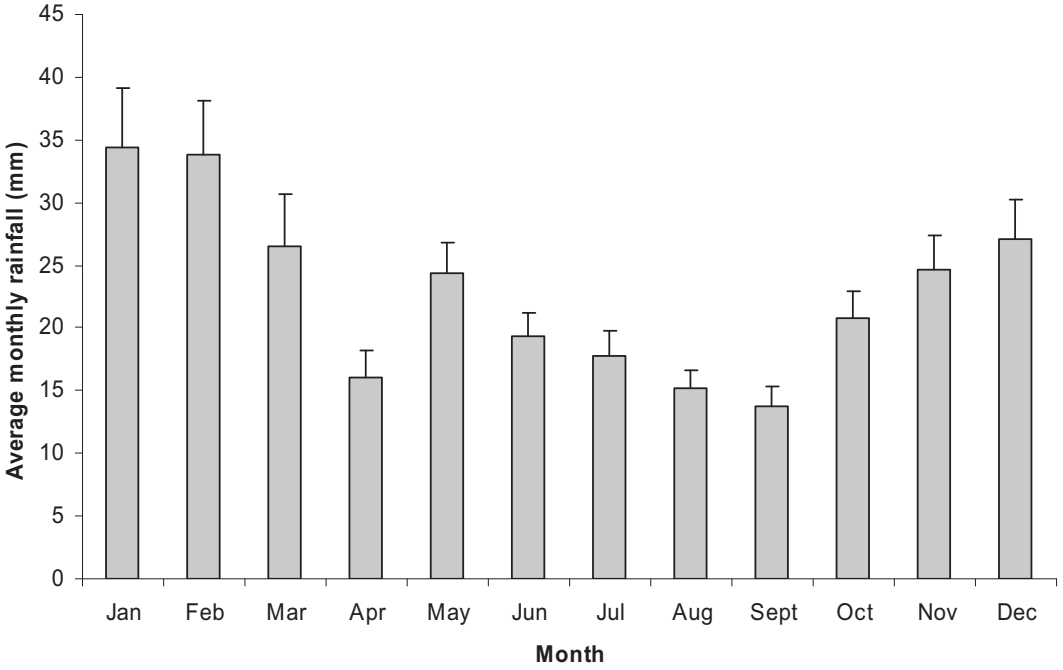

Figure 19: Mean monthly rainfall at Wanaaring Post Office weather station between 1884 and 2006
Note: Error bars are standard errors. Some data are missing for 1970 and parts of 1884, 1885, 1903, 1971, 1987 and 2002.
Source: BoM (2006)

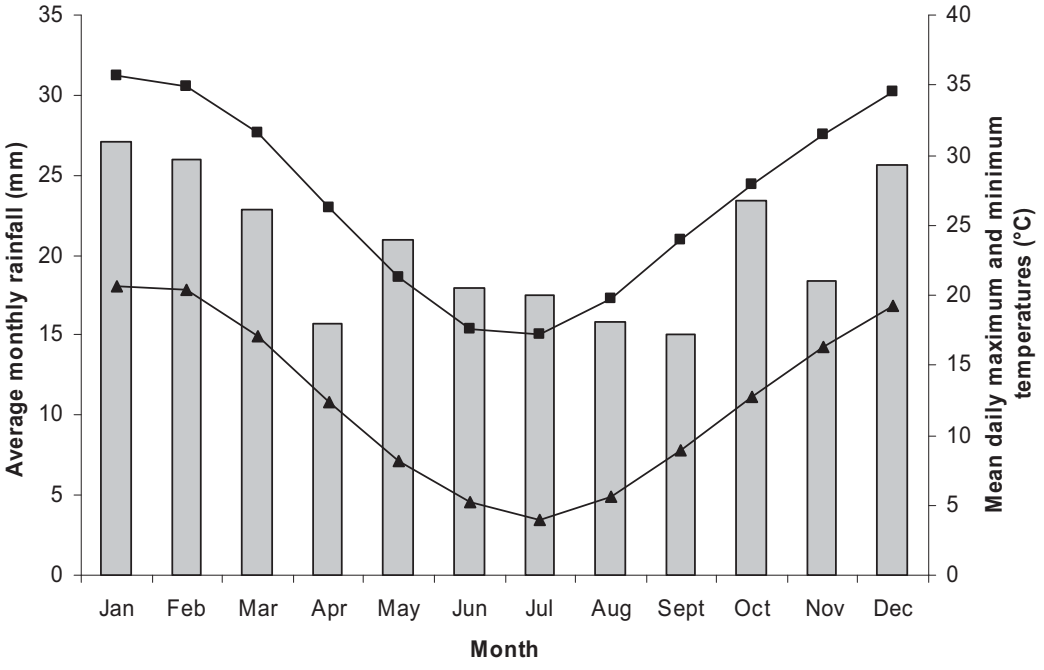

Figure 20: Mean monthly rainfall and mean daily maximum and minimum temperatures at White Cliffs Post Office weather station between 1901 and 2004
Source: Bureau of Meteorology, www.bom.gov.au/climate/averages/tables/cw_046042.shtml

There are no specific records for evaporation rates in the Paroo River Wetlands Ramsar site. However, evaporation rates are likely to be within the range of average annual values for the Paroo River catchment (2400–2600 mm; WISE database for the Paroo–Warrego Catchment 2003). These rates of evaporation greatly exceed mean rainfall in the area, and this has implications for the retention of water in the soil that is available for plants that support animals.

3.2.2 Physicochemical processes

Floods along the Paroo River alter the size, shape and connectivity of aquatic habitats for biota at critical stages in their life cycles (McComb and Qiu 1998; Boulton 1999; Brock 1999; Kingsford 1999a; Watts 1999; Brock et al. 2006). Floods are therefore critical in forming habitats and for the conservation of wildlife in the Paroo River catchment.

Flow regime of the Paroo River

Due to differences in the way that wetlands fill (from river flows or local rainfall) and the order of filling of wetlands reliant on river flows (upstream wetlands usually fill before downstream wetlands), wetlands in the Paroo River Wetlands Ramsar site are subject to high hydrological variability (flow variability). Flow variability is complex and exerts its influence through frequency (how often filling and drying occurs), timing (when water is present), duration (period of inundation), extent and depth (the area of inundation and water depth) and the variability (the degree to which these features change over a range of time scales) of flooding (Puckridge 1999; Young 1999).

Compared with many other arid-zone rivers, the Paroo River often floods (Young et al. 2006). Median flow data collected between 1976 and 1995 from Willara Crossing on the Paroo River near the Queensland and NSW border revealed that the Paroo River is a ‘large’ river in the annual time frame, indicating frequent floods with a median annual flow of 311,009 ML at Willara Crossing (Young 1999). Seasonal analysis of monthly flows indicated that the usual time for high flows at Willara Crossing is between February and April, and monthly flows in the Paroo River were also least variable during this period (Young and Kingsford 2006).

In terms of flow variability over longer periods of time, time series plots of flows in the Paroo River show that there are frequent periods of zero flow and irregular floods. Figure 21 shows annual flows for the Paroo River measured at Willara Crossing, with floods occurring approximately every three years (Young and Kingsford 2006). A monthly model can be used to predict the timing, magnitude and duration of flows in the Paroo River since the early 1900s, based on flows between 1976 and 2000 (Young et al. 2006). Monthly flows in the Paroo River are highly intermittent. In the NSW sections of the Paroo River (monitored at Willara Crossing and a gauging station at Wanaaring), periods of high flow only occur for 15% of all months.

After they fill, wetlands in the Ramsar site hold water for variable periods. Small wetlands that fill from local rainfall in Nocoleche Nature Reserve dry quickly due to their shallow depths and high evaporation in the area. Peery and Poloko lakes can hold water for up to 22 and 36 months respectively (Maher 1991). Water depths for Peery and Poloko lakes are not known; however, the depths of other overflow lakes when full are 3.5–5.5 m (RIS 2007). Waterholes in Nocoleche Nature Reserve, such as King Charlie Waterhole, are deep and hold water permanently.

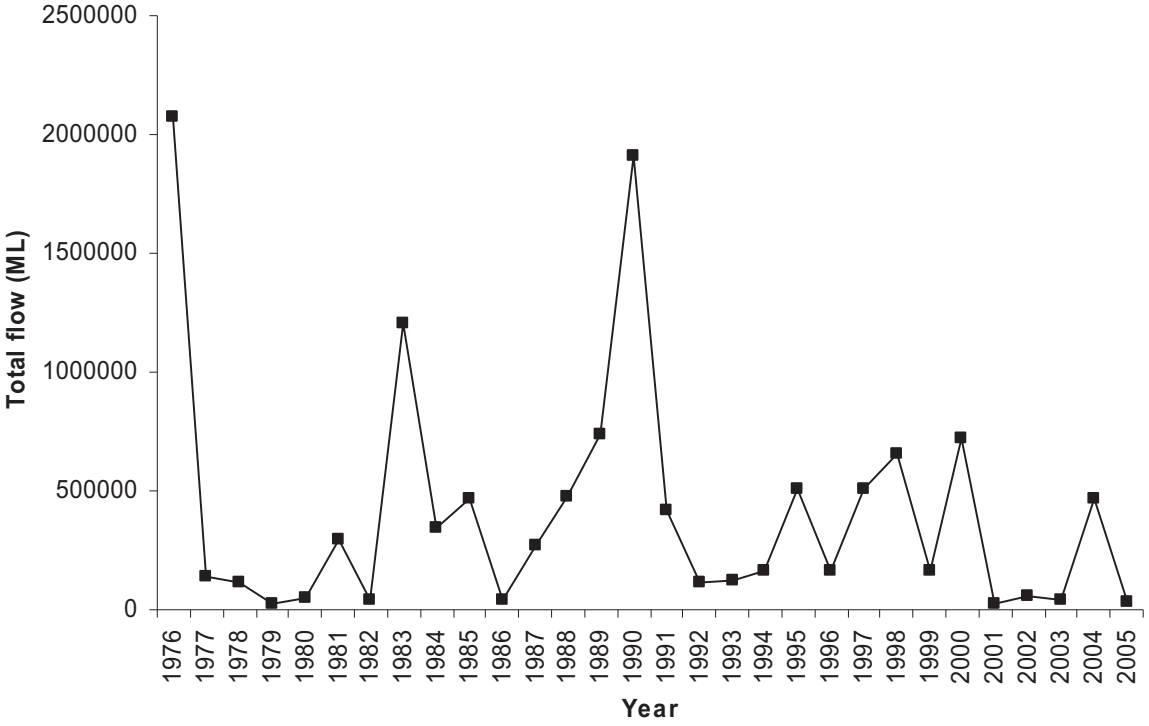

Figure 21: Annual flows for the Paroo River measured at Willara Crossing from 1976 to 2005
Note: Data for 47 days in 2005 are missing.
Source: NSW Department of Natural Resources surface water archive 2006

Ecology flow relationships

Variable flooding and drying patterns are a hallmark of arid wetlands; habitat expands and contracts over wide spatial and long temporal scales. The succession of plant and animal communities in the Paroo River catchment is largely driven by the flooding and drying cycles of the Paroo River which are driven by unpredictable catchment rainfall and affected by geomorphology.

The hydrology of the Paroo River catchment is the main determinant of river form, wetland type and structural habitat (Casanova 1999; Young 1999; Young and Kingsford 2006). This is because the movement of flood waters across the Paroo landscape acts as a natural disturbance, creating and removing patches of habitat (Young and Kingsford 2006). The variability of flooding also creates a range of inundation patterns that influences wetland type and structural habitat. Creation of habitat due to flooding can allow plants and animals to disperse (Kingsford et al. 2006). The movement of flood waters across the Paroo River catchment acts as a natural disturbance (Young and Kingsford 2006), creating and removing habitat and driving reproduction, recruitment and mortality (Puckridge et al. 1998; Boulton 1999; Brock et al. 2006). Geomorphology influences the extent and direction of flows across the landscape, as well as the depth and duration of inundation. Deep waterholes along the Paroo River (for example King Charlie Waterhole) hold water for long periods and act as refuges.

Changes in water quality, including salinity and turbidity, and the release of nutrients that results from flooding and drying cycles determine the distribution and abundance of flora and fauna (Young and Kingsford 2006). Flooding releases and transports nutrients that drive food webs (Boulton 1999; Bunn et al. 2006). It is the main abiotic determinant of the structure and composition of aquatic plant (Brock 1999; Brock et al. 2006), invertebrate (Boulton 1999;

Boulton et al. 2006), fish (Gehrke et al. 1999; Puckridge 1999) and waterbird (Kingsford and Norman 2002; Roshier et al. 2002; Kingsford et al. 2004) communities in the Paroo River catchment (Table 17). Extremely wet periods favour the germination and establishment of yapunyah, with the establishment of young plants dependent on water remaining in the soil (Casanova 1999).

Groundwater

The Peery component of the Paroo River Wetlands Ramsar site receives water from the Great Artesian Basin, and this water supports the artesian mound springs and the associated community on the bed of Peery Lake. Groundwater moves to the surface from deep aquifers through faults in overlying bedrock and is driven by the hydraulic pressure exerted by the Great Artesian Basin (McMahon et al. 2005). Water discharged from the springs is moderate to high in temperature (20–45°C) and slow flowing, with most artesian springs in the Great Artesian Basin discharging less than 0.5 ML per day (McMahon et al. 2005).

The artesian mound spring community is adapted to the temperature and water quality conditions of the artesian springs. It also relies on the groundwater discharged through the springs and is unlikely to withstand other conditions. For example, the mound spring community is probably compromised when water from river flows or local rainfall fills Peery Lake. Such a reliance on artesian water means that a loss of flow could threaten the integrity of the artesian mound community.

Table 17: Response of some components of the Ramsar site to wetting and drying

Biotic component	On flooding	On drying
Soil	Pulse of nutrients, sedimentation	Nutrients lock up, soils crack
Aquatic plants: submerged	Germinate, grow and reproduce	Seed bank
Aquatic plants: amphibious	Aquatic form or seed bank	Seed bank: seeds grow while there are damp areas
Phytoplankton	Photosynthesise in water column, light dependent, reproduce	Propagule bank of resistant spores
Birds	Waterbirds feed and nest in available habitat, birds of prey feed on small mammals	Waterbirds disperse to other wetlands; birds disperse to areas with greater prey resources
Mammals	Move between dry areas and wetland for water and food supply. Some species migrate to wetland and reach large numbers	Wetland dependent species disperse to other wetlands; other species may remain in dry country
Reptiles	Move between dry areas and wetland for water and food supply. Some species migrate to wetland and reach large numbers	Some species will move to find food; other species will remain in dry country
Amphibians	Eggs in or near wetland, tadpoles grow, mature in water, many adults leave, return to lay	Adults lay briefly resistant eggs in riparian vegetation; some adults move to find water or aestivate
Zooplankton	Feed and reproduce	Propagule bank of resistant eggs
Benthic invertebrates	Many larval stages of aerial adults, aquatic larvae and adults	Terrestrial adults, resistant eggs
Microorganisms	Process nutrients and organic matter	Change from anaerobic to aerobic forms, resistant stages

Source: Adapted from Boulton and Brock (1999) in DECC (2008)

A major issue in the Great Artesian Basin is the sustainable use of its groundwater resources. Groundwater pressure has already declined in parts of the Great Artesian Basin and this has led to reduced flows to bores and natural artesian springs (McMahon et al. 2005).

Geomorphology

The wetlands of Nocoleche Nature Reserve comprise undulating sandplains and dunes, a reticulate system of broad, shallow, flat-bottomed distributary channels, floodplains and small lakes of the Paroo River and Cuttaburra and Kulkyne creeks. Soils are dominated by sandy red earths and grey cracking clays.

The Peery component contains sandstone hills surrounded by stony plains, parallel dunes with swales, claypans and two overflow lakes, Peery and Poloko, which are terminal playa lakes. Peery Lake contains artesian mound springs in its northern basin. These overflow lakes are the result of channel systems being blocked by ranges of palaeozoic bedrock. Soils are dominated by reddish clay sands (RIS 2007).

3.3 Ecosystem services and benefits

Ecosystem services and benefits provided by the Paroo River Wetlands Ramsar site and wetlands in the Paroo River catchment include provisioning, regulating, cultural and supporting services. These are outlined below and are summarised in Table 18 which also provides information on the ecosystem components and processes that support ecosystem services.

3.3.1 Provisioning services

Wetland products

Drinking supply for people and livestock

Some water is extracted from the Paroo River in the Nocoleche Nature Reserve for domestic purposes to service the homestead and shearers' quarters. Water is also used for livestock outside the Ramsar site in surrounding pastoral properties and towns (for example Eulo, Hungerford and Wanaaring). The wetlands in the Paroo River catchment probably improve overall water quality for stock and domestic use. Flooding allows plants to filter fine sediment from the water thereby reducing turbidity.

Livestock

Although the Paroo River Wetlands Ramsar site does not support grazing of domestic livestock, surrounding wetland areas in the Paroo River catchment, upstream and downstream of Nocoleche Nature Reserve, are leased to pastoralists to graze cattle and sheep. The wool and meat produced generate a reliable income for graziers, mostly as a result of feed produced as aquatic and terrestrial plants germinate and grow after floods on the Paroo River (Kingsford 1999b). Floods stimulate the growth of grasses such as Queensland bluegrass (*Dicantheum sericeum*), bottle washers (*Enneapogon avenaceus*) canegrass (*Eragrostis australasica*), native millet (*Panicum decompositum*), sedges and rushes such as common spike rush (*Eleocharis acuta*) and macrophytes (oral accounts, WISE database). Common spike rush and many grass species (see Appendix 2) provide feed for cattle and sheep (Roberts and Marston 2000). This vegetation response is important to graziers in the Paroo River catchment since floodwaters originating from the northern part of the catchment produce vegetation growth that would not have resulted from local rainfall.

Fishing

Fishing is permitted in the Paroo River Wetlands Ramsar site and in surrounding areas in the Paroo River catchment. Fishing is mainly recreational, and the main fish species caught

include bony bream (*Nematalosa erebi*), golden perch (*Macquaria ambigua*), spangled perch (*Leiopotherapon unicolour*) and Hyrtle's tandan (*Neosilurus hyrtlii*) (oral accounts, WISE database). Before the 1970s, local fisherman caught the threatened Murray cod (*Maccullochella peelii*) in the Paroo River catchment (vulnerable under the TSC Act). However, the number of Murray cod has declined since the 1970s with the introduction and subsequent increase of European carp (*Cyprinus carpio*), and they are rarely caught today (oral accounts, WISE database). Freshwater yabbies (*Cherax destructor*) are also caught in the river.

Bee-keeping

Twenty-two sites are licensed to a keeper of the honeybee (*Apis mellifera*) in the Nocoleche Nature Reserve (RIS 2007). Each site is limited to a maximum of 50 stock hives and 20 nucleus hives (NPWS 2000). Honeybees in Nocoleche Nature Reserve harvest pollen from flowering floodplain eucalypts, such as yapunyah (*Eucalyptus ochrophloia*), black box (*E. largiflorens*), coolibah (*E. coolabah*) and plants such as lignum (*Muehlenbeckia florulenta*) (oral accounts, WISE database); the honey produced has a unique flavour (Kingsford 1999b).

3.3.2 Regulating services

Flood mitigation and beneficial flooding

Wetlands in the Paroo River catchment control floodwaters by slowing the flows and reducing erosion. Water flowing down the Paroo River first fills the Currawinya Lakes and then floods areas of canegrass and lignum. After filling a series of freshwater lakes and lignum and an extensive floodplain, the waters flow to the Paroo Overflow before eventually flowing to the Darling River. The filling of deep holes and lakes slows water and vegetation protects the system from severe erosion. Only particularly large floods detrimentally affect settlements and livestock, and most landholders welcome the slow floods that allow them to move their stock to high ground before the floods arrive. People on the Paroo River welcome the floods and their positive ecological and economic values.

3.3.3 Cultural services

Cultural heritage

Aboriginal heritage

The Budjiti, Kunja, Mardgany and Baakandji (Paruntji) people are the traditional owners of the wetlands in the Paroo River catchment (Goodall 1999). Archaeological evidence indicates that Aboriginal people have been in the area for at least 14,000 years (Robins 1999). They are traditionally fisherman, gatherers, hunters and seed harvesters (Lourandos 1997). With the arrival of graziers in the 1840s there were clashes between the traditional owners and graziers well into the 1860s. Following this time, Aboriginal people were employed as pastoral workers until the 1960s when employment opportunities for them became scarce (Goodall 1999). Traditional ceremonies continued to be held in the Paroo region until at least the mid-1910s to the 1930s when the government interfered in the lives of these people. Aboriginal people in this area were denied access to education from 1902 until the 1960s and were consequently disempowered and unskilled well into recent times. However, local Aboriginal people are current and future active participants in the management of the Paroo River Wetlands Ramsar site (NPWS 2009) as they are elsewhere in the Darling River catchment (Goss and Mclellan 2004).

Wetlands in the Paroo River catchment are significant to Aboriginal people for their traditional, spiritual, cultural and contemporary values. The Paroo Overflow and areas around Peery Lake are particularly important focal points to Baakandji values due to their significant role in the regional system of 'dreaming tracks'. Aboriginal people believe that ancestral

beings, such as Kuluwirru (a big fellow) and the two Ngyati (water serpents), travelled through the area, creating many of the landscape features including boulders, rivers, lakes and the springs. Some of the areas created by Kuluwirru were particularly important as places of law enforcement where unacceptable social behaviour was punished (Wharton 2000). Although the traditional lifestyles of the Aboriginal people were disrupted by the arrival of graziers, there was no government interference until the 1930s, and traditional ceremonies continued to be held in the Paroo River catchment until at least the 1930s. Thus, many present-day Budjiti and Baakandji retain a strong affiliation with their country and maintain a strong oral history of the region (RIS 2007).

Both components of the Paroo River Wetlands Ramsar site contain significant numbers of Aboriginal artefacts, including ground stone artefacts, stone tools and stone arrangements (NPWS 2000, 2009). The existence of these artefacts in the Ramsar site is of significance to Aboriginal people and visitors alike.

Non-indigenous heritage

There are a number of structures from the early 1800s in the Paroo River Wetlands Ramsar site that are of significance to pastoral heritage. These include homesteads sheds, shearers' quarters and tanks, and are of importance due to their age, representation of pastoral infrastructure and, in some cases, unique design (NPWS 2000, 2009).

Education

As the Paroo River catchment is remote, visitor numbers to the area are low (RIS 2007). In addition, the visitor centre at White Cliffs established in early 2006 promotes the diversity of wildlife throughout the Paroo River catchment and highlights management issues. Nocoleche Nature Reserve is open to universities, local schools and community groups to improve understanding of the natural and cultural heritage of the reserve and of the Paroo River catchment, and of the processes that affect them (NPWS 2000).

Scientific research

Research at Peery has concentrated primarily on vegetation mapping, but other work has focused on reptile surveys, carbon dating of Aboriginal cultural sites and pastoral heritage sites (NPWS 2009). Further research projects were proposed in the Nocoleche Nature Reserve plan of management (NPWS 2000) to extend previous research areas and to understand river flows and their importance in flooding. In particular, relatively little is known of the effects of flooding on many plants, or the impacts of fishing on aquatic fauna and the ecology of invertebrates and frog species. The draft Paroo–Darling National Park plan of management (NPWS 2009) similarly proposes to extend research to understand flooding requirements for vegetation and compile comprehensive fauna lists for the park. Other research projects related to ecological indicators for which there is relatively little information could also be supported. In particular these could include biological indicators (invertebrates, fish, amphibians, reptiles, small mammals, terrestrial bird species) and chemical indicators (water quality, soil characteristics).

Table 18: Summary of ecosystem services provided by wetlands in the Paroo River catchment and Ramsar site and the key components and processes that support these services

Service		Examples	Source	Key components	Related processes
Provisioning	Wetland products	Drinking water for people and livestock	1,3	Hydrology and geomorphology	Geomorphological processes, climate, and energy and nutrient dynamics
		Sustenance for people (for example grazing stock, fishing, bee-keeping)	1,3,15	Hydrology, fauna, physico-chemical environment	
		Delivery of water (beneficial flooding)	16	Hydrology	
Regulating	Flood mitigation	Overflow lakes hold water for long periods of time, some deep waterholes in Nocoleche Nature Reserve are permanent	2,3	Hydrology and geomorphology	Geomorphological processes and climate
	Delivery of water (beneficial flooding)	Stimulate vegetation growth and provide essential conditions for wildlife	9,16,17,18	Hydrology	Geomorphological processes, climate, and energy and nutrient dynamics
Cultural	Cultural heritage	Aboriginal heritage	3,15,19,20	Aboriginal artefacts and sites, flora and fauna	Geomorphological processes and climate
		Non-indigenous heritage	15,20	Evidence of early explorers; pastoral infrastructure	
	Education	Conservation education	3,15,20	Hydrology, geomorphology, physicochemical environment, habitat, fauna	Geomorphological processes, climate, energy and nutrient dynamics, species interactions and processes that maintain populations
	Scientific research	Research in Nocoleche Nature Reserve			
	Recreation and tourism	Camping and touring	3,20	Camping infrastructure and access	Climate
		Bird watching	1,2,3,10,11, 12,13	Hydrology, geomorphology, physicochemical environment, habitat, fauna	Geomorphological processes, climate, energy and nutrient dynamics, species interactions and processes that maintain populations

Service		Examples	Source	Key components	Related processes
Supporting	Wetland type	Supports a unique wetland type *	1,2,3	Hydrology and geomorphology	Geomorphological processes and climate
		Supports a rare wetland type *	3,4		
	Wildlife conservation	Supports threatened species *	2,3	Hydrology: flooding and drying regime Geomorphology: topography and soil type Physicochemistry: salinity and turbidity Habitat: vegetation type and structure, suitable nest sites Fauna: birds, mammals, reptiles, amphibians, fish	Geomorphological processes: sedimentation and erosion Climate Energy and nutrient dynamics: primary production, nutrient cycling Processes that maintain populations: reproduction and migration Species interactions: predation, competition, disease
		Supports a threatened ecological community *	3		
		Supports high biodiversity *	2,3,5,6,7,8,9		
		Supports migratory waterbirds at critical stages of their life cycles *	3,2,10,11		
		Supports waterbirds at critical stages of their life cycles (i.e. breeding) *	2,10,11		
		Provides drought refuge for waterbirds and other fauna *	2,3,11,12		
		Supports an abundance of waterbirds *	2,10,11,12,13		
		Supports a significant proportion of native fish species *	14		

* Ramsar-related services

Sources: 1: Kingsford 1999b; 2: Kingsford and Porter 1999; 3: RIS 2007; 4: Ponder 1999; 5: Watts 1999; 6: Westbrooke et al. 2003; 7: Pellow and Porter 2005; 8: Keenan et al. 1998; 9: Bunn et al. 2006; 10: Kingsford 1998; 11: Kingsford et al. 1994; 12: Kingsford et al. 1997; 13: Kingsford et al. 2006; 14: Gehrke et al. 1999; 15: NPWS 2000; 16: Young and Kingsford 2006; 17: Boulton et al. 2006; 18: Brock et al. 2006; 19: Goodall 1999; 20: NPWS 2009. 4646

Recreation and tourism

Tourism services for Peery are currently being developed through the draft Paroo–Darling National Park plan of management (NPWS 2009). Tourism will focus on the cultural and biophysical features of the park. Nocoleche Nature Reserve remains a site of scientific research and thus access to the public for tourism is prohibited. The spectacular contrasting environments of dry and wet periods on Peery Lake will undoubtedly increase the number of visitors in future years.

3.3.4 Supporting services

Wildlife conservation

Wetlands in the Paroo River catchment represent one of Australia's most important national wetland areas and play an essential role in the conservation of wildlife. Wetlands in both the Paroo River catchment and the Ramsar site conserve wildlife by supporting threatened species, a threatened ecological community (the artesian springs ecological community), high biodiversity, migratory waterbirds at critical stages of their life cycles, waterbird breeding, an abundance of waterbirds, a significant proportion of native fish species, and by providing drought refuge for waterbirds and other fauna.

3.4 A conceptual model

Flows in the Paroo River primarily depend on rainfall in the catchment that may be delivered by cyclonic activity from northern Australia (Figure 22), hence the summer pattern of flows. These flows are supplemented by flows from the Cuttaburra Creek system which is a large distributary system of the Warrego River. Local rainfall can also play a part by filling many of the claypans that rely on local rainfall. These flows are predominantly within the Nocoleche Nature Reserve but large local storms can also fill Peery Lake.

The spatial and temporal variability of the river and its flooding is determined by the amount of catchment rainfall and the amount of water that is needed to inundate the intervening floodplain, including Nocoleche Nature Reserve, before the flows reach the Paroo Overflow Lakes where Peery and Poloko lakes are located. Once the floodplains and other wetlands are inundated, there is a cascade of ecological processes and food webs established for the full range of aquatic plants, animals and other organisms. These reproduce and recruit usually within the time frame of the flood. Sequences of floods are also important. During dry times, many plants and invertebrates are equipped to lie dormant either as seeds or eggs, or to halt their growth (for example floodplain eucalypts, lignum). Waterbirds go to other wetlands or congregate with fish and turtle species on the remaining waterholes until the next flood arrives.

The hydrological regime of the artesian mound springs on Peery Lake differs to that driving the other wetlands in the Paroo River Wetlands Ramsar site. Instead of water from rainfall delivered through river flows or locally, water is derived from groundwater flows and this drives the cascade of ecological processes and establishes food webs (Figure 23). The artesian mound springs and associated flora and fauna communities are dependent on these groundwater flows and are adapted to the unique temperature and water quality conditions and the slow groundwater discharge. Groundwater is dependent on recharge from the Great Artesian Basin.

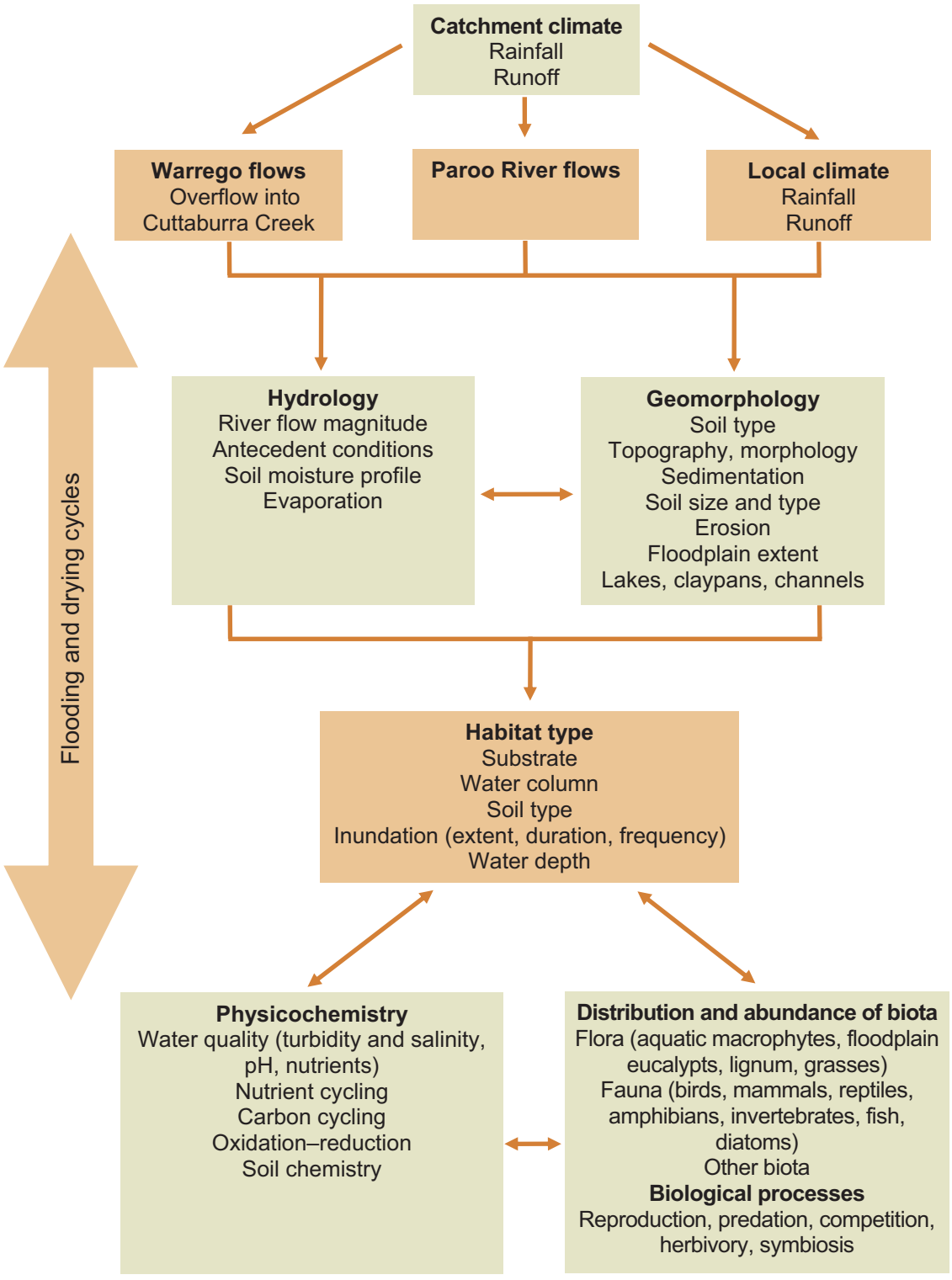

Figure 22: Conceptual model of relationships among key physical, chemical and biological components and processes in surface Paroo River Ramsar wetlands

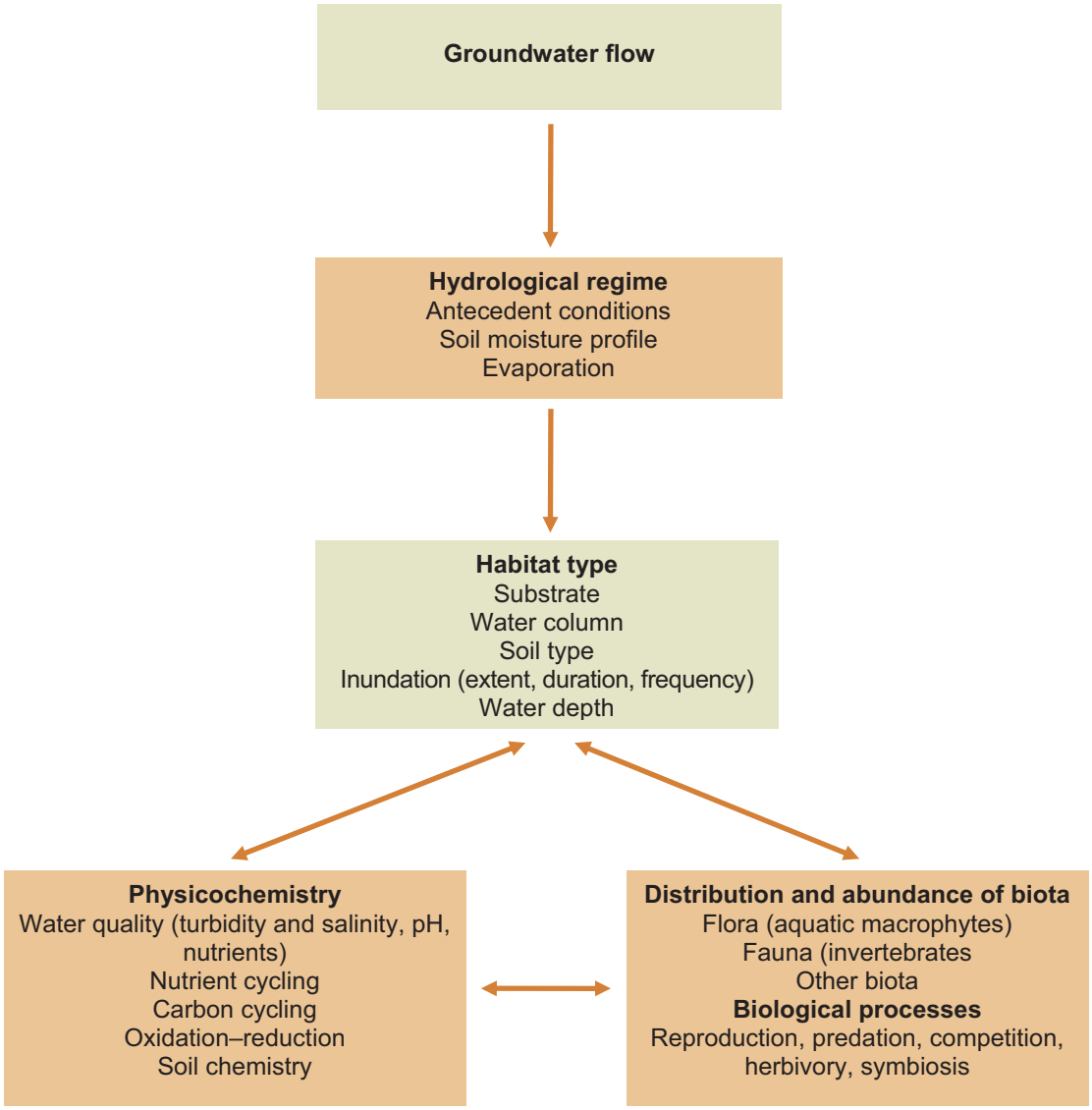

Figure 23: Conceptual model of relationships among key physical, chemical and biological components and processes in the mound springs of Peery Lake

4 Natural variability and limits of acceptable change

Understanding the range of natural variation in wetland ecosystem components and processes is important in describing the ecological character of wetlands and determining when ecological character may have changed. This is particularly important for Australian Ramsar wetlands given that they often have a large range in natural variability. Ecological character changes when key parameters of a wetland ecosystem fall outside their normal range (Ramsar Convention 1996, Annex to Resolution VI.1).

Limits of acceptable change (LACs) in ecosystem components and processes, which may subsequently trigger management actions, can be identified by values that lie outside the range of known values for those components and processes for which there are adequate temporal data. For the Paroo River Wetlands Ramsar site, such suitable indicators for which benchmarks or ranges of known values have been established are the richness, abundance and breeding of waterbirds, water flow down the Paroo River, and the richness and abundance of fish. Table 19 summarises the LAC indicators and their benchmark values or known ranges of natural variation, and outlines the trends in indicators that could trigger management action.

Table 19: Limits of acceptable change indicators that could trigger management action

LAC indicator	Baseline condition or known range of natural variation	Triggers for management action
Waterbird richness (wet periods)	Known range for Peery Lake: 8–30 species Known range for Poloko Lake: 5–28 species Known range for five lakes north of the Ramsar site: 2–24 species	Overall reduction in waterbird richness
Waterbird abundance (wet periods)	Known range for Peery Lake: 190–38,000 Known range for Poloko Lake: 40–28,000 Common species (populations >1000 in a single survey) known for Peery and Poloko lakes	Overall reduction in waterbird abundance Reduction in the abundance of common waterbird species Reduction in the abundance of less common species or functional groups
Waterbird breeding (wet periods)	Known number of species breeding on Peery Lake: 10 Known number of species breeding on Poloko Lake: 5 Known number of species breeding on lakes north of the Ramsar site: at least 17	Overall reduction in numbers of waterbird species breeding Loss of breeding for species known to breed
Water flow down the Paroo River	Paroo River usually floods annually between February and April around Nocoleche Based on decadal data, the whole Paroo River floods about every three years	Changes in pattern of flow for the Paroo River
Fish richness	Known number of native fish species: 8 Known range of native fish species in different habitat types: 3–7 Known number of exotic fish species: 4	Overall reduction in native fish species Overall increase in exotic fish species
Fish abundance	Bony bream known to comprise over half the fish population in the Paroo River Spangled and golden perch known to together comprise a quarter of the fish population	Overall reduction in native fish relative to exotic fish

The ranges of known values of the number of waterbird species counted in the Paroo River Wetlands Ramsar site are 8–30 species for Peery Lake and 5–28 species for Poloko Lake. From data collected from five similar wetlands outside of the Ramsar site, the range of average values for species numbers is 2–24 species. The highest numbers of waterbird species recorded at Nocoleche Nature Reserve, Peery Lake and Poloko Lake are 63, 42 and 35 species, respectively. Management action should be taken if there are trends for overall reductions in the numbers of waterbird species counted on wetlands both within and outside of the Paroo River Wetlands Ramsar site.

For the total abundance of waterbirds in the Ramsar site, the ranges of known values are 190–38,000 waterbirds for Peery Lake and 40–28,000 waterbirds for Poloko Lake. Numbers usually build up as the lakes dry. Common species (those that number >1000 individuals during a single survey) on Peery Lake are pink-eared duck, grey teal, red-necked avocet, hardhead, eurasian coot, freckled duck, black swan and Australian wood duck. Common species on Poloko Lake are grey teal, pink-eared duck, black-tailed native-hen, red-necked avocet, black swan, and Pacific black duck. Common species on five similar wetlands outside of the Ramsar site are grey teal, freckled duck, eurasian coot, red-necked avocet, whiskered tern, Australasian shoveler, pink-eared duck and hardhead. Management action should be taken if there are trends for overall reduction in the total abundance of waterbirds or the abundance of common waterbird species. In addition, management action should be taken if there are trends showing reduction in less common waterbird species or in functional groups.

Ten species of waterbird were recorded breeding on Peery Lake and five species on Poloko Lake. On five similar wetlands near Peery and Poloko lakes, at least 17 species of waterbird were recorded breeding. Although the numbers of broods, nests or breeding pairs were recorded for each species on Peery and Poloko lakes, numbers may be too low to warrant their use as LACs. Thus, management action should be taken if there are trends of overall reductions in the diversity of waterbird species that are breeding or if there are losses in breeding of species known to breed.

In the NSW sections of the Paroo River (monitored at Willara Crossing and Wanaaring gauging stations), models indicate that monthly flows were highly intermittent, with flows in about 15% of months. The Paroo River usually floods frequently during the year, with the common time for high flows at Willara Crossing between February and April. Over decades or more, the Paroo River has frequent periods of zero flow and irregular floods, with large floods about every three years. Management action should be taken if there are changes in patterns of flow. In particular, any levee banks with the potential to interrupt flow patterns over watercourses in the Paroo River should not be built and, if already established, they should be removed.

Ten fish species were recorded from four habitat types in the Paroo Overflow, although a total of 12 fish species are known to be present in the Paroo River Wetlands Ramsar site. The fish community in the Paroo Overflow is dominated by native species (seven native compared to three exotic species). Lake habitats have the highest number of native species (seven native species) followed by creek and river habitats (five native species) and floodplain habitats (three native species). Fish populations are dominated by bony bream (half the population). Spangled perch and golden perch together comprise almost a quarter of the fish population. Management action should be taken if there are reductions in the number of native fish species, increases in the number of exotic fish species, reductions in the abundance of native fish species, or increases in the abundance of exotic fish species.

5 Actual or potential threats or risks

This section describes the key threats to the maintenance of the ecological character of the Paroo River Wetlands Ramsar site. The potential effects of these threats, status of threats, and suggested monitoring actions and frameworks under which the threats are managed are also described (Table 20).

Table 20: Threats to the maintenance of the ecological character of the Ramsar site, the potential effects of threats, status of threats, and suggested monitoring and management

Threat	Potential effect	Threat status	Monitoring or management
Changes in flooding patterns through water extractions and/or diversions upstream of the site	- Reduced timing, magnitude, extent and frequency of flooding. - Impacts on flora and fauna distribution, breeding and recruitment.	Major	Natural flows are maintained and enforced under various legislative frameworks, notably the Paroo River Agreement.
Changes in flooding patterns through building of levee banks that interrupt natural flooding regimes	- Reduced timing, magnitude, extent and frequency of flooding. - Impacts on flora and fauna distribution, breeding and recruitment.	Major	Relatively poor focus on this aspect. Requires monitoring of areas between the two parts of the Ramsar site to ensure that flows are not interrupted.
Climate change	- Reduced timing, magnitude, extent and frequency of flooding. - Impacts on flora and fauna distribution and recruitment.	Major	Monitor flood events for reductions in flood magnitude, extent and frequency.
Introduced flora	- Affect the survival of native flora. - Change the composition of vegetation communities. - Assist the spread of feral fauna. - Water dispersed flora may spread to floodplain areas and change floodplain communities.	Major	Threat abatement and recovery plans and control of introduced flora are outlined in plans of management for Nocoleche Nature Reserve and Paroo–Darling National Park.
Introduced fauna	- Damage native flora and fauna populations through predation, competition, habitat destruction and disease.	Major	Threat abatement plans and control of introduced fauna are outlined in plans of management for Nocoleche Nature Reserve and Paroo–Darling National Park.
Fire	- Impacts growth and breeding cycles of flora and survival of fauna. - Removes resources from the environment.	Minor	Plans to manage wild fires and prescribed burns are outlined in plans of management for Nocoleche Nature Reserve and Paroo–Darling National Park.
Natural processes (floods, weathering, fire) and use impacts (manage-ment and visitors)	- Damage cultural heritage. - Impact historic heritage.	Minor	Plans to protect and maintain heritage sites are outlined in plans of management for Nocoleche Nature Reserve and Paroo–Darling National Park.

5.1 Changes in flooding patterns

The most significant threat to the Paroo River Wetlands Ramsar site and to wetlands in the larger Paroo River catchment is the extraction of water from the Paroo River and potentially the Warrego River (Kingsford 1999c). Changes to the natural patterns of water flow (for example through the building of levee banks) also represent significant threats (Kingsford and Porter 1999), and there have been several instances of proposals to build levee banks locally which could significantly alter flow patterns to the wetlands.

Water extraction and changes to natural flow patterns threaten the ecological character of the Paroo River Wetlands Ramsar site and wetlands in the larger Paroo River catchment because water extractions or alterations to water flow along the river change the natural flooding patterns (frequency, duration, extent and timing) (Brock 1999). Changed patterns of flooding may affect wetland health at a variety of levels. At the genetic level, changed flooding patterns may fragment populations into small breeding groups, resulting in inbreeding and loss of genetic diversity. This is more likely for short-lived species, such as invertebrates, than for long-lived species, such as fish and waterbirds, which could survive long enough to reproduce during larger floods (Watts 1999; Kingsford et al. 2006).

Fragmentation of breeding populations, such as golden perch (*Macquarie ambigua*), may be particularly threatening for endemic species in the Paroo River catchment. Golden perch form a separate breeding population in the Paroo River that is genetically distinct from other golden perch populations in the Murray–Darling Basin (Keenan et al. 1996, 1998). Genetic diversity in golden perch is only maintained in the Paroo River through river connectivity during periods of high river flow which allows individuals to migrate to other areas along the Paroo River.

At the species level, changed flooding patterns may remove cues that stimulate breeding or prevent the completion of breeding (Boulton 1999; Watts 1999; Kingsford et al. 2006). Some waterbirds, particularly colonial waterbirds, require long periods of inundation to complete their breeding as they need adequate food resources to raise their young, although many waterbirds, such as ducks, do not breed where inundation is permanent (Briggs et al. 1997). In wetlands of regulated rivers, such as the Murray and Macquarie rivers, waterbird breeding has declined as a result of reduced flooding (Kingsford and Johnson 1999; Leslie 2001), and egrets have stopped breeding in wetlands of the Murrumbidgee River due to prolonged flooding (Briggs et al. 1994). Changed flooding patterns may also affect the dispersal, germination and growth of plants that in turn affect fauna (Brock et al. 2006; Bunn et al. 2006). For example, reduced floods may prevent the dispersal, germination and growth of aquatic plants such as charophytes which complete their life cycles under water (Brock 1999). Further, changed flooding patterns may favour the establishment of species that prefer stable water conditions and are less adapted to variable flow conditions (Brock et al. 2006; Kingsford et al. 2006), and this could result in some species outcompeting others, the loss of native species that are not adapted to prolonged flooding, and decreases in species richness (Cottingham 1999; Gerhke et al. 1999; Brock et al. 2006). In parts of the Murray–Darling Basin where weirs and dams have created stable water conditions, species richness has decreased, with European carp (*Cyprinus carpio*) outcompeting threatened native fish species such as Murray cod (*Maccullochella peelii*) in the lower Murray River (Walker 2006). In addition, prolonged flooding in the lower Murray River has resulted in the death of floodplain eucalypts and lignum (*Meuhlenbeckia florulenta*) (Kingsford 2000), which only tolerate short periods (less than one year) of flooding (Roberts and Marsten 2000).

At the ecosystem level, changed flooding patterns may result in a loss of habitat diversity as different wetland types may no longer be maintained (Casanova 1999; Watts 1999). For example, the loss of connectivity to the river may change aquatic ecosystems to terrestrial ecosystems, with plants that make up various wetland types eventually dying (Kingsford

2000). Moreover, the loss of habitats may reduce the diversity of wetland communities (Watts 1999; Brock et al. 2006). These changed communities may in turn alter natural ecological processes and are likely to upset the ecological integrity of the Paroo River wetlands (Timms 1999), since wetland nutrient cycles are disrupted and terrestrial ecosystems cannot support wetland processes such as aquatic plant reproduction and dispersal, or water-dependent breeding (for example aquatic invertebrate, fish and waterbird breeding).

Alteration to the natural flow regime of rivers is regarded as a key threatening process in NSW under the TSC Act. It is imperative that there is good management and prevention of any changes to water flows which could affect flooding patterns in the Paroo River due to its status as the last remaining free-flowing river in the Murray–Darling Basin.

Current management frameworks to ensure the maintenance of natural flows include the EPBC Act, the Paroo River Agreement 2003 between the NSW and Queensland governments, the Queensland Government Water Resource Plan 2003 (Warrego, Paroo, Bulloo and Nebine rivers), and plans of management developed under the *National Parks and Wildlife Act 1974* for Nocoleche Nature Reserve, Paroo–Darling National Park and Currawinya National Park.[9]

There remains the potential to alter natural flow patterns in the Paroo River through the construction of local levee banks. This has been proposed already for areas upstream of Peery Lake (for example Klondyke). Such developments can potentially reduce flooding patterns downstream by redirecting floodwaters. There are few clear local policies that monitor or provide a policy framework that restricts such developments even though the Paroo River Agreement commited the NSW and Queensland governments to protect the natural flow variability of the Paroo River.

5.2 Climate change

Australia has experienced greater temperature anomalies, greater mean maximum temperatures, and lower rainfall since 2002 than previously (BoM 2007). It is thought that an enhanced greenhouse effect is increasing the severity of Australian droughts as higher temperatures are increasing evaporation rates (Nicholls 2004).

Although understanding of how climate change could affect Australian arid areas is limited, future climate change is potentially a major threat to the Paroo River Wetlands Ramsar site. This is because wetlands in the Ramsar site rely on flows from the Paroo River that originate from rainfall draining the Warrego, Willie and Walters Ranges in south-western Queesland, as well as local rainfall. Reductions in flow in the Paroo River or reduced rainfall could reduce the frequency, duration and extent of floods in the Paroo River catchment leading to consequences to wetland health. The consequences of climate change are similar to those of changed flooding patterns from reductions in flows, so are not repeated here.

Climate change is listed under the EPBC Act and the TSC Act as a key threatening process. Current plans of management for Nocoleche Nature Reserve and the Paroo–Darling National Park do not directly address the issue of climate change. No threat abatement plan is currently available for climate change in Australia or NSW.

5.3 Introduced flora and fauna

Introduced flora and fauna are significant threats to the Paroo River Wetlands Ramsar site and other wetlands in the Paroo River catchment. In Nocoleche Nature Reserve, 25 of the 302 recorded plant species are introduced, and these include weeds such as noogoora burr

[9] www.derm.qld.gov.au/register/p00200aa.pdf

(*Xanthium occidentale*), three-cornered jack (*Emex australis*), athol pine (*Tamarix aphylla*) saffron thistle (*Carthamus lanatus*), common heliotrope (*Heliotropium europaeum*) and prickly pear (*Opuntia stricta*) (NPWS 2000). In the Paroo–Darling National Park, 55 of the 424 recorded plant species are introduced, and include noogoora burr, Bathurst burr (*Xanthium spinosum*) and African boxthorn (*Lycium ferocissimum*) (Westbrooke et al. 2003). These exotic plant species may affect the survival of native plant species through competition, changing the composition of vegetation communities in the wetlands of the Paroo and assisting the spread of feral animals (such as pigs, goats and rabbits) (NPWS 2000). Some, such as noogoora burr, represent even greater threats to the wetlands of the Paroo because they are spread by water, making control difficult (Brock et al. 2006). These weeds can spread to all wetland types, potentially reach high densities and threaten floodplain communities (Brock et al. 2006). At present, no exotic aquatic plants are known in the Paroo wetlands but, if changes occur in water flow, exotic aquatic plants may be introduced (Brock 1999).

Introduced fauna in both the Paroo River Wetlands Ramsar site and in the Paroo River catchment include pigs (*Sus scrofa*), cats (*Felis catus*), foxes (*Vulpes vulpes*), goats (*Capra hircus*), rabbits (*Oryctolagus corniculatus*), European honeybees (*Apis mellifera*), European carp (*Cyprinus carpio*), goldfish (*Carrasius auratus*) and gambusia (*Gambusia holbrooki*) (NPWS 2000, 2009). Stock animals (sheep and cattle) from neighbouring properties occasionally wander onto the Ramsar site.

Introduced fauna damage native flora and fauna populations through predation, competition, habitat destruction and disease (NPWS 2000). Pigs create drainage channels in swamps, cause silting and erosion on rivers and creeks, destroy brolga (*Grus rubicunda*) and ibis nests, and predate on frogs and invertebrates. Pigs may also impact on the endangered artesian mound springs community associated with the artesian mound springs at Peery Lake (Figure 10) and the endangered salt pipewort (*Eriocaulon carsonii*) (DEC 2005). The trampling and grazing of goats, loose stock and rabbits also threaten the endangered mound springs community by affecting recruitment of plant species (NPWS 2009).

Past impacts of grazing by goats, livestock and rabbits on the Paroo River Wetlands Ramsar site (prior to its acquisition by the NPWS, up to 1978 for Nocoleche Nature Reserve and 2000 for Peery) are not well documented, but anecdotal evidence of, for example, the silting up of some wetland areas, suggests that erosion and sedimentation may have occurred as a result of grazing (Timms 1998; Kingsford and Porter 1999; RIS 2007). Grazing is also likely to have affected recruitment and establishment of plant species such as lignum, which is important for waterbird breeding (Maher and Braithwaite 1992) and may have contributed to the proliferation of woody weeds in Nocoleche Nature Reserve.

Cats and foxes prey on small to medium sized fauna species including threatened species (endangered and vulnerable) listed under the TSC Act, and may also prey on waterbird and terrestrial bird eggs (NPWS 2003). Feral bee swarms compete with and displace native animals, particularly native bees and nectar feeding birds, and have damaging effects on native plants (Anderson 1989; Paton 1996; Butz Huryn 1997). European carp, gambusia, and other feral fish species impact native fish and frog species through competition and predation (Gerhke et al. 1999). Local residents of the Paroo River catchment have noted a significant reduction in the abundance of the threatened Murray cod (*Maccullochella peelii*) (vulnerable in NSW under the TSC Act) and other native fish species since the 1970s when European carp entered the Paroo River from the Darling River (oral accounts; WISE database).

The activities of many of these introduced fauna are recognised as key threatening processes in Australia and NSW under the EPBC Act and TSC Act. Specific threats are competition and land degradation (EPBC Act) and competition and grazing (TSC Act) by

feral rabbits, competition and habitat degradation by feral goats (EPBC Act and TSC Act), competition from feral honeybees (TSC Act), predation, habitat degradation, competition and disease transmission by feral pigs (EPBC Act and TSC Act), predation by feral cats (EPBC Act and TSC Act), and predation by red foxes (EPBC Act and TSC Act).[10] Plans of management for both Nocoleche Nature Reserve and Paroo–Darling National Park therefore recognise the impacts of feral animals as serious and have assigned their control a high priority. Threat abatement and recovery plans for the threatened mound springs community and the salt pipewort are also given high priority (NPWS 2000; DEC 2005).

5.4 Fire

Fire represents a minor threat to the Paroo River Wetlands Ramsar site. The frequency of fire is low, and neither Nocoleche Nature Reserve nor Peery has experienced fire since their gazettal (NPWS 2000, 2009). Fires have been caused by lightning strikes in the 1950s and 1960s in Nocoleche Nature Reserve and in the early 1950s, mid-1970s and mid-1980s in Paroo–Darling National Park (NPWS 2000, 2009), but have tended to go out of their own accord. There is generally insufficient fuel to sustain fires to the point where they become dangerous to life or property, or pose a risk to flora and fauna communities (NPWS 2009). Fire is managed in both components of the Paroo River Wetlands Ramsar site through fire management plans for Nocoleche Nature Reserve and the Paroo–Darling National Park (NPWS 2000, 2009). These plans manage fire to ensure that life and property are protected, native plant and animal species, populations and ecological communities are maintained, and Aboriginal sites, historic places and visitor and management assets are protected within reserve and park boundaries.

5.5 Other natural processes and use impacts

Threats to cultural heritage in the Paroo River Wetlands Ramsar site are natural processes due to flooding of sites, weathering actions and animal damage, management activities such as road and track maintenance, and visitor impacts. Threats to historic heritage on the Ramsar site are neglect, visitor impacts and lack of maintenance. These threats to the ecological character of the Paroo River Wetlands Ramsar site are minor. However, plans of management for both Nocoleche Nature Reserve and Paroo–Darling National Park have incorporated consultation with Aboriginal communities for management of heritage sites, and include protection and maintenance of cultural and heritage sites on the Ramsar site (NPWS 2000, 2009).

[10] www.environment.nsw.gov.au/threatenedspecies/KeyThreateningProcesses.htm

6 Knowledge gaps

This description of the ecological character of the Paroo River Wetlands Ramsar site is limited by the availability of spatial and temporal data on ecosystem components and processes supporting ecosystem services. Table 21 shows the number of publications which provide information on components and processes of the Ramsar site. Information on services is not shown as many publications not directly dealing with services overlap with components and processes. For Peery, information was quantified from the WISE database.[11] For Nocoleche Nature Reserve, the amount of published information was gathered manually as the WISE database can only search for publications for named wetlands, and many of the wetlands in Nocoleche Nature Reserve are not named (for example, there are more than 250 unnamed claypans) (Lawler and Briggs 1991). Publications common to both components of the Ramsar site are accounted for in the total number of publications.

Table 21: Number of publications on components and processes

Ecological component or process	Type	No. of publications for Peery	No. of publications for Nocoleche Nature Reserve	Total no. of publications for the Paroo River Wetlands
Birds	Biological	10	7	14
Invertebrates (butterflies, dragonflies, macroinvertebrates)	Biological	2	1	3
Fish	Biological	0	2	2
Reptiles (snakes, turtles)	Biological	1	3	4
Amphibians (frogs)	Biological	0	3	3
Mammals	Biological	1	2	3
Vegetation	Biological	8	6	12
Water quality	Chemical	2	1	3
Soil characteristics	Chemical	3	0	3
Hydrology	Physical	12	1	12
Geomorphology	Physical	9	0	9

Only three out of 11 components and processes are described in more than 10 publications. Thus, where there is a lack of specific information, data from the entire Paroo River catchment were considered for this description of the ecological character of the Paroo River Wetlands Ramsar site. This approach is supported by Sorrell (2006), who recommended that some interpretation be made from data from similar sites where there is a lack of site-specific information. The area of the Ramsar site is not sufficient to sustain entire populations of plants and animals for which the site is recognised, so using data from the entire Paroo River catchment also takes into consideration areas which support the same ecosystem components, processes and services of the Ramsar site. Although rarely used in this ecological character description, some consideration of data from the neighbouring Warrego catchment is important as the Warrego catchment supplies some water to Peery (Kingsford and Porter 1999; Kingsford et al. 2001; Figure 5).

[11] http://wtest2.science.unsw.edu.au/wise_v4.html

The use of data from studies conducted in the entire Paroo River catchment still yields little spatial or temporal information for most components and processes in the Paroo River Wetlands Ramsar site and in the entire Paroo River catchment, however. There are obvious gaps in knowledge and this is clearly illustrated in Table 22 which classifies the amount of spatial and temporal information on components and processes into categories based on the amount of data per component and process; poor means that there was less than one detailed dataset, medium that there was at least one detailed dataset, where datasets were considered to be detailed if descriptions were given or data were quantified. This analysis is based on a comprehensive assessment of the available datasets.

There are spatial and temporal data for waterbird abundance and breeding from 1983 to the present, flows of the Paroo River (1976–2000) and the abundance of fish (1992–95). Also, there are some spatial vegetation data for Peery, although none for vegetation over time. For most other biological components, such as mammals and invertebrates, and physical and chemical components, virtually no spatial or temporal data are available. Knowledge of these components is restricted to general information of occurrence rather than abundance of species. Specific knowledge gaps and recommended monitoring strategies to address these knowledge gaps are outlined in Table 23.

Table 22: Availability of data on components and processes

Ecological component or process	Peery	Nocoleche Nature Reserve	Wetlands in the Paroo River catchment	Temporal data
Waterbirds	Medium	Medium	Medium	Medium
Invertebrates	Poor	Poor	Poor	Poor
Fish	Poor	Poor	Medium	Medium
Reptiles	Poor	Poor	Poor	Poor
Amphibians	Poor	Poor	Poor	Poor
Mmammals	Poor	Poor	Poor	Poor
Vegetation	Medium	Medium	Medium	Poor
Water quality	Poor	Poor	Poor	Poor
Soil characteristics	Poor	Poor	Poor	Poor
Hydrology	Poor	Poor	Medium	Medium
Geomorphology	Poor	Poor	Poor	Poor

Table 23: Key knowledge gaps and recommended strategies

Area	Knowledge gaps	Recommended strategies
Hydrology	Information is not available.	Measure the extent of flooding by monitoring floods with aerial photos or satellite imagery and gauges.
	Contributions from groundwater are not quantified.	Monitor groundwater levels.
Geomorphology	Digital elevation maps are not available.	Construct a digital elevation map using Lidar technology.
	Extent of sedimentation and erosion is not known.	Monitor deposition rates.
Physicochemical environment	Water quality data are needed.	Monitor water quality (turbidity, pH and salinity) during periods of flood and drought.
Vegetation	Vegetation map is required for Nocoleche Nature Reserve.	Map vegetation types and distribution in Nocoleche Nature Reserve using aerial photos,satellite imagery and ground-truthing.
Fauna	Spatial and temporal knowledge of invertebrates assemblages and abundance is lacking.	Monitor invertebrates using appropriate methods, such as trawling.
	Spatial and temporal knowledge of amphibian assemblages and abundance is lacking.	Monitor amphibians using appropriate methods.
	Spatial and temporal knowledge of fish assemblages and abundance (on the Ramsar site) is lacking.	Monitor fish using appropriate methods, such as gillnets, trawls, seine nets.
	Spatial and temporal knowledge of reptile assemblages and abundance is lacking.	Monitor reptiles using appropriate methods such as pitfall traps.
	Spatial and temporal knowledge of small mammal assemblages and abundance is lacking.	Monitor small mammals using appropriate methods such as pitfall traps.
	Spatial and temporal knowledge of terrestrial bird abundance is lacking.	Monitor terrestrial birds using appropriate methods such as line transects.
	Spatial and temporal knowledge of threatened species abundance is lacking.	Conduct targeted surveys of threatened species to estimate their abundance.

7 Key site-monitoring needs

Long-term changes to the ecological character of wetlands in the Paroo River Wetlands Ramsar site can currently only be identified by changes in suitable indicators for which temporal data exist (the abundance and breeding of waterbirds, hydrology and fish) (Table 19). These suitable indicators also provide a means for which the effectiveness of current management regimes can be assessed. Thus, it is imperative that suitable indicators continue to be monitored. Table 24 outlines how suitable indicators could be monitored. New methods could also be used to monitor additional suitable indicators. Such methodologies could include using satellite images of large flood or rain events to interpret the extent of flooding over time.

Table 24: Future monitoring of suitable indicators

Indicators	Future monitoring
Abundance, richness and breeding of waterbirds	Continue annual aerial surveys of waterbirds in the Ramsar site and in wetlands in the Paroo River catchment.
Hydrology	Continue monitoring streamflow along the Paroo River.
Fish abundance and richness	Continue monitoring fish in the Paroo River.

Another key requirement for the site is the monitoring, spatially and temporally as appropriate, of new indicators for assessing changes in ecological character. These could include invertebrate, frog, reptile and small mammal populations, threatened species, vegetation communities, chemical indicators such as water quality or hydrological indicators such as groundwater. Monitoring could allow benchmark levels or limits of acceptable change to be established. Some of these indicators, such as water quality and invertebrate assemblages and abundance, may have rapid responses that indicate the relative changes in wetland health. They can also be more spatially and temporally variable. Other indicators, such as groundwater, could be key to signalling changes in ecological character. Groundwater, or artesian water, naturally discharged through mound springs on Peery Lake supports the endangered artesian mound spring community and endangered plant species on Peery Lake. Thus, any reduction in groundwater pressure may signal a change in ecological character. Monitoring programs should have clear objectives linked to management requirements.

The monitoring of threats also needs to be undertaken, particularly for major threats. This will allow assessment of whether management actions for reducing the impacts of threats are effective in maintaining the ecological character of the Paroo River Wetlands Ramsar site.

8 Triggers for management action

The greatest threats to both the Paroo River Wetlands Ramsar site and wetlands in the larger Paroo River catchment are changes in flooding patterns, followed by climate change, introduced flora and fauna, fire, and the impacts of natural processes and use. Increased water resource development within the Warrego catchment could affect flows down Cuttaburra Creek that reach the Paroo River Wetlands Ramsar site. At a local level, the most serious threat is the building of levee banks upstream that could affect flow patterns to the Ramsar site, and monitoring of these developments should be a high priority. Current surface water use in the Paroo River catchment in Queensland is very low, at less than 0.1% of the available water. The Queensland Water Resource Plan that relates to the Queensland portion of the Paroo River region requires that at least 99% of the average 'without development' flow into NSW is maintained. Consequently, diversions in Queensland should not reduce flow across the border by more than 1% of the average 'without development' cross-border flow. This requirement is being met in Queensland under current surface water entitlements (CSIRO 2007).

High priority activities in management plans for Nocoleche Nature Reserve and Paroo–Darling National Park (improved management of river flows to return them to a natural state, protection of flows from extraction, pest plant and pest animal control, implementation of recovery plans for threatened species such as the salt pipewort) that also deal with managing threats to wetlands in the Paroo River catchment should be continued (NPWS 2000, 2009).

There could be an increased focus on managing threats outside of the Paroo River Wetlands Ramsar site. Catchment management is essential for maintaining wetlands within catchments and should be the smallest scale of management. At present, some adjoining properties to the Ramsar site cooperate with management activities within the Ramsar site (NPWS 2000). This cooperation could be extended to properties throughout the Paroo River catchment. Indeed, cooperation in managing threats could be extended to properties throughout the neighbouring Warrego River catchment due to the interconnectedness of flows down the Paroo and Warrego rivers and movement of introduced wildlife through the two catchments. The Paroo River Agreement 2003, the Water Resource Plan 2003 (Warrego, Paroo, Bulloo and Nebine), and the National Water Initiative 2004 (see Appendix 1) are encouraging signs that water flows may be protected from adverse changes, although the construction of local levee banks may need to be prevented. In addition, threats of introduced flora and fauna need to be addressed by investment in appropriate mitigation and control measures.

Finally, a critical component of management for the Paroo River Wetlands Ramsar site is the ongoing monitoring of key ecological indicators to measure the ecological character of the site. Monitoring will allow managers to establish whether the criteria for which the site was gazetted and listed as a Ramsar site are still met and the general character of the site is maintained.

9 Communication, education and public awareness

The conservation importance of the Paroo River and its associated reserves is well known. Opportunities still exist for better communication of management options between NSW and Queensland in relation to river flows and protection of ecosystems. Interpretative activities can continue to grow as visitor centres provide information about the importance of this river system (for example, the NPWS visitor centre at White Cliffs). Such communication activities will build opportunities for tourism to this unique river system.

Glossary

Acceptable change: the variation that is considered 'acceptable' in a particular measure or feature of the ecological character of a wetland. Acceptable variation is that variation that will sustain the component or process to which it refers.

Assessment: the identification of the status of, and threats to, wetlands as a basis for the collection of specific information through monitoring activities.

Attributes: biological diversity and unique cultural and heritage features. These lead to uses or derivations of products, but they may also have intrinsic, unquantifiable importance.

Baseline: condition at a starting point, usually the time of listing.

Benchmark: a pre-determined state (based on the values that are sought to be protected) to be achieved or maintained.

Benefits: the benefits that people receive from ecosystems.

Change in ecological character: For the purposes of Article 3.2 of the Ramsar Convention, change in ecological character is the human-induced adverse alteration of any ecosystem component, process and/or ecosystem benefit/service.

Character: a descriptive snapshot which lists the elements present at a site and their relationships. It is a 'value-free' statement.

Condition (ecological condition): the health or quality of a site. It involves analysis, assessment, and value-based judgement. The assessment is made comparative to other sites.

Criteria: the nine criteria for the listing of a site as internationally significant under the provision of the Ramsar Convention (as recently amended at CoP 9), namely a wetland:

1 … contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
2 … supports vulnerable, endangered or critically endangered species or threatened ecological communities.
3 … supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
4 … supports plant and/or animal species at a critical stage of their life cycles, or provides refuge during adverse conditions.
5 … regularly supports 20,000 or more waterbirds.
6 … regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
7 … supports a significant proportion of indigenous fish subspecies, species or families, life history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
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.
9 … regularly supports more than 1% of the population of a non-avian species of animal.

Components: physical, chemical and biological parts (from large scale, such as habitat, to very small scale, such as genes).

Drivers: direct or indirect human forces of change. Examples include laws, institutional arrangements, river basin management, and water allocation.

Ecological character: the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.

Ecosystem services: benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (such as food and water),

regulating (flood control), cultural (spiritual, recreational), and supporting (nutrient cycling, ecological value).

Functions: activities or actions, natural, a product of interactions between ecosystem structure and processes, for example flood control, sediment retention, food web support. Functions include floodwater control; nutrient, sediment and contaminant retention; food web support; shoreline stabilisation and erosion controls; storm protection; and stabilisation of local climatic conditions, particularly rainfall and temperature.

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.

Processes: changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological.

Values: the perceived benefits to society, either direct or indirect, that result from wetland functions. These values include human welfare, environmental quality and wildlife support.

Wetlands: areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. Many wetlands in arid and semi-arid areas spend much of their time dry and there is a need to consider both the wet and dry phases.

Abbreviations

CAMBA	China–Australia Migratory Bird Agreement 1986
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
JAMBA	Japan–Australia Migratory Bird Agreement 1974
NPWS	National Parks and Wildlife Service
NSW	New South Wales
NWI	National Water Initiative
RIS	Ramsar Information Sheet
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement 2006
ROTAP	rare or threatened Australian plants
TSC Act	*Threatened Species Conservation Act 1995*
WISE	Water Information System for the Environment

Appendix 1: Policy and management frameworks relevant to the Paroo River Wetlands Ramsar site

Migratory bird agreements

International agreements to protect migratory birds which use the Paroo River Wetlands each northern hemisphere winter and southern hemisphere summer, such as the Japan–Australia Migratory Bird Agreement (JAMBA) 1974, the China–Australia Migratory Bird Agreement (CAMBA) 1986, and the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA) 2006, apply to migratory birds in the Paroo River catchment. Fifteen migratory bird species recorded in the Paroo River Wetlands Ramsar site are covered by JAMBA, CAMBA and ROKAMBA (see Appendix 3 for species list). Migratory species are now also covered by the EPBC Act.

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act protects the environment, particularly matters of national environmental significance. It streamlines the national environmental assessment and approvals process, protects Australian biodiversity and integrates management of important natural and cultural places. Under the Act, approval is required for actions that are likely to have a significant impact on any matter of national environmental significance.[12] For example, migratory waterbirds are considered a matter of national environmental significance.

Threatened Species Conservation Act 1995

The TSC Act protects threatened species, communities and critical habitats in NSW. An independent scientific committee has been set up under the Act to determine which species, populations and ecological communities should to be listed as endangered, vulnerable or extinct under the Act (see Appendices 2 and 3 for threatened species listed under the Act), and also to determine key threatening processes.[13] Under the Act, key threatening processes are managed through the adoption of measures involving cooperative management. Key threatening processes that affect the Paroo River Wetlands Ramsar site are alteration of the natural flow regimes of rivers, streams, floodplains and wetlands; competition and grazing by feral rabbits; competition and habitat degradation by feral goats; competition from feral honeybees; predation, habitat degradation, competition and disease transmission by feral pigs; predation by feral cats; and predation by feral red foxes. Cooperative management measures are outlined in management plans for Nocoleche Nature Reserve and Paroo–Darling National Park. This legislation is limited to NSW and does not extend upstream to the Paroo River in Queensland.

Nocoleche Nature Reserve Management Plan 2000

The plan of management for Nocoleche Nature Reserve was developed in 2000. Its specific objectives are to protect river flows and groundwater in the Paroo and Warrego catchments, to manage wetlands within the nature reserve to avoid affecting flow patterns and protect waterbird breeding areas, to protect flora and fauna within the nature reserve, and to provide opportunities for scientific research and environmental education that are compatible with conservation of the nature reserve (NPWS 2000). Actions that were highlighted as high in priority in the management plan are: liaising with other authorities to improve management of river flows and protect flows from extraction; identifying where pipes are required to re-establish the natural regime of wetland flooding and drying; assessing the need for artificial water sources; continuing feral fauna and weed control; developing cooperative pest control

[12] www.environment.gov.au/epbc/
[13] www.legislation.nsw.gov.au/viewtop/inforce/act+101+1991+FIRST+0+N

programs with neighbours; surveying the river road and other access roads for Aboriginal sites; preparing a conservation plan and maintenance schedule for shearers' quarters and associated buildings; restricting vehicular access to King Charlie Waterhole; and reviewing and issuing (if appropriate) licences for bores to neighbours.[14]

Paroo River Agreement 2003

The Intergovernmental Agreement for the Paroo River between Queensland and NSW, signed in 2003 under the Border Catchments Memorandum of Understanding covering all the rivers that flow between Queensland and NSW, aims to protect the Paroo River through whole of catchment protection. The agreement recognises that naturally variable flow regimes and the maintenance of water quality are fundamental to the health of aquatic ecosystems and biodiversity and should be maintained; that flooding of the Paroo River is beneficial for pastoral activities and floodplain ecosystem processes; that storage and use of water resources in the Paroo River catchment, including off-river storages, are linked and should be managed on an integrated basis; that decisions need to be based on scientific and technical information, as well as on local knowledge and experience of the Paroo River community, including indigenous communities; and that precautionary approaches need to be taken to minimise the impact of known environmental effects and reduce the possibility of affecting poorly understood ecological functions. Through the agreement, the NSW and Queensland governments have roles and responsibilities for the implementation of natural resource management within the Paroo River Agreement area (the Paroo River system and associated catchments, floodplains, overflow channels, lakes, wetlands, and subartesian waters dependent on surface flows). Some of these responsibilities include assisting in the research and monitoring of the Paroo River Agreement area for informed management, particularly as it concerns water quality and river flows, and consulting with local governments and the Paroo River community.

Water Resource Plan 2003 (Warrego, Paroo, Bulloo and Nebine)

As half of the Paroo River lies in Queensland and half lies in NSW, the river is subject to different state laws. In 2003, the Queensland Government developed the Water Resource Plan 2003 (Warrego, Paroo, Bulloo and Nebine) under the Water Act 2000.[15] The Water Resource Plan provides a framework for the allocation and sustainable management of surface and overland flow water in Queensland. Under Clause 11 of the plan, 'the volume of water that crosses the Queensland–New South Wales border must not be less than 99% of the end of system flow for the pre-development flow pattern from Paroo and associated streams'. For the Warrego, which flows into the Paroo through the Cuttaburra Channels, 'the volume of water that crosses the Queensland–New South Wales border must not be less than 89% of end of system flow for the pre-development flow pattern from Paroo and associated streams.' As set out in the plan, up to 100 ML of unallocated water can be extracted annually from the Paroo River catchment for town water supply, ecotourism or similar use. Similarly, 100 ML of unallocated water can be extracted from the Warrego catchment for the same use (Water Resource Plan 2003 (Warrego, Paroo, Bulloo and Nebine)). The plan expires on 1 September 2014.

National Water Initiative 2004

In 2004, the Council of Australian Governments agreed to the NWI (Tasmania and Western Australia became signatories in 2005 and 2006, respectively) which will chart the future responsibilities and progress towards sustainable management of the nation's rivers and aquifers. The NWI is a comprehensive strategy driven by the Australian Government to improve water management across the country. It recognises that Australia's highly variable and often scarce water resources are crucial for economic, social and environmental

[14] www.environment.nsw.gov.au/resources/parks/pomfinalnocoleche.pdf
[15] www.legislation.qld.gov.au/LEGISLTN/CURRENT/W/WaterReWarP03.pdf

wellbeing. Provisions in the intergovernmental agreement on the NWI commit the participating parties to identify, protect and manage high-conservation-value rivers and aquifers and the ecosystems that depend on them, and return allocations to sustainable levels.[16]

Draft Paroo–Darling National Park Management Plan 2009

A draft plan of management for the Paroo–Darling National Park was on public exhibition in 2009 and is being finalised. The draft plan of management emphasises the conservation of the natural and cultural heritage values of the park (NPWS 2009). Minimal impact recreational practices are encouraged as public awareness of the natural and cultural heritage values of the park is a high priority. Other high priorities include investigating grazing impacts on the mound springs at Peery Lake; completing vegetation mapping of the park; implementing measures included in recovery plans for threatened native flora, such as the salt pipewort (*Eriocaulon carsonii*) and threatened native fauna; investigating options for cooperative park management with traditional Aboriginal land owners and involving traditional Aboriginal land owners in the conservation and protection of Aboriginal heritage in the park; conserving and protecting pastoral heritage in the park; controlling pest species with the cooperation of adjacent landholders; maintaining close liaison with neighbouring landholders and local communities regarding matters of mutual interest; and providing interpretive, directional and regulatory signage at appropriate locations throughout the park. Attention could focus on wetland management and monitoring and studying local and regional hydrology (for example, monitoring groundwater levels and investigating how hydraulic pressure changes may affect the discharge of artesian water from mound springs).

Water Act 2007

The *Water Act 2007* (Cwlth)[17] commenced on 3 March 2008 and implemented key reforms for water management in Australia. The Act establishes the Murray–Darling Basin Authority and requires it to prepare the Basin Plan, a strategic plan for the integrated and sustainable management of water resources in the Murray–Darling Basin.

[16] www.nwc.gov.au/www/html/672-objectives-key-elements.asp?intSiteID=1
[17] www.environment.gov.au/water/australia/water-act/index.html#water-act

Appendix 2: Plant species

Family	Species	Common name	Conservation status**
Characeae	*Chara australis*		
	Chara braunii		
	Chara fibrosa		
	Chara preissii		
	Nitella 'claypan 18'		
	Nitella cristata		
	Nitella 'parooensis'		
	Nitella partita		Endangered (TSC Act)
	Nitella psuedoflabellata		
	Nitella sonderi		
	Nitella subtillisima		
Marsiliaceae	*Marsilea drummondii*	Nardoo	
	Marsilea angustifolia	Narrow-leaf nardoo	
Ophioglossaceae	*Ophioglossum polyphyllum*	Adders tongue	
Sinopteridaceae	*Cheilanthes sieberi*	Rock fern	
Angiosperms: Monocots			
Alismataceae	*Damasonium minus*	Starfruit	
Amaryllidaceae	*Crinum flaccidum*	Darling lily	
Aponogetonaceae	*Aponogeton queenslandicus*		Endangered (TSC Act), ROTAP
Asphodelaceae	*Asphodelus fistulosus**		
Cyperaceae	*Cyperus bifax*	Downs nutgrass	
	Cyperus difformis	Dirty dora	
	Cyperus gilesii		
	Cyperus gymnocaulos		
	Cyperus iria		
	Cyperus laevigatus		
	Cyperus pygmaeus	Dwarf sedge	
	Cyperus squarrosus	Bearded-flat sedge	
	Eleocharis acuta	Common spike rush	
	Eleocharis pallens	Pale spike rush	
	Eleocharis plana		
	Eleocharis pusilla	Small spike rush	
	Fimbristylis dichotoma	Common fringe rush	
	Isolepis australiensis		
	Lipocarpha microcephala		
	Schoenoplectus dissacanthus	Club rush	

Family	Species	Common name	Conservation status**
Hydrocharitaceae	*Ottelia ovalifolia*	Swamp lily	
Juncaceae	*Juncus aridicola*	Tussock rush	
Liliaceae	*Thysanotus bauerii*	Mallee fringe lily	
Lythraceae	*Ammania multiflora var multiflora*	Jerry-Jerry	
Najadaceae	*Najas tenuifolia*	Water nymph	
Poaceae	*Agrostis avenacea var. avenacea*	Blown grass	
	Aristida anthoxanthoides	Pale wiregrass	
	Aristida contorta	Bunched kerosene grass	
	Aristida holathera var. holathera	Erect kerosene grass	
	Astrebla pectinata	Barley Mitchell grass	
	Bothriochloa erianthoides	Satintop grass	
	*Cenchrus ciliaris**	Buffel grass	
	*Cenchrus incertus**		
	Chrysopogen fallax		
	Chloris divaricata	Windmill grass	
	Chloris pectinata	Comb-windmill grass	
	Chloris truncata	Windmill grass	
	Chrysopogen fallax	Golden beard grass	
	Cymbopogen obtectus	Silky heads	
	Dicantheum sericeum	Queensland bluegrass	
	Digitaria coenicola	Finger panic	
	Digitaria brownii	Cotton panic grass	
	Diplachne fusca	Brown beetle grass	
	Elytrophorus spicatus	Spikegrass	Conservation concern in western NSW
	Enneapogon avenaceus	Bottle washers	
	Enteropogon acicularis	Curly windmill grass	
	Eragrostis australasicus	Canegrass	
	Eragrostis basedowii		
	*Eragrostis cilianensis**	Stinkgrass	
	Eragrostis dielsii	Mulka	
	Eragrostis eriopoda	Woolybutt	
	Eragrostis kennedyae	Small flowered lovegrass	
	Eragrostis lacunaria	Purple lovegrass	
	Eragrostis laniflora	Woollybutt	
	Eragrostis parviflora	Weeping lovegrass	
	Eragrostis setifolia	Neverfail	
	Eriochloa australiensis	Australian cupgrass	
	Leptochloa digitata	Umbrella canegrass	

Family	Species	Common name	Conservation status**
	Panicum decompositum	Native millet	
	*Panicum gilvum**		
	Paspalidium jubiflorum	Warrego grass	
	*Pennisetum setaceum**	Fountain grass	
	Sporobolus caroli	Fairy grass	
	Stipa scabra ssp. *scabra*		
	Stipa variabilis		
	Themeda australis	Kangaroo grass	
	Thyridolepis mitchelliana	Mulga Mitchell grass	
	Tragus australianus	Small burrgrass	
	Triraphis mollis	Purple needlegrass	
Angiosperms: Dicots			
Aizoaceae	*Glinus lotoides*	Carpet-weed	
	Glinus orygiodes	Desert carpet-weed	ROTAP
	Mollugo cerviana	Wire-stem chickweed	
Amaranthaceae	*Alternanthera angustifolia*	Narrow-leaf joyweed	
	Alternanthera denticulata	Lesser joyweed	
	Alternanthera nodiflora	Common joyweed	
	Ptilotus atriplicifolius var.atriplicifolius	Crimson foxtail	
	Ptilotus gaudichaudii var.parviflorus	Paper foxtail	
	Ptilotus luecocoma		
	Ptilotus nobilis	Regal foxtail	
	Ptilotus obovatus var.obovatus	Smoke bush, cotton bush	
	Ptilotus polystachyus var. *polystachyus*	Long-tails	
Apiaceae	*Daucus glochidiatus*	Australian carrot	
	Eryngium plantagineum	Long eryngium	
Asteraceae	*Actinobole uliginosum*	Flannel cudweed, cotton weed	
	*Arctotheca calendula**	Capeweed	
	*Bidens pilosa**		
	Brachycome ciliaris var. *lanuginosa*	Variable daisy	
	Brachycome ciliocarpa	Showy daisy	
	Brachycome goniocarpa	Dwarf daisy	
	Brachycome lineariloba	Hard-headed daisy	
	Calocephalus platycephalus	Western beauty-heads	
	Calotis cuneifolia	Purple burr-daisy	
	Calotis erinacea	Tangled burr-daisy	

Family	Species	Common name	Conservation status**
	Calotis hispidula	Bogan flea	
	Calotis inermis	Fluffy burr-daisy	
	Calotis plumulifera (multicaulis)	Woolly-headed burr-daisy	
	*Carthamus lanatus**	Saffron thistle	
	Centipeda cunninghamii	Common sneeze weed	
	Chthonocephalus psuedevax	Ground heads	
	Craspedia sp. aff. *chrysantha*		
	Eclipta platyglossa	Yellow twin heads	
	Epaltes australis	Spreading nut-heads	
	Eriochlamys sp. aff. *behrii*	Woolley mantle	
	Gnaphalium sphaericum		
	Gnaphalium luteo-album		
	Gnephosis eriocarpa	Native chamomile	
	Gnephosis arachnoidea (previously *G. foliata*)	Erect yellow heads	
	Hyalosperma semisterile (*Helipterum jessenii*)	Orange sunray	
	Ixiolaena leptolepis	Stalked plover daisy	
	Lemooria burkittii	Wires and wool	
	Millotia greevsii ssp. *greevsii* var. *greevsii*	Creeping millotia	
	Minuria denticulata	Woolly minuria	
	Minuria integerrima	Smooth minuria	
	Myriocephalus stuartii	Poached eggs	
	Myriocephalus rhizocephalus	Woolley heads	
	Olearia pimeleoides	Showy daisy bush	
	Podolepis capillaris	Invisible plant	
	Psuedo-gnaphalium luteoalbum	Jersey cudweed	
	Pterocaulon sphacelatum	Applebush	
	Pycnosorus sp. aff. *chrysanthus*		
	Rhodanthe floribunda	Common white sunray	
	Rhodanthe moschata	Musk sunray	
	Rhodanthe stricta	Slender sunray	
	Rutidosis helychrysoides		
	Senecio glossanthus	Slender groundsel	
	Senecio quadridentatus		
	Vittadinia cuneata		

Family	Species	Common name	Conservation status**
	Vittadinia dissecta var. *hirta*		
	*Xanthium occidentale**	Noogoora burr	
	*Xanthium spinosum**	Bathurst burr	
Boraginaceae	*Heliotropium curassavicum**	Smooth heliotrope	
	*Heliotropium europaeum**	Common heliotrope	
	Heliotropium supinum	Prostrate heliotrope	
Brassicaceae	*Arabidella eremigena*	Priddiwalkatji	
	*Brassica tournefortii**	Mediterranean turnip	
	Cuphonotis andraeanus	Downy mother of misery	
	Lepidium oxytrichum	Green peppercress	
	Stenopetalum nutans	Stinking thread petal	
Cactaceae	*Opuntia stricta* var. *dellieni**	Creeping pear, prickly pear	
Campanulaceae	*Wahlenbergia communis*	Tufted bluebell	
	Wahlenbergia tumidifructa		
Capparaceae	*Capparis mitchellii*	Wild orange, native orange	
Caryophyllaceae	*Polycarpaea arida*		
	*Spergularia diandra**		
	Spergularia rubra	Sandspurry	
Chenopodiaceae	*Atriplex limbata*	Spreading saltbush	
	Atriplex holocarpa		
	Atriplex nummularia	Old man saltbush	
	Atriplex vesicaria	Bladder saltbush	
	Chenopodium auricomum	Golden goosefoot	
	Chenopodium truncatum		
	Disphyma crassifolium ssp. *clavellatum*		
	Dissocarpus paradoxus	Cannoonball burr	
	Dysphania platycarpa		Endangered (TSC Act 1995)
	Einadia nutans		
	Enchylaena tomentosa	Ruby saltbush	
	Maireana aphylla		
	Maireana brevifolia	Yanga bush	
	Maireana cheelii		
	Maireana pyramidata	Black bluebush	
	Maireana sclerolaeniodes		
	Rhagodia nutans	Climbing saltbush	
	Rhagodia parabolica		

Family	Species	Common name	Conservation status**
	Rhagodia spinescens	Thorny saltbush	
	Salsola kali var.strobilifera	Knobby buckbush	
	Sclerolaena bicornis	Galvanised burr	
	Sclerolaena birchii		
	Sclerolaena convexula	Green copperburr	
	Sclerolaena decurrens	Grey copperburr	
	Sclerolaena diacantha	Streaked poverty-bush	
	Sclerolaena tricuspis	Giant redburr	
	Sclerostegia tenuis		
Convolvulaceae	*Evolvulus alsiniodes*		
	Convolvulus erubescens	Australian bindweed	
	Convolvulus remotus		
Elatinaceae	*Bergia trimera*	Small water fire	
	Elatine gratioloides	Waterwort	
Eriocaulaceae	*Eriocaulon carsonii*	Salt pipewort	Endangered (TSC Act and EPBC Act), ROTAP
Euphorbiaceae	*Chamaesyce drummondii*	Caustic weed	
	Sauropus trachyspermus	Slender spurge	
Fabaceae			
Subfamily Caesalpinioideae	*Senna* (Cassia) *artemesioides* ssp. *filifolia*	Silver cassia	
	Senna artemesioides ssp. *sturtii*	Grey cassia	
Subfamily Faboideae	*Aeschynomene indica*	Budda pea	
	Glycine canescens	Silky glycine	
	Glycyrrhiza acanthocarpa	Native liquorice	
	Lotus cruentus	Red-flowered lotus	
	*Medicago laciniata**	Cut-leaf medic	
	Psoralea cinerea		
	Swainsona microphylla ssp. *tomentosa*		
	Swainsona phacoides		
	Trigonella suavissima		
Subfamily Mimosoideae	*Acacia anuera*	Mulga	
	Acacia cambadgei	Gidgee	
	Acacia excelsa	Ironwood	
	Acacia ligulata	Umbrella bush	
	Acacia microcarpa		
	Acacia oswaldii	Miljee	
	Acacia salicina	Cooba	

Family	Species	Common name	Conservation status**
	Acacia stenophylla	River cooba	
	Acacia tetragonophylla	Dead finish	
	Acacia victoriae	Prickly wattle	
Frankeniaceae	*Frankenia gracilis*	Dainty sea-heath	
	Frankenia serpyllifolia	Bristly sea-heath	
Gentianaceae	*Centaurium spicatum*		
	Sebaea ovata		
Geraniaceae	*Erodium cicutarium*	Common stalksbill, common crowfoot	
	Erodium crinitum	Blue stalksbill, blue crowfoot	
Goodeniaceae	*Goodenia* sp. 'Nocoleche'	Goodenia nocoleche	Endangered (TSC Act)
	Scaevola parvibarbata		
	Scaevola spinescens	Spiny fan flower	
Haloragaceae	*Haloragis aspera*	Rough raspwort	
	Myriophyllum verrucosum	Red water-milfoil	
Lamiaceae	*Mentha australis*	River mint	
	*Salvia verbenaca**	Wild sage	
	Teucrium racemosum	Grey germander	
Lentibulariaceae	*Utricularia dichotoma*		
Lobeliaceae	*Pratia concolor*	Poison pratia	
	Pratia darlingensis	Matted pratia	
Loranthaceae	*Amyena maidenii* ssp. *maidenii*	Pale leaf mistletoe	
	Amyena miraculosum ssp. *boormanii*	Fleshy mistletoe	
	Lysania exocarpi	Harlequin mistletoe	
Lythraceae	*Ammannia multiflora*	Jerry-jerry	
Malvaceae	*Abutilon luecopetalum*	Lantern bush	
	Abutilon otocarpum	Desert Chinese lantern	
	Hibiscus sturtii	Hill hibiscus	
	Lavatera plebeia		
	*Malva parviflora**	Small-flowered mallow	
	Malvastrum americanum	Malvastrum	
	Sida ammophila	Sand sida	
	Sida platycalyx	Lifesaver bush	
Menyanthaceae	*Nymphoides crenata*	Wavy marshwort	
Myoporaceae	*Eremophila bignoniiflora*	Eurah	
	Eremophila bowmannii var. *latifolia*	Silver turkeybush	
	Eremophila divaricata ssp. *divaricata*	Spreading emubush	

Family	Species	Common name	Conservation status**
	Eremophila duttonii	Budda, harlequin fuchsia bush	
	Eremophila gilesii	Desert fuschsia	
	Eremophila glabra	Tar bush	
	Eremophila latrobei	Crimson turkeybush	
	Eremophila longifolia	Berrigan, emu bush	
	Eremophila maculata	Spotted fuchsia	
	Eremophila polyclada	Flowering lignum	
	Eremophila sturtii	Turpentine bush	
	Myoporum montanum	Western boobialla	
Myrtaceae	*Eucalyptus camaldulensis*	Red gum	
	Eucalyptus coolabah	Coolibah	
	Eucalyptus largiflorens	Black box	
	Eucalyptus ochrophloia	Yapunyah	
	Eucalyptus populnea ssp. *bimbil*	Poplar box, bimblebox	
	Eucalyptus opaca (terminalis)	Western bloodwood	
	Melaleuca densispicata	Swamp paperbark	
Nyctaginaceae	*Boerhavia dominii* (diffusa)	Tar vine	
Oleaceae	*Jasminium lineare*	Native jasmin, desert jasmin	
Onagraceae	*Ludwigia peploides* ssp. *montevidensis*	Water primrose	
Oxalidaceae	*Oxalis corniculata*	Yellow wood sorrel	
Papaveraceae	*Argemone ochroleuca* ssp. *ochroleuca**	Mexican poppy	
Pittosporaceae	*Pittosporum phylliraeoides*	Butter bush	
Plantaginaceae	*Plantago turrifera*	Small sago weed	
Polygonaceae	*Acetosa vesicaria**	Wild hops, bladder dock	
	*Emex australis**	Spiny emex, three-cornered Jack	
	Muehlenbeckia florulenta	Lignum	
	Muehlenbeckia horrida	Spiny lignum	
	Persicaria attenuata	Knotweed	
	Persicaria lapathifolia	Pale knotweed	
	Polygonum arenastrum	Wire weed	
	Polygonum plebium	Small knotweed	
	Rumex crystalinus	Shiny dock	
Portulacaceae	*Calandrinia balonensis*	Broad leaf parakeelya	
	Calandrinia eremaea	Small purslane	
	Calandrinia pumila	Tiny purslane	

Family	Species	Common name	Conservation status**
	Portulaca filifolia	Slender pigweed	
	Portulaca intraterranea	Large pigweed	
Primulaceae	*Anagallis arvensis**	Pimpernel	
Proteaceae	*Grevillea striata*	Beefwood	
	Hakea ivoryi	Corkbark	
	Hakea leucoptera	Needlewood	
	Hakea tephrosperma		
Ranunculaceae	*Mysurus minimus*	Mouse-tail	
	Ranunculus pentandrus		
	Ranunculus sessiflorus		
Rubiaceae	*Dentella minutissima*	Starfruit	Endangered (TSC Act)
Rutaceae	*Flindersia maculosa*	Leopard wood	
Santalaceae	*Santalum lanceolatum*	Sandlewood	
Sapindaceae	*Alectryon oleifolius* (*Heterodendrum oleifolium*)	Western rosewood	
	Atalaya hemiglauca	Whitewood	
	Dodonaea viscosa ssp. *angustissima*	Hopbush	
Scrophulariaceae	*Glossostigma diandrum*	Mudmat	
	Gratiola pumilio		
	Mimulus prostratus	Creeping monkey flower	
	Mimulus repens		
	Peplidium foecundum	Dward peplidium	
	Stemodia florulenta	Bluerod	
Solanaceae	*Lycium ferocissimum**	African boxthorn	
	Nicotiana simulans	Native tobacco	
	*Solanum nigrum**	Blackberry nightshade	
Tamaricaceae	*Tamarix aphylla**	Tamarisk, Athol pine	
Thymeliaceae	*Pimelea microcephala ssp microcephala*	Shrubby rice flower	
	Pimelea trichostachya	Spiked rice flower	
Verbenaceae	*Verbena officinalis*	Common verbena	
	*Verbena supina**	Trailing verbena	

Source: RIS (2007) as adapted from Kingsford and Porter (1999) and updated by Porter (2007)
* Introduced species
** ROTAP: Rare or threatened Australian plants (after Leigh et al. 1981)

Appendix 3: Animal species recorded in the Paroo River Wetlands Ramsar site

Family	Species	Common name	Conservation status
Amphibians: Frogs			
Hylidae	*Cyclorana cultripes*	Grassland collared frog	
	Cyclorana platycephala	Water-holding frog	
	Cyclorana verrucosa	Rough frog, warty water-holding frog	Conservation concern in western NSW
	Litoria alboguttata	Striped burrowing frog	Conservation concern in western NSW
	Litoria caerulea	Green tree frog	
	Litoria latopalmata	Broad-palmed frog	
	Litoria peronii	Peron's tree frog	
	Litoria rubella	Desert tree frog	
Myobatrachidae	*Limnodynastes fletcheri*	Long-thumbed frog, Barking marsh frog	
	Limnodynastes tasmaniensis	Spotted marsh frog	
	Neobatrachus sudelli	Painted burrowing frog, common spadefoot toad	
	Notaden bennettii	Holy cross toad, crucifix toad	
	Crinia deserticola	Brown toadlet	Conservation concern in western NSW
	Crinia parinsignifera	Eastern sign-bearing froglet, plains froglet	Conservation concern in western NSW
	Uperoleia rugosa	Red-groined froglet	
Reptiles: Turtles			
Chelidae	*Emydura macquarii*	Murray turtle	
Reptiles: Lizards			
Agamidae	*Ctenophorus nuchalis*	Central netted dragon	
	Ctenophorus pictus	Painted dragon	
	Lophognathus gilberti	Gilbert's dragon	
	Pogona vitticeps	Central bearded dragon	
	Tympanocryptis lineata	Lined earless dragon	
Gekkonidae	*Diplodactylus byrnei*	Gibber gecko	
	Diplodactylus ciliaris	Spiny-tailed gecko	
	Diplodactylus conspicillatus	Fat-tailed gecko	Endangered (TSC Act), conservation concern in western NSW
	Diplodactylus steindachneri	Steindachner's gecko	
	Gehyra dubia	Northern dtella	Conservation concern in western NSW

	Gehyra variegata	Tree dtella	
	Heteronotia binoei	Bynoe's gecko	
	Lucasium damaeum	Beaded gecko	
	Nephrurus levis	Smooth knob-tailed gecko	
	Rhynchoedura ornata	Beaked gecko	
Pygopodidae	*Delma tincta*	Legless lizard	
	Lialis burtonis	Burton's legless lizard	
Scincidae	*Cryptoblepharus carnabyi*	Carnaby's wall skink	
	Cryptoblepharus plagiocephalus		
	Ctenotus leonhardii	Leonhardi's ctenotus	
	Ctenotus regius	Pale-rumped ctenotus	
	Ctenotus schomburgkii	Barred wedgesnout ctenotus	
	Ctenotus strauchii	Eastern wedgesnout ctenotus	Conservation concern in western NSW
	Egernia inornata	Desert skink	
	Eremiascincus richardsonii	Broad-banded sand swimmer	
	Morethia boulengeri	Boulenger's skink	
	Tiliqua scincoides	Eastern blue-tongued lizard	
	Trachydosaurus rugosus	Shingle-back	
Varanidae	*Varanus gouldii*	Gould's goanna, sand goanna	
	Varanus tristis	Black-headed monitor	
Reptiles: Snakes			
Boidae	*Morelia spilota variegata*	Carpet python	Conservation concern in western NSW
Elapidae	*Pseudechis australis*	Mulga or king brown snake	
	Pseudonaja nuchalis	Western brown snake	
	Pseudonaja textilis	Eastern brown snake	
	Simoselaps australis	Coral snake	
	Simoselaps fasciolatus	Narrow-banded snake	Vulnerable (TSC Act)
Typhlopidae	*Ramphotyphlops bituberculatus*	Blind snake	
Mammals: Monotremes			
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked echidna	
Mammals: Marsupials			
Dasyuridae	*Sminthopsis crassicaudata*	Fat-tailed dunnart	
Macropodidae	*Macropus fuliginosus*	Western grey kangaroo	
	Macropus giganteus	Eastern grey kangaroo	
	Macropus robustus	Common wallaroo	

	Macropus rufus	Red kangaroo	
Mammals: Placentals			
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied sheathtail-bat	Vulnerable (TSC Act)
Molossidae	*Tadarida australis*	White-striped mastiff-bat	
Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat	
	Chalinolobus picatus	Little pied bat	Vulnerable (TSC Act)
	Vespadelus baverstocki	Inland forest bat	Vulnerable (TSC Act)
	Vespadelus vulturnus	Little forest bat	
	Nyctophilus geoffroyi	Lesser long-eared bat	
	Scotorepens balstoni	Western broad-nosed bat	
	Scotorepens greyii	Little broad-nosed bat	
Muridae	*Hydromys chrysogaster*	Water rat	Conservation concern in western NSW
	*Mus musculus**	House mouse	
Canidae	*Canis familiaris*	Dingo	
	*Vulpes vulpes**	Fox	
Felidae	*Felis catus**	Cat	
Leporidae	*Oryctolagus cuniculus**	Rabbit	
Suidae	*Sus scrofa**	Pig	
Bovidae	*Bos taurus**	Cow	
	*Capra hircus **	Goat	
	*Ovis aries**	Sheep	
Equidae	*Equus caballus **	Horse	
Birds			
Casuariidae	*Dromaius novaehollandiae*	Emu	
Anatidae	*Anas castanea*	Chestnut teal	
	Anas gracilis	Grey teal	
	Anas rhynchotis	Australasian shoveler	
	Anas superciliosa	Pacific black duck	
	Aythya australis	Hardhead	
	Biziura lobata	Musk duck	
	Chenonetta jubata	Australian wood duck, maned duck	
	Cygnus atratus	Black swan	
	Dendrocygna eytoni	Plumed whistling-duck	
	Malacorhynchus membranaceus	Pink-eared duck	
	Oxyura australis	Blue-billed duck	Vulnerable (TSC Act)
	Stictonetta naevosa	Freckled duck	Vulnerable (TSC Act)
Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed grebe	
	Tachybaptus novaehollandiae	Australasian grebe	

	Podiceps cristatus	Great crested grebe	Conservation concern in western NSW
Anhingidae	*Anhinga melanogaster*	Darter	Conservation concern in western NSW
Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant	Conservation concern in western NSW
	Phalacrocorax melanoleucos	Little pied cormorant	
	Phalacrocorax sulcirostris	Little black cormorant	
	Phalacrocorax varius	Pied cormorant	Conservation concern in western NSW
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican	Conservation concern in western NSW
Ardeidae	*Ardea novaehollandiae*	White-faced heron	
	Ardea pacifica	White-necked heron	
	Ardea alba	Great egret	Conservation concern in western NSW, JAMBA, CAMBA
	Egretta garzetta	Little egret	
	Ardea intermedia	Intermediate egret	Conservation concern in western NSW
	Nycticorax caledonicus	Nankeen night heron, rufous night heron	
Plataleidae	*Platalea flavipes*	Yellow-billed spoonbill	
	Platalea regia	Royal spoonbill	Conservation concern in western NSW
	Plegadis falcinellus	Glossy ibis	Conservation concern in western NSW, JAMBA, CAMBA
	Threskiornis molucca	Australian white ibis	Conservation concern in western NSW
	Threskiornis spinicollis	Straw-necked Ibis	Conservation concern in western NSW
Accipitridae	*Accipiter cirrocephalus*	Collared sparrowhawk	
	Accipiter fasciatus	Brown goshawk	
	Aquila audax	Wedge-tailed eagle	
	Circus assimilis	Spotted harrier	
	Circus approximans (aeruginosus)	Swamp (marsh) harrier	
	Haliastur sphenurus	Whistling kite	
	Hamirostra melanosternon	Black-breasted buzzard	Vulnerable (TSC Act)
	Hieraaetus morphnoides	Little eagle	
	Lophoictinia isura	Square-tailed kite	Vulnerable (TSC Act)
	Milvus migrans	Black kite	
Falconidae	*Falco berigora*	Brown falcon	
	Falco cenchroides	Nankeen kestrel, Australian ketrel	

	Falco hypoleucos	Grey falcon	Vulnerable (TSC Act)
	Falco longipennis	Australian hobby	
	Falco peregrinus	Peregrine falcon	
	Falco subniger	Black falcon	
Gruidae	*Grus rubicunda*	Brolga	Vulnerable (TSC Act)
Rallidae	*Fulica atra*	Eurasian coot	
	Gallinula ventralis	Black-tailed native-hen	
	Porzana fluminea	Australian spotted crake	
	Porzana pusilla	Baillon's crake	
	Porzana tabuensis	Spotless crake	
Otididae	*Ardeotis australis*	Australian bustard	Endangered (TSC Act)
Phasianidae	*Coturnix ypsilophora*	Brown quail	Conservation concern in western NSW
Turnicidae	*Turnix velox*	Little button quail	
Scolopacidae	*Limosa lapponica*	Bar-tailed godwit	JAMBA, CAMBA, ROKAMBA
	Limosa limosa	Black-tailed godwit	Vulnerable (TSC Act), JAMBA, CAMBA, ROKAMBA
	Actitis hypoleucos	Common sandpiper	JAMBA, CAMBA, ROKAMBA
	Calidris acuminata	Sharp-tailed sandpiper	JAMBA, CAMBA, ROKAMBA
	Calidris ferruginea	Curlew sandpiper	JAMBA, CAMBA, ROKAMBA
	Calidris ruficollis	Red-necked stint	JAMBA, CAMBA, ROKAMBA
	Calidris subminuta	Long-toed stint	JAMBA, CAMBA, ROKAMBA
	Tringa glareola	Wood sandpiper	JAMBA, CAMBA, ROKAMBA
	Tringa nebularia	Common greenshank	JAMBA, CAMBA, ROKAMBA
	Tringa stagnatilis	Marsh sandpiper	JAMBA, CAMBA, ROKAMBA
Rostratulidae	*Rostratula benghalensis*	Painted snipe	Vulnerable (TSC Act), JAMBA, CAMBA
Recurvirostridae	*Himantopus himantopus*	Black-winged stilt	
	Recurvirostra novaehollandiae	Red-necked avocet	
Charadriidae	*Elseyornis melanops*	Black-fronted dotterel	
	Charadrius ruficapillus	Red-capped plover	
	Erythrogonys cinctus	Red-kneed dotterel	
	Charadrius australis	Inland dotterel	
	Vanellus miles	Masked lapwing	
	Vanellus tricolour	Banded lapwing	
Glareolidae	*Stiltia isabella*	Australian pratencole	

Laridae	*Larus novaehollandiae*	Silver gull	Conservation concern in Western NSW
	Chlidonias leucoptera	White-winged black tern	JAMBA, CAMBA
	Chlidonias hybridus	Whiskered tern	
	Sterna caspia	Caspian tern	Conservation concern in Western NSW, JAMBA, CAMBA
	Sterna nilotica	Gull-billed tern	
Columbidae	*Geopelia cuneata*	Diamond dove	
	Geopelia placida	Peaceful dove	
	Ocyphaps lophotes	Crested pigeon	
	Phaps chalcoptera	Common bronzewing	
Cacatuidae	*Cacatua galerita*	Sulphur-crested cockatoo	
	Cacatua leadbeateri	Major Mitchell's cockatoo	Vulnerable (TSC Act)
	Cacatua sanguinea	Little corella	
	Eolophus roseicapillus	Galah	
Polytelitidae	*Nymphicus hollandicus*	Cockatiel	
	Aprosmictus erythropterus	Red-winged parrot	
Platyceridae	*Barnardius zonarius*	Australian ringneck	
	Melopsittacus undulatus	Budgerigar	
	Northiella haematogaster	Blue bonnet	
	Psephotus haematonotus	Red-rumped parrot	
	Psephotus varius	Mulga parrot	
	Neophema chrysostoma	Blue-winged parrot	
	Neopsephotus bourkii	Bourke’s parrot	
Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo	
	Chalcites osculans	Black-eared cuckoo	
	Cuculus pallidus	Pallid cuckoo	
Strigidae	*Ninox boobook*	Southern boobook	
Podargidae	*Podargus strigoides*	Tawny frogmouth	
Caprimulgidae	*Eurostopodus argus*	Spotted nightjar	
Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar	
Halcyonidae	*Dacelo novaeguineae*	Laughing kookaburra	
	Todiramphus pyrrhopygia	Red-backed kingfisher	
	Todiramphus sanctus	Sacred kingfisher	
Meropidae	*Merops ornatus*	Rainbow bee-eater	
Climacteridae	*Climacteris picumnus*	Brown treecreeper	Vulnerable (TSC Act)
Maluridae	*Malurus lamberti*	Variegated fairy-wren	
	Malurus leucopterus	White-winged fairy-wren	
Pardalotidae	*Pardalotus rubricatus*	Red-browed pardalote	
	Pardalotus striatus	Striated pardalote	

	Gerygone fusca	Western gerygone	
	Smicrornis brevirostris	Weebill	
	Acanthiza apicalis	Inland thornbill	
	Acanthiza chrysorrhoa	Yellow-rumped thornbill	
	Acanthiza nana	Yellow thornbill	
	Acanthiza reguloides	Buff-rumped thornbill	Conservation concern in western NSW
	Acanthiza uropygialis	Chestnut-rumped thornbill	
	Aphelocephala leucopsis	Southern whiteface	
Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked honeyeater	
	Certhionyx niger	Black honeyeater	
	Certhionyx variegatus	Pied honeyeater	Vulnerable (TSC Act)
	Entomyzon cyanotis	Blue-faced honeyeater	
	Lichenostomus penicillatus	White-plumed honeyeater	
	Lichenostomus virescens	Singing honeyeater	
	Lichmera indistincta	Brown honeyeater	
	Manorina flavigula	Yellow-throated miner	
	Melithreptus brevirostris	Brown-headed honeyeater	
	Melithreptus gularis	Black-chinned honeyeater	Conservation concern in western NSW
	Philemon citreogularis	Little friarbird	
	Phylidonyris albifrons	White-fronted honeyeater	
	Plectorhyncha lanceolata	Striped honeyeater	
	Epthianura albifrons	White-fronted chat	
	Epthianura aurifrons	Orange chat	
	Epthianura tricolor	Crimson chat	
Petroicidae	*Microeca fascinans*	Jacky winter	
	Petroica goodenovii	Red-capped robin	
Pomatostomidae	*Pomatostomus halli*	Hall's babbler	Vulnerable (TSC Act)
	Pomatostomus ruficeps	Chestnut-crowned babbler	
	Pomatostomus superciliosus	White-browed babbler	
Cinclosomatidae	*Psophodes cristatus*	Chirruping wedgebill	
	Cindosoma costaneothorax	Chestnut-breasted quail thrush	Conservation concern in western NSW
Neosittidae	*Daphoenositta chrysoptera*	Varied sittella	
Pachycephalidae	*Colluricincla harmonica*	Grey shrike-thrush	
	Oreoica gutturalis	Crested bellbird	
	Pachycephala rufiventris	Rufous whistler	

Dicruridae	*Myiagra inquieta*	Restless flycatcher	
	Rhipidura albiscapa	Grey fantail	
	Rhipidura leucophrys	Willie wagtail	
	Grallina cyanoleuca	Magpie-lark	
Campephagidae	*Coracina maxima*	Ground cuckoo-shrike	
	Coracina novaehollandiae	Black-faced cuckoo-shrike	
	Lalage tricolor	White-winged triller	
Artamidae	*Artamus cinereus*	Black-faced woodswallow	
	Artamus cyanopterus	Dusky woodswallow	
	Artamus leucorynchus	White-breasted woodswallow	
	Artamus personatus	Masked woodswallow	
	Artamus superciliosus	White-browed woodswallow	
	Cracticus nigrogularis	Pied butcherbird	
	Cracticus torquatus	Grey butcherbird	
	Gymnorhina tibicen	Australian magpie	
Corvidae	*Corvus bennetti*	Little crow	
	Corvus coronoides	Australian raven	
Corcoracidae	*Corcorax melanorhamphos*	White-winged chough	
	Struthidea cinerea	Apostlebird	
Ptilonorhynchidae	*Chlamydera maculata*	Spotted bowerbird	
Motacillidae	*Anthus novaeseekandiae*	Richard's pipit	
Passeridae	*Taeniopygia guttata*	Zebra finch	
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird	
Hirundinidae	*Hirundo neoxena*	Welcome swallow	
	Petrochelidon ariel	Fairy martin	
	Petrochelidon nigricans	Tree martin	
Sylviidae	*Acrocephalus stentoreus*	Clamorous reed-warbler	
	Cincloramphus cruralis	Brown songlark	
	Cincloramphus mathewsi	Rufous songlark	
	Megalurus gramineus	Little grassbird	
Sturnidae	*Sturnus vulgaris**	Common starling	
Fish			
Cichlidae	*Oereochromis mossambicus**	Tilapia	
Clupeidae	*Nematolosa erebi*	Bony bream	
Cyprinidae	*Cyprinus carpio**	European carp	
	*Carassius auratus**	Goldfish	
Melanotaenidae	*Melanotaenia fluviatilis*	Crimson-spotted rainbowfish	

Percichthyidae	*Macquarie ambigua*	Golden perch	
Percidae	*Perca fluviatilis**	Redfin perch	
Plotosidae	*Neosilurus hrytlii*	Hyrtl's tandan	
Poeciliidae	*Gambusia holbrooki**	Gambusia	
Retropinnidae	*Retropinna semoni*	Australian smelt	
Terapontidae	*Bidyanus bidyanus*	Silver perch	Vulnerable (TSC Act)
	Leiopotherapon unicolor	Spangled perch	

Source: RIS (2007) as adapted from Kingsford and Porter (1999) and NSW Wildlife Atlas (2000)

Species of conservation concern in western NSW are listed in Dickman et al. (1993,) Smith et al. (1995), Sadlier et al. (1996).

* Introduced species

Invertebrates

Phylum	Class	Order	Family	Common name
Annelida	Oligochaeta			Segmented aquatic worms
Mollusca	Gastropoda	Basommatophora	Ancylidae	Freshwater limpits
Mollusca	Bivalva		Corbiculidae	Freshwater mussels
Arthropoda	Arachnida	Acariformes		Mites
Arthropoda	Crustacea	Isopoda	Cirolanidae	
Arthropoda	Crustacea	Decapoda	Palaemonidae	Freshwater prawns
Arthropoda	Crustacea	Decapoda	Parastacidae	Freshwater crayfish and yabbies
Arthropoda	Insecta	Ephemeroptera	Caenidae	Mayflies
Arthropoda	Insecta	Odonata	Gomphidae	Dragonflies
Arthropoda	Insecta	Odonata	Libellulidae	Dragonflies
Arthropoda	Insecta	Hemiptera	Notonectidae	Backswimmers
Arthropoda	Insecta	Hemiptera	Corixidae	Waterboatmen
Arthropoda	Insecta	Hemiptera	Hydrometridae	Water measurers
Arthropoda	Insecta	Hemiptera	Mesoveliidae	Dwarf pond skaters
Arthropoda	Insecta	Hemiptera	Veliidae	Small water striders
Arthropoda	Insecta	Coleoptera	Dytiscidae	Predatory diving water beetles
Arthropoda	Insecta	Coleoptera	Heteroceridae	Water beetles
Arthropoda	Insecta	Coleoptera	Hydraenidae	Minute rove beetles
Arthropoda	Insecta	Coleoptera	Staphylinidae	Rove beetles

Appendix 4: Mean numbers of waterbird species on Peery Lake 1987–90

Survey period	Species	Mean abundance
June 1987	Australian pelican	40
	Black swan	6
	Grey teal	1397
	Pacific black duck	22
	Pink-eared duck	1248
	Red-necked avocet	1820
	Silver gull	214
	Small waders	44
September 1987	Australasian shoveler	230
	Black swan	10
	Black-winged (pied) stilt	200
	Freckled duck	8
	Grey teal	40
	Hardhead	10
	Pink-eared duck	16,814
	Red-necked avocet	80
	Silver gull	48
	Small waders	10
December 1987	Australasian shoveler	166
	Black swan	19
	Grey teal	239
	Gull-billed tern	8
	Hardhead	33
	Pink-eared duck	73
	Red-necked avocet	33
	Silver gull	11
	Whiskered terns	94
June 1988	Australian pelican	10
	Australasian shoveler	59
	Black swan	44
	Black-winged (pied) stilt	60
	Great cormorant	18
	Grey teal	438
	Hardhead	7
	Masked lapwing	20
	Pink-eared duck	139
	Red-necked avocet	102
	Silver gull	471

Survey period	Species	Mean abundance
	Small waders	4
	Whiskered tern	4
September 1988	Australian pelican	2
	Australasian shoveler	10
	Black swan	324
	Black-winged (pied) stilt	37
	Eurasian coot	115
	Freckled duck	1029
	Grey teal	3375
	Hardhead	472
	Masked lapwing	10
	Pacific black duck	52
	Pink-eared duck	2229
	Red-necked avocet	87
	Silver gull	379
	Whiskered tern	30
	Yellow-billed spoonbill	2
December 1988	Australian pelican	40
	Australasian shoveler	72
	Banded stilt	2
	Black swan	65
	Black-tailed native-hen	62
	Black-winged (pied) stilt	5
	Blue-billed duck	2
	Caspian tern	2
	Eurasian coot	30
	Freckled duck	96
	Great cormorant	2
	Great egret	10
	Grey teal	1216
	Gull-billed tern	125
	Hardhead	811
	Little black cormorant	10
	Maned duck	127
	Masked lapwing	7
	Pacific black duck	103
	Pink-eared duck	1301
	Red-necked avocet	769
	Silver gull	12
	Small grebes	5
	Small waders	5
	Whiskered tern	277

Survey period	Species	Mean abundance
March 1989	Australian pelican	5
	Australasian shoveler	100
	Banded stilt	25
	Black swan	65
	Black-winged (pied) stilt	474
	Eurasian coot	176
	Freckled duck	232
	Grey teal	1808
	Hardhead	117
	Large wader	75
	Masked lapwing	5
	Pacific black duck	117
	Pink-eared duck	7527
	Red-necked avocet	2124
	Royal spoonbill	2
	Silver gull	125
	Small grebes	12
	Small waders	141
	Whiskered tern	30
	Yellow-billed spoonbill	458
June 1989	Australian shelduck	5
	Australasian shoveler	57
	Black swan	82
	Black-winged (pied) stilt	25
	Caspian tern	2
	Grey teal	555
	Hardhead	12
	Maned duck	5
	Pacific black duck	68
	Pink-eared duck	75
	Silver gull	777
	Small waders	7
	White-faced heron	2
September 1989	Australian pelican	5
	Black swan	215
	Black-tailed native-hen	5
	Black-winged (pied) stilt	30
	Brolga	20
	Egrets	10
	Eurasian coot	210
	Gloosy ibis	20
	Grey teal	328

Survey period	Species	Mean abundance
	Gull-billed tern	15
	Hardhead	519
	Maned duck	10
	Masked lapwing	20
	Musk duck	15
	Pacific black duck	175
	Pink-eared duck	140
	Purple swamphen	5
	Red-necked avocet	105
	Silver gull	10
	Small grebes	25
	Small waders	5
	Straw-necked ibis	30
	Whiskered tern	50
	Yellow-billed spoonbill	5
December 1989	Australian pelican	60
	Australian shelduck	7
	Australasian shoveler	89
	Black swan	706
	Black-tailed native-hen	92
	Black-winged (pied) stilt	66
	Caspian tern	12
	Darter	5
	Egrets	25
	Eurasian coot	260
	Freckled duck	75
	Glossy ibis	2
	Great cormorant	2
	Great egret	2
	Grey teal	2147
	Gull-billed tern	25
	Hardhead	497
	Maned duck	200
	Masked lapwing	12
	Musk duck	5
	Pacific black duck	675
	Pacific heron	2
	Pink-eared duck	2504
	Red-necked avocet	112
	Royal spoonbill	2
	Australian white ibis	5
	Silver gull	61

Survey period	Species	Mean abundance
	Small waders	75
	Whiskered tern	108
	Yellow-billed spoonbill	55
March 1990	Australian pelican	82
	Australian shelduck	22
	Australasian shoveler	807
	Black swan	1198
	Black-tailed native-hen	314
	Black-winged (pied) stilt	51
	Brolga	6
	Caspian tern	138
	Egrets	100
	Eurasian coot	1752
	Freckled duck	439
	Grey teal	17,313
	Hardhead	36
	Maned duck	639
	Masked lapwing	64
	Musk duck	4
	Pacific black duck	454
	Pied cormorant	2
	Pink-eared duck	9816
	Red-necked avocet	20
	Royal spoonbill	8
	Australian white ibis	12
	Silver gull	62
	Small grebes	20
	Small waders	173
	Straw-necked ibis	2
	White-faced heron	6
	Yellow-billed spoonbill	86
June 1990	Australian pelican	5
	Australasian shoveler	7
	Black swan	20
	Black-winged (pied) stilt	10
	Caspian tern	2
	Eurasian coot	60
	Freckled duck	2
	Great cormorant	20
	Great egret	2
	Grey teal	133
	Hardhead	27

Survey period	Species	Mean abundance
	Maned duck	20
	Masked lapwing	12
	Musk duck	2
	Pacific black duck	40
	Pacific heron	10
	Pied cormorant	5
	Pink-eared duck	75
	Silver gull	103
	Small waders	15
	Straw-necked ibis	45
	White-faced heron	47
September 1990	Australian pelican	40
	Black swan	86
	Black-tailed native-hen	36
	Eurasian coot	18
	Grey teal	94
	Hardhead	6
	Maned duck	4
	Masked lapwing	2
	Musk duck	2
	Pacific black duck	6
	Pink-eared duck	24
	Australian white ibis	2
	Silver gull	10
	Yellow-billed spoonbill	10
December 1990	Australian pelican	80
	Australasian shoveler	32
	Banded lapwing	28
	Black swan	425
	Black-tailed native-hen	853
	Brolga	4
	Caspian tern	46
	Darter	6
	Egrets	20
	Eurasian coot	85
	Freckled duck	64
	Great cormorant	20
	Great egret	10
	Grey teal	473
	Gull-billed tern	16
	Hardhead	89
	Maned duck	74

Survey period	Species	Mean abundance
	Masked lapwing	38
	Pacific black duck	73
	Pacific heron	2
	Pied cormorant	12
	Pink-eared duck	122
	Red-necked avocet	67
	Royal spoonbill	48
	Australian white ibis	20
	Silver gull	48
	Straw-necked ibis	44
	Whiskered tern	40
	White-faced heron	8
	Yellow-billed spoonbill	40
March 1993	Australian pelican	10
	Australian shelduck	9
	Australasian shoveler	742
	Black swan	212
	Black-tailed native-hen	4
	Brolga	2
	Caspian tern	24
	Darter	2
	Eurasian coot	542
	Freckled duck	1373
	Grey teal	7359
	Hardhead	2022
	Maned duck	1136
	Masked lapwing	16
	Pacific black duck	47
	Pink-eared duck	21,390
	Red-necked avocet	260
	Silver gull	458
	Small grebes	22
	Small waders	160
	Straw-necked ibis	1
	Whiskered tern	40
	Yellow-billed spoonbill	50

Source: Kingsford et al. (1994)

Numbers are calculated from four counts recorded every three months on Peery Lake between 1987 and 1990.

Appendix 5: Mean numbers of waterbird species on Poloko Lake 1987–90

Survey period	Species	Mean abundance*
June 1987	Australasian shoveler	4
	Grey teal	3372
	Hardhead	4
	Maned duck	28
	Pacific black duck	16
	Pink-eared duck	1372
	Red-necked avocet	34
September 1987	Black swan	52
	Black-winged (pied) stilt	20
	Freckled duck	34
	Grey teal	232
	Pink-eared duck	269
	Red-necked avocet	40
	Small waders	100
December 1987	Black swan	10
	Black-winged (pied) stilt	60
	Grey teal	50
	Pink-eared duck	100
	Red-necked avocet	6
	Whiskered tern	32
June 1988	Australasian shoveler	21
	Black swan	9
	Caspian tern	2
	Hardhead	14
	Red-necked avocet	23
	Silver gull	59
September 1988	Australasian shoveler	4
	Black swan	20
	Black-winged (pied) stilt	20
	Grey teal	14
	Pink-eared duck	403
	Red-necked avocet	373
	Silver gull	30
	Yellow-billed spoonbill	4
March 1989	Grey teal	210
	Hardhead	20
	Pink-eared duck	1070
	Red-necked avocet	375

Survey period	Species	Mean abundance*
	Small waders	100
June 1989	Black swan	28
	Grey teal	40
	Pacific black duck	24
	Pink-eared duck	20
	Red-necked avocet	30
	Silver gull	15
	Whiskered tern	5
September 1989	Australasian shoveler	73
	Black swan	46
	Black-winged (pied) stilt	103
	Caspian tern	33
	Freckled duck	166
	Grey teal	941
	Hardhead	359
	Maned duck	385
	Masked lapwing	9
	Musk duck	6
	Pacific black duck	119
	Pied cormorant	3
	Pink-eared duck	511
	Red-necked avocet	478
	Silver gull	56
	Small grebes	6
	Small waders	6
	Straw-necked ibis	19
	Whiskered tern	6
	White-faced heron	9
December 1989	Australasian shoveler	10
	Black swan	14
	Black-tailed native-hen	22
	Black-winged (pied) stilt	82
	Caspian tern	2
	Eurasian coot	64
	Freckled duck	44
	Great crested grebe	2
	Great egret	2
	Grey teal	206
	Hardhead	243
	Maned duck	12
	Musk duck	10
	Pacific black duck	108

Survey period	Species	Mean abundance*
	Pacific heron	2
	Pink-eared duck	139
	Purple swamphen	2
	Red-necked avocet	407
	Silver gull	82
	Small grebes	2
	Small waders	50
	Whiskered tern	4
	White-faced heron	16
	Yellow-billed spoonbill	26
March 1990	Australian shelduck	4
	Australasian shoveler	506
	Black swan	46
	Black-winged (pied) stilt	20
	Caspian tern	4
	Egrets	60
	Eurasian coot	4
	Freckled duck	200
	Grey teal	5127
	Hardhead	64
	Maned duck	390
	Pacific black duck	101
	Pacific heron	6
	Pink-eared duck	6495
	Purple swamphen	8
	Red-necked avocet	642
	Australian white ibis	20
	Silver gull	100
	Small grebes	112
	Small waders	150
	White-faced heron	6
	Yellow-billed spoonbill	269
June 1990	Australian pelican	5
	Australasian shoveler	5
	Black swan	51
	Grey teal	82
	Pacific black duck	28
	Silver gull	5
	Whiskered tern	2
	White-faced heron	10
September 1990	Australian pelican	25
	Australasian shoveler	2

Survey period	Species	Mean abundance*
	Black swan	32
	Black-tailed native-hen	60
	Black-winged (pied) stilt	2
	Eurasian coot	5
	Great egret	2
	Grey teal	55
	Hardhead	5
	Maned duck	15
	Masked lapwing	5
	Pacific black duck	12
	Pacific heron	12
	Pied cormorant	2
	Pink-eared duck	100
	Red-necked avocet	22
	Silver gull	10
	Straw-necked ibis	25
	Yellow-billed spoonbill	7
December 1990	Australian pelican	66
	Australasian shoveler	149
	Banded lapwing	371
	Banded stilt	2
	Black swan	1713
	Black-tailed native-hen	5188
	Black-winged (pied) stilt	46
	Caspian tern	136
	Eurasian coot	60
	Freckled duck	295
	Great egret	13
	Grey teal	7631
	Gull-billed tern	3
	Hardhead	481
	Maned duck	191
	Masked lapwing	123
	Pacific black duck	1329
	Pied cormorant	3
	Pink-eared duck	6526
	Purple swamphen	3
	Red-necked avocet	3722
	Royal spoonbill	2
	Australian white ibis	6
	Silver gull	123
	Small waders	450

Survey period	Species	Mean abundance*
	Straw-necked ibis	3
	White-faced heron	6
	Yellow-billed spoonbill	63
March 1993	Australian pelican	22
	Australasian shoveler	2
	Black swan	114
	Black-tailed native-hen	358
	Caspian tern	1
	Egrets	4
	Eurasian coot	9
	Freckled duck	22
	Grey teal	173
	Hardhead	3
	Maned duck	129
	Masked lapwing	8
	Musk duck	1
	Pacific black duck	40
	Pink-eared duck	5057
	Red-necked avocet	101
	Royal spoonbill	49
	Australian white ibis	2
	Small waders	31
	Yellow-billed spoonbill	80

Source: Kingsford et al. 1994

* Numbers are calculated from four counts recorded every three months on Poloko Lake between 1987 and 1990.

References

Anderson, J.M.E. (1989) Honeybees in natural ecosystems, in *Mediterranean landscapes in Australia: Mallee ecosystems and their management*, J.C. Noble and R.A. Bradstock (eds), CSIRO, Melbourne

Bailey, P.C.E., Boon, P.I., Blinn, D.W. and Williams, W.D. (2006). Salinisation as an ecological perturbation to rivers, streams, and wetlands of arid and semi-arid regions, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.) pp. 280–314, Cambridge University Press, Cambridge UK

BoM (2006). Australian Daily Rainfall. Bureau of Meteorology, Commonwealth of Australia.

BoM (2007). Bureau of Meteorology, Commonwealth of Australia, www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/variability.cgi

Boulton, A.J. (1999). Why variable flows are needed for invertebrates of semi-arid rivers, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 113–128, NSW National Parks and Wildlife Service, Sydney

Boulton, A.J., Sheldon, F. and Jenkins, K.M. (2006). Natural disturbance and aquatic invertebrates in desert rivers, in: *Ecology of desert rivers*, R.T. Kingsford (ed.) pp. 133–153, Cambridge University Press

Bowen, P.F. and Pressey, R.L. (1993). *Localities and habitats of plants with restricted distributions in the Western Division of NSW*, Occasional Paper No. 17, NSW National Parks and Wildlife Service, Hurstville

Briggs, S.V. (1992). Wetlands as drylands: a conservation perspective. *Bulletin of the Ecological Society of Australia*, 22: 109–110

Briggs, S.V., Hodgson, P.F. and Ewon, P. (1994). Changes in populations of waterbirds on a wetland following water storage. *Wetlands (Australia)*, 13: 36–48

Briggs, S.V., Thornton, S.A. and Lawler, W.G. (1997). Relationships between hydrological control of river red gum wetlands and waterbird breeding, *Emu*, 97: 31–42

Brock, M.A. (1999). Are aquatic plant seed banks resilient to water regime alteration? Implications for the Paroo River system, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 129–137. NSW National Parks and Wildlife Service, Sydney

Brock, M.A., Capon, S.J. and Porter, J.L. (2006). Disturbance of plant communities dependent on desert rivers, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 100–132, Cambridge University Press

Brooker, M.I.H. and Kleinig, D.A. (1990). *Field guide to the Eucalypts*, Vol. 2, Inkata Press, Melbourne

Bunn, S.E., Balcombe, S.R., Davies, P.M., Fellows, C.S. and McKenzie-Smith, F.J. (2006). Aquatic productivity and food webs of desert river ecosystems, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 76–99, Cambridge University Press

Butz Huryn, V.M. 1997, 'Ecological impacts of introduced honey bees', *Quarterly Review of Biology*, 72: 275–297

Casanova, M.T. (1999). Plant establishment in Paroo wetlands: The importance of water regime, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.) pp. 138–148. NSW National Parks and Wildlife Service, Sydney

Cottingham, P. (1999). *Scientific forum on river condition and flow management of the Moonie, Warrego, Paroo, Bulloo and Nebine River Basins*. Queensland Department of Natural Resources, Brisbane

CSIRO (2007). *Water availability in the Paroo. A report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project.* CSIRO, Australia.

Cunningham, G.M., Mulham, W.E., Milthorpe, P.L. and Leigh, J.H. (1992). *Plants of western New South Wales*, Inkata Press, Sydney

DEC (2005). *Salt pipewort: Priority actions*, www.threatenedspecies.environment.nsw.gov.au/tsprofile/pas_profile.aspx?id=10277

DECC (2008). *Ecological character description of the Lake Pinaroo Ramsar site*, Department of Environment and Climate Change, Sydney
DEWHA (2008). National framework and guidance for describing the ecological character of Australia's Ramsar wetlands. Department of Environment Heritage, Water and the Arts, Canberra
DFAT (2006). *Agreement between the Government of Australia and the Government of the Republic of Korea on the protection of migratory birds*. Department of Foreign Affairs and Trade, Canberra.
DSE (2005). *Framework for describing the ecological character of Ramsar wetlands*, Department of Sustainability and Environment (Victoria), Melbourne
Dickman, C.R., Pressey, R.L., Lim, L. and Parnaby H.E. (1993). Mammals of particular conservation concern in the Western Division of NSW, *Biological Conservation* 65: 219–248
Fisher, C.D., Lindgren, E. and Dawson, W.R. (1972). Drinking patterns and behavior of Australian desert birds in relation to their ecology and abundance, *Condor* 74(2): 111–136
Gehrke, P.C., Schiller, C.B. and Brown, P. (1999). Native fish and river flows: the Paroo perspective, in *A free flowing river: the ecology of the Paroo River,* R.T. Kingsford (ed.) pp. 210–222, NSW National Parks and Wildlife Service, Sydney
Goodall, H. (1999). Living with the river: Social research and river change in rangelands, in *A free flowing river: the ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 179–200, NSW National Parks and Wildlife Service, Sydney
Goodrick, G.N. (1984). *Wetlands of north-western New South Wales*, Occasional paper No. 6, National Parks and Wildlife Service, Sydney
Goss, K. and Mclellan, J. (2004). The way ahead for the Darling, in *The Darling*, R. Breckwoldt, R. Boden and J. Andrew (eds), pp. 436–443, Murray-Darling Basin Commission, Canberra
Harris, J.H. and Gehrke, P.C. (eds) (1997). *Fish and rivers in stress. The NSW Rivers Survey*, NSW Fisheries and the Cooperative Research Centre for Freshwater Ecology
Keenan, C., Watts, R. and Serafini, L. (1996). Population genetics of golden perch, silver perch and catfish within the Murray–Darling Basin, in *Proceedings for the 1995 Riverine Environment Forum, October 1995*, R.J. Banens and R. Lehane (eds), pp.17–26, Murray-Darling Basin Commission, Attwood
Keenan, C., Watts, R. and Serafini, L. (1998). *Population genetics of golden perch (*Macquaria ambigua*), silver perch* (Bidyanus bidyanus*) and eel-tailed catfish* (Tandanus tandanus*) within the Murray–Darling Basin*, Final report on NRMS Project M262 to the Murray-Darling Basin Commission, Southern Fisheries Centre, Department of Primary Industries, Brisbane
Kingsford, R.T. (1998). Management of wetlands for waterbirds, in *Wetlands in a dry land: Understanding for management*, W.D. Williams (ed.), pp. 111–121, Environment Australia, Department of the Environment, Canberra
Kingsford, R.T. (1999a). Aerial survey of waterbirds on wetlands as a measure of river and floodplain health, *Freshwater Biology* 41: 425–438
Kingsford, R.T. (1999b). What future for our free-flowing rivers and their wetlands – the Paroo River? An introduction, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 7–12, NSW National Parks and Wildlife Service, Sydney
Kingsford, R.T. (1999c). The potential impact of water extraction on the Paroo and Warrego Rivers, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 257–274, NSW National Parks and Wildlife Service, Sydney
Kingsford, R.T. (2000). Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia, *Austral Ecology* 25: 109–127
Kingsford, R.T. and Porter, J. (1994). Waterbirds on an adjacent freshwater lake and salt lake in arid Australia, *Biological Conservation*, 69: 219–228

Kingsford, R.T. and Johnson, W. (1999). The impact of water diversions on colonially nesting waterbirds in the Macquarie Marshes in arid Australia, *Colonial Waterbirds*, 21: 159–170
Kingsford, R.T. and Porter, J. (1999). Wetlands and waterbirds of the Paroo and Warrego Rivers, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 23–50, NSW National Parks and Wildlife Service, Sydney
Kingsford, R.T. and Thomas, R.F. (1995). The Macquarie Marshes in arid Australia and their waterbirds – a 50-year history of decline. *Environmental Management* 19: 867–878
Kingsford, R.T. and Norman, F.I. (2002). Australian waterbirds – products of the continent's ecology, *Emu* 102: 47–69
Kingsford, R.T. and Thomas, R.F. (2004). Destruction of wetlands and waterbird populations by dams and irrigation on the Murrumbidgee River in arid Australia, *Environmental Management* 34: 383–396
Kingsford, R.T. and Thompson, J.R. (2006). Desert or dryland rivers of the world: an introduction, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 3–10, Cambridge University Press
Kingsford, R.T., Bedward, M. and Porter, J.L. (1994). *Wetlands and waterbirds in northwestern New South Wales*, Occasional paper No. 19. National Parks and Wildlife Service, Sydney
Kingsford, R.T., Brandis, K. and Thomas, R. (2002). Progress Report Year 2 (Final Report) Paroo and Warrego Rivers Environmental Flows Project, NSW National Parks and Wildlife Service
Kingsford, R.T., Thomas, R.F. and Wong, P.S. (1997). *Significant wetlands for waterbirds in the Murray–Darling Basin*, Murray-Darling Basin Commission, Canberra
Kingsford, R.T., Thomas, R.F. and Curtin, A.L. (2001). Conservation of wetlands in the Paroo and Warrego River catchments in arid Australia, *Pacific Conservation Biology*, 7: 21–33
Kingsford, R.T., Brandis, K., Thomas, R.F., Crighton, P., Knowles, E. and Gale, E. (2004). Classifying landform at broad spatial scales: the distribution and conservation of wetlands in New South Wales, *Australia Marine and Freshwater Research* 55: 1–15
Kingsford, R.T., Jenkins, K.M. and Porter, J.L. (2004). Imposed hydrological stability on lakes in arid Australia and effects on waterbirds, *Ecology* 85: 2478–2492
Kingsford, R.T., Georges, A. and Unmack, P.J. (2006). Vertebrates of desert rivers: meeting the challenges of temporal and spatial unpredictability, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 154–202, Cambridge University Press
Kingsford, R.T., Lemly, A.D. and Thompson, J.R. (2006). Impacts of dams, river management and diversion on desert rivers, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 203–247, Cambridge University Press
Lambert, J. and Elix. J. (2006). Workshop Report: Ecological Character Description of Ramsar Wetlands. Prepared for the Commonwealth Department of the Environment and Heritage. Community Solutions: Fairlight, NSW
Lawler, W. and Briggs, S.V. (1991). Breeding of maned duck and other waterbirds on ephemeral wetlands in north-western NSW, *Corrella* 15: 65–76
Leigh, J., Briggs, J. and Hartley, W. (1981). *Rare or Threatened Australian Plants*. Australian National Parks and Wildlife Service, Special Publication 7
Leslie, D.J. (2001). Effect of river management on colonially-nesting waterbirds in the Barmeh–Millewa Forest, south-eastern Australia, *Regulated Rivers: Research and Management* 17: 21–36
Lourandos, H. (1997). *Continent of hunter-gatherers: A new perspective in Australian prehistory*, Cambridge University Press, Cambridge
Maher, M.T. (1991). *An Inland Perspective on the Conservation of Australian Waterbirds*, PhD thesis, University of New England, Armidale
Maher, M.T. and Braithwaite, L.W. (1992). Patterns of waterbird use in wetlands of the Paroo: A river system of inland Australia, *Rangelands Journal* 14: 128–142

McComb, A. and Qiu, S. (1998). The effects of drying and reflooding on nutrient release from wetland sediments, in *Wetlands in a dry land: Understanding for management*, W.D. Williams (ed.), pp. 147–162, Environment Australia, Department of the Environment, Canberra
McGrath, C. (2006). *Legal review of the framework for describing the ecological character of Ramsar wetlands to support implementation of the EPBC Act*, Report to the Department of the Environment and Heritage, unpublished
McMahon, T.A., Murphy, R., Little, P., Costelloe, J.F., Peel, M.C., Chiew, F.H.S., Hayes, S., Nathan, R. and Kandel, D.D. (2005). *Hydrology of Lake Eyre Basin, Project Report*, Sinclair Knight Merz, Armadale Victoria
Millennium Ecosystem Assessment (2003). *Ecosystems and Human Well-being: a Framework for Assessment. Millennium Ecosystem Assessment Series*, Island Press, Washington D.C.
Mitsch, W.J. and Gosselink, J.G. (2000) *Wetlands*, Van Nostrand Reinhold Co., New York
Morton, S.R., Short, J. and Barker, R.D. (1995). Refugia for Biological Diversity in arid and Semi-arid Australia, *Biodiversity Series No.4.* Department of Environment and Heritage, Canberra
Nicholls, N. (2004). The changing nature of Australian droughts, *Climate Change* 63: 323–336
NPWS (2000). *Nocoleche Nature Reserve Plan of Management*, NSW National Parks and Wildlife Service, Sydney
NPWS (2002). *Threatened Species Conservation Amendment Act 2002.* NSW National Parks and Wildlife Service, Hurstville
NPWS (2003). *Far West Region Pest Management Strategy 2003–2006*, NSW National Parks and Wildlife Service, Hurstville
NPWS (2009). *Paroo–Darling National Park and State Recreation Area: Draft Plan of Management*. NSW National Parks and Wildlife Service, Sydney
Paton, D.C. (1996). *Overview of feral and managed honeybees in Australia: distribution, abundance, extent of interactions with native biota, evidence of impacts and future research*, ANCA, Canberra
Pellow, B.J. and Porter, J.L. (2005). A new species of goodenia (Goodeniaceae) from Nocoleche Nature Reserve, far western plains, New South Wales, *Telopea* 11: 35–41
Pickard, J. (1992). *Artesian springs in the Western Division of NSW*, Macquarie University, Sydney
Pickard, J. (1996). *Conservation recovery plan:* Eriocaulon carsonii, NSW National Parks and Wildlife, Sydney
Ponder, W.F. (1986). Mound springs of the Great Artesian Basin, in *Limnology in Australia*, P. de Deckker and W.D. Williams (eds). pp. 403–420, CSIRO, Melbourne, and W. Junk, The Hague
Ponder, W.F. (1999) Box 4.5, Mound Springs, in *Australian Freshwater Ecology: Processes and management*, A.J. Boulton and M.A. Brock (eds), pp. 50, Glen Eagles Publishing, Adelaide
Puckridge, J.T. (1999). The role of hydrology in the biology of dryland rivers, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 97–112, NSW National Parks and Wildlife Service, Sydney
Puckridge, J.T., Sheldon, F., Walker, K.F. and Boulton, A.J. (1998). Flow variability and the ecology of arid zone rivers, *Marine and Freshwater Research* 49: 55–72
QMDC and SWNRM (2004). Regional Natural Resource Management Plan. Queensland Murray–Darling Committee and South West Natural Resource Management Group, Toowoomba
Queensland Parks and Wildlife Service (1999). *Currawinya National Park Management Plan*, Queensland Parks and Wildlife Service
Ramsar Convention Secretariat (2007). *Managing wetlands: Frameworks for managing Wetlands of International Importance and other wetland sites.* Ramsar handbooks for

the wise use of wetlands, 3rd edition, vol. 16. Ramsar Convention Secretariat, Gland, Switzerland
RIS (2007). *Draft Ramsar Information Sheet for the Paroo River Wetlands*, Department of Environment and Conservation NSW, Sydney
Roberts, R. and Marston, F. (2000). *Water regime of wetland and floodplain plants in the Murray–Darling Basin: A source book of ecological knowledge*, CSIRO Land and Water Technical Report 30-00, October 2000, CSIRO Land and Water, Canberra
Robins, R. (1999). Clocks for rocks: An archaeological perspective on the Currawinya lakes, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 150–178, NSW National Parks and Wildlife Service, Sydney
Roshier, D.A., Robertson, A.I. and Kingsford, R.T. (2002). Responses of waterbirds to flooding in an arid region of Australia and implications for conservation, *Biological Conservation* 106: 399–411
Sadlier, R.A., Pressey, R.L. and Whish, G.L. (1996). Reptiles and amphibians of particular conservation concern in the Western Divison of New South Wales: Distributions, habitats, and conservation status, *Biological Conservation* 69: 41–54
Smith, P.J., Smith, J.E., Pressey, R.L. and Whish, G.L. (1995). Birds of particular conservation concern in the Western Division of New South Wales: Distributions, habitats and threats, *Biological Conservation*, 69: 315–338
Sorrell, B. (2006). *A review of the practical application of the framework for describing the ecological character of Ramsar sites in Australia.* Prepared for the Department of Environment and Heritage. National Institute of Water and Atmospheric Research Ltd: Christchurch, New Zealand.
Thoms, M.C., Beyer, P.J. and Rogers, K.H. (2006). Variability, complexity and diversity: the geomorphology of river ecosystems in dryland regions, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 47–75, Cambridge University Press
Timms, B.V. (1998). Spatial and temporal variation in inundation of wetlands in the Paroo catchment of the Murray–Darling, in *Wetlands in a dry land: Understanding for management*, W.D. Williams (ed.), pp. 123–129, Environment Australia, Department of the Environment, Canberra
Timms, B.V. (1999). Local runoff, Paroo floods and water extraction impacts on wetlands of Currawinya National Park, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 51–66, NSW National Parks and Wildlife Service, Sydney
Timms, B.V. and Boulton, A.J. (2001). Typology of arid-zone floodplain wetlands of the Paroo River (inland Australia) and the influence of water regime, turbidity, and salinity on their aquatic invertebrate assemblages, *Archiv Für Hydrobiologie*, 153: 1–27
Walker, K.F. (2006). Serial weirs, cumulative effects: the Lower River Murray, Australia, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 203–247, Cambridge University Press
Water Information System for the Environment (2003). Paroo–Warrego Catchment, National Parks and Wildlife Service, Sydney
Water Resource (Warrego, Paroo, Bulloo and Nebine) Plan (2003). Office of the Queensland Parliamentary Counsel
Watts, R.J. (1999). Biodiversity in the Paroo River and its wetlands, in: *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 13–22, NSW National Parks and Wildlife Service, Sydney
WCMA (2005). *Summary of the Draft Western Catchment Plan*, Western Catchment Management Authority, Cobar
Westbrooke, M., Leversha, J., Gibson, M., O'Keefe, M., Milne, R., Gowans, S., Harding, C., and Callister, K. (2003). Vegetation of Peery Lake area, Paroo–Darling National Park, western New South Wales, *Cunninghamia* 8: 111–128
Wharton, W. (2000). *Changing fortunes of the Paroo*, Australian Heritage Commission, Canberra

Young, W.J. (1999). Hydrologic description of semi-arid rivers: an ecological perspective, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 77–96, NSW National Parks and Wildlife Service, Sydney

Young, W.J. and Kingsford, R.T. (2006). Flow variability in large unregulated dryland rivers, in *Ecology of Desert Rivers*, R.T. Kingsford (ed.), pp. 11–46, Cambridge University Press

Young, W.J., Brandis, K. and Kingsford, R.T. (2006). Modelling monthly streamflows in two Australian dryland rivers: matching model complexity to spatial scale and data availability, *Journal of Hydrology* 331: 242–256