NSW GOVERNMENT
Office of Environment & Heritage

Macquarie Marshes Ramsar site

Ecological character description
Macquarie Marshes Nature Reserve and U-block components

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River red gum, northern Macquarie Marshes Nature Reserve (©OEH)
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Summary

This ecological character description (ECD) is for the Macquarie Marshes Nature Reserve and U-block components of the Macquarie Marshes Ramsar site. The ECD has been developed in accordance with the *National framework and guidance for describing the ecological character of Australia's Ramsar wetlands* (DEWHA 2008). A separate ECD for the Wilgara wetland was prepared in 2005 (Biosis Research 2006).

Under the Ramsar Convention, ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at 'a given point in time', which is usually taken to be the time the site was listed as a Wetland of International Importance. The Macquarie Marshes Nature Reserve and U-block were both part of the Ramsar site when it was listed in 1986, which is therefore the baseline for this ECD.

The Macquarie Marshes are located on the lower floodplain of the Macquarie River in central western NSW. The Macquarie Marshes Nature Reserve and U-block are about 100 km north of Warren and 30 km west of Quambone. When listed in 1986, the site was named the Macquarie Marshes Nature Reserve Ramsar site and comprised three separate areas: a northern section and a southern section currently referred to as the northern and southern nature reserve, with a total area of 18,192 hectares; and U-block, with an area of 197.5 ha (including a road reserve). U-block is now privately owned but the road reserve through U-block will be excluded from the Ramsar site in the updated Ramsar Information Sheet (RIS).

In 2000, part of the privately owned property 'Wilgara' comprising 583 ha was added, and the Ramsar site was renamed the Macquarie Marshes Ramsar site. In 2012 the property 'Creswell', which is a recent addition to the nature reserve, was added to the Ramsar site. Altogether the Ramsar site covers about 10 per cent of the greater Macquarie Marshes.

The Macquarie Marshes are one of the largest freshwater wetlands in the Murray–Darling Basin (MDB). The ecological system contains a variety of wetland types, ranging from semi-permanent and frequently inundated marshes to ephemeral wetlands inundated by only the largest floods. Core areas of semi-permanent wetlands occur within the nature reserve. They include river red gum forests and woodlands and common reed reed beds which are fed by overbank flooding from many small channels.

The Marshes are one of the MDB's most biologically diverse wetland systems and support some of the largest waterbird breeding events in Australia (Macquarie Marshes Investigation Committee 1951; Marchant & Higgins 1990; Kingsford & Auld 2005). They provide essential breeding and feeding habitat for hundreds of species of animals and plants. Of particular value is their role in absorbing, recycling and releasing nutrients. This provides conditions suitable for some of the highest densities of microinvertebrates reported in wetlands anywhere in the world (Jenkins & Wolfenden 2006). These microinvertebrates form the basis of the food web for many larger animals.

The Marshes not only support a diverse range of plants and animals but are also an iconic natural area with significant cultural values. Many people have significant links with the Marshes through historic connections, land and water management roles, living and/or working in the vicinity or they are involved with an environmental or a primary production group. Aboriginal cultural values relate to both the deep history of Aboriginal interaction with the wetlands, and the values, interests and aspirations of contemporary Aboriginal communities with custodial relationships to the wetlands. Aboriginal cultural values relate to specific places, specific plants and animals, and also the wetlands landscape as a whole.

Critical components, processes and benefits/services and their limits of acceptable change

The critical components, processes and benefits/services identified in this ECD reflect the values for which the site was Ramsar listed: expansive areas of semi-permanent wetland vegetation including river red gum forests and woodlands; common reed reed beds and water couch grasslands, which are dependent on frequent inundation events; large scale colonial waterbird breeding events; abundance and diversity of waterbird species; and threatened species such as the Australian painted snipe, Murray cod and superb parrot. In 2012 the Ramsar site was also recognised as meeting the Ramsar listing criterion for fish (criterion 8).

The critical components, processes, benefits and services for the nature reserve and U-block components of the Ramsar site and their requirements are summarised in Section 5 of this ECD. Information from studies carried out in the Marshes for the period between 1981 and 1991 has been used to describe the baseline condition for some of the critical components and processes including vegetation communities, waterbird breeding, geomorphology and hydrology. Limits of acceptable change (LACs) have been set in relation to extent and condition of semi-permanent wetland vegetation, floodplain wetland vegetation, the aquatic ecological community, waterbirds and waterbird breeding, and nationally threatened species. The LACs for the critical components, processes and benefits/services are described in Section 7 of this ECD.

Conceptual models

Conceptual diagrams of the relationships among critical components and processes in the Macquarie Marshes during wet and dry phases explain the dynamic nature of the Marshes and are presented in Section 6. The conceptual diagrams provide a representation of the current knowledge and understanding of the Macquarie Marshes. The soils, channel morphology and flooding are identified as the key ecosystem drivers. The vegetation communities present relate to the seasonality, regularity, depth and duration of inundation, and in turn these factors provide habitats for waterbirds and fish. Inundation causes the rapid release of nutrients from the soil, the decay of plant matter, and emergence of egg and seed banks, which results in a massive pulse of aquatic biofilm and invertebrate biomass which helps to support fish and waterbird breeding in the warmer seasons.

Change since time of listing

The Macquarie Marshes have existed in their current location and maintained their general wetland state for the last 6000 to 8000 years. Evidence of landscape change is available for both pre-European and post-European periods. Prior to European settlement the indigenous people of the Lower Macquarie used the Marshes. Grazing by domestic animals began in the 1830s with the establishment of cattle stations. Irrigated agriculture began in the 1840s in the South Marsh but it was not until the completion of Burrendong Dam in 1967 that large scale irrigation began. By the mid 1990s irrigated agriculture on the lower Macquarie floodplain had reached its peak both in terms of area and water use.

It is this land-use change that has led to major ecological changes. The wetlands of the Macquarie Marshes are competing for water with agricultural and urban/domestic needs. Using 1986 as the baseline condition, the nature reserve component of the Ramsar site has changed beyond acceptable limits. The most significant changes have been to the Marshes' flow regime and inundation patterns. This has led to changes in its semi-permanent wetland vegetation and the size and frequency of waterbird breeding events. In July 2009 a notification of likely change in ecological character of the Macquarie Marshes Ramsar site, principally as the result of changes to flow regime, was submitted to the Ramsar Secretariat under Article 3.2 of the Ramsar Convention.

Section 9 of this ECD establishes that actual change has taken place in the reed beds of the southern section of the nature reserve and in the river red gum forests and woodlands in the northern section of the nature reserve. The area of water couch, cumbungi and mixed marsh has also reduced to be outside the LAC set for the time of Ramsar listing, as a result of changes to the flow regime and drought conditions from 2001 to 2010.

Waterbird abundance and diversity had declined beyond the LAC by early 2010 and there had been no large scale colonial waterbird breeding events since 2000. There were two small breeding events in 2008 and 2010 and in spring–summer 2010/2011 there was a large breeding event in the Marshes, in response to a large flood event. This shows that if suitable habitat and appropriate floodplain inundation is available, large numbers of waterbirds (>20,000) and waterbird breeding events can still be supported by the Ramsar site.

It is noted that at the time of Ramsar listing in 1986, the Macquarie Marshes were already on a trajectory of change that has taken 20 years to emerge. Wetland decline in the MDB biogeographic region has been widespread. Despite this decline, in 2012 the nature reserve and U-block components of the Ramsar site still meet the Ramsar criteria for which the site was originally listed.

Threats

In 2012, the Ramsar site faces the same threats it did in 1986, though exacerbated by drought between 2001 and 2010. Those threats are changes to the flow regime resulting from river regulation and water extraction, loss of connectivity due to the alteration of channels and floodplains by structures that regulate flows, drought, fire, pests and weeds. Threats are further described in Section 8 of the ECD.

Knowledge gaps

There are a number of key knowledge gaps that limit the description of ecological character and the setting of limits of acceptable change for the nature reserve and U-block components of the Ramsar site. For example, there is little information about cryptic bird species such as the Australian painted snipe and whether the waterbirds using the Marshes also breed at other sites in the MDB. There is limited knowledge about the flow regime at the time of listing. There are species lists for woodland birds, but little is known of their abundance and habitat requirements. There is also inadequate knowledge about the habitat requirements of mammals, reptiles, fish and amphibians that live within the Macquarie Marshes, the interactions between species, the functional processes that support the Marshes, water quality, soil characteristics, natural versus human induced changes to geomorphology, and the interactions between fire and other ecosystem components and processes. Detailed analysis of knowledge gaps is provided in Section 11 of this ECD.

Monitoring

Monitoring recommendations for the critical ecological components and processes that combine to form the ecological character of the nature reserve, are provided in Section 11 of this ECD.

Recommended monitoring for the Macquarie Marshes Ramsar site includes: flow regime characteristics (depth, duration, timing); inundation extent; extent and condition of wetland vegetation communities; waterbird abundance and diversity; waterbird breeding events; diversity and density of macro and microinvertebrates that respond to inundation; native fish diversity, abundance and recruitment; and other vertebrate fauna diversity and abundance.

Communication, education, participation and awareness (CEPA)

Communication, education, participation and awareness activities can play an important role in wetland conservation, wise use and management. Actions that could be included in a CEPA plan for the Macquarie Marshes Ramsar site include:

- Advise relevant stakeholders of proposed studies, position papers, consultation and reviews to be undertaken to secure a greater understanding and ecological future for waterbird breeding sites. This includes any emerging information associated with the impacts of climate change.
- Advise government agencies and stakeholders of ecological and water requirements for wetland vegetation including river red gum forest and woodland, common reed reed beds, cumbungi and water couch marsh.
- Inform relevant landholders who are likely to be impacted by any proposed change to environmental water allocations to the Marshes.
- Consult Aboriginal people to ascertain their requirements to research, support, maintain and manage sites of significance and access to the nature reserve.
- Raise awareness of management actions that impact on the Macquarie Marshes Ramsar site through national media organisations.
- Develop and promote educational material in relation to wetlands, ecological communities, cultural heritage sites and current research findings to local, state and national media organisations, provided the information is ethically approved and in the interests of the preservation and conservation of specific sites, values and interests.

1 Introduction

This ecological character description (ECD) is for the Macquarie Marshes Nature Reserve and U-block components of the Macquarie Marshes Ramsar site. It collates the best available information about the ecological character of these parts of the Ramsar site when the site was listed in 1986, and changes in ecological character since that time. There is a separate ECD for the Wilgara wetland (Biosis Research 2006) with a baseline set at the year 2000.

This ECD has been prepared using the *National framework and guidance for describing the ecological character of Australia's Ramsar wetlands* (DEWHA 2008).

1.1 Site details

The Macquarie Marshes are located on the lower reaches of the Macquarie River in central western NSW (see Figures 1 and 2). In 1986, the Macquarie Marshes Nature Reserve Ramsar site comprised three separate areas of the wetland: a northern section (11,716 ha; includes Lots 8 and 10) and a southern section (6476.5 ha), collectively referred to as the northern and southern nature reserve and with a total area of 18,192 ha (gazetted area), and U-block with an area of 197.5 ha (gazetted area, including road reserve[1]). U-block is now privately owned (see Section 2.1.1). A portion of the privately owned property 'Wilgara' was added to the Ramsar site in 2000 and has an area of approximately 583 ha. In 2000, with the addition of 'Wilgara', the Ramsar site was renamed the Macquarie Marshes Ramsar site. Altogether the Ramsar area covers about 10 per cent of the greater Macquarie Marshes.

Figure 3 shows the different parts of the Ramsar site and their current tenure. Changes to the boundary occurred in 1995 with the addition of Lots 8 and 10 to the nature reserve. This change is minor with regard to the ecological character of the site and these have been included in the baseline description. 'Creswell' (688 ha gazetted area), which was gazetted by the NSW Government in 2006 as part of the nature reserve, was added to the Ramsar site in the 2012 RIS review.

The nature reserve contains a variety of wetlands, ranging from semi-permanent and frequently inundated marshes to ephemeral wetlands inundated by only the largest floods. Core areas of semi-permanent wetlands are made up of reed beds and eucalypt forests and woodlands which are fed by overbank flooding from many small channels. Core areas of semi-permanent wetland are critical for supporting waterbird and fish populations of the Macquarie Marshes at critical stages of their life cycles. U-block lies at the junction of the Old Macquarie River and Bulgeraga Creek. It also supports semi-permanent wetlands, river red gum and grassland and provides habitat for waterbirds and woodland birds. The Ramsar site is an integral part of the greater Macquarie Marshes and is dependent on the extent and condition of the greater area of the Marshes being maintained by regular floods. In this ECD, where appropriate to the Ramsar site values, information for areas beyond the Ramsar site boundary is included.

Table 1 provides concise details of the Ramsar site and further information about the compilation of this ecological character description.

[1] Note that the road reserve that runs through U-block has been excluded from this land parcel and is not included in the Ramsar site or described in this ecological character description, as it has no wetland values.

Table 1: Site details of the Macquarie Marshes Ramsar site

Site name	The Macquarie Marshes
Location	30º 45’ S 147º 33’ E
General location	The Macquarie Marshes are in central western New South Wales, southeastern Australia. The Ramsar site is comprised of the Macquarie Marshes Nature Reserve component, U-block and part of the property ‘Wilgara’. The Macquarie Marshes Nature Reserve and U-block are about 100 km north of the town of Warren and 30 km west of the town of Quambone.
Area	In 1986 the Macquarie Marshes Nature Reserve Ramsar site consisted of a northern area of approximately 11,537 ha (excludes Lots 8 and 10 and ‘Creswell’), a southern area of approximately 6476.5 ha, and U-block which had an area of approximately 197.5 ha (including the road reserve). The total area of this section of the Ramsar site was approximately18,211 ha (gazetted area). In 2012 the site was extended to 19,850 ha.
Ramsar site designation	1 August 1986
Ramsar criteria	The Macquarie Marshes Nature Reserve and U-block together met Ramsar criteria 1 to 5 in 1986. In 2012 the site still meets these Ramsar criteria and the newly defined criterion 8.
Management authority	Parks and Wildlife Group, Western Branch, Office of Environment and Heritage, NSW Department of Premier and Cabinet.
Status of description	This is the first description of the ecological character of the Macquarie Marshes Nature Reserve and U-block components of the Macquarie Marshes Ramsar site.
Date of compilation	June 2012
Names of compilers	Jo Smith, Environmental Planner, Canberra Richard T Kingsford, Silke Nebel and Kate Brandis School of Biological, Earth & Environmental Sciences University of New South Wales, Kensington NSW 2052 email: richard.kingsford@unsw.edu.au; silke.nebel@unsw.edu.au; kate.brandis@unsw.edu.au Kerrylee Rogers and Alison Curtin, Office of Environment and Heritage Bill Johnson, Murray–Darling Basin Authority Tim Ralph, Macquarie University
Ramsar Information Sheet	*The Macquarie Marshes Ramsar Information Sheet*, January 2000, NSW National Parks and Wildlife Service www.environment.gov.au/water/topics/wetlands/database/pubs/28-ris.pdf
Management plans	*Macquarie Marshes Nature Reserve Plan of Management* (1993) NSW National Parks and Wildlife Service *Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003*, NSW Government *Macquarie Marshes Adaptive Environmental Management Plan* (2010) NSW Department of Environment and Climate Change

1.2 Purpose of the ecological character description

The purpose of the ecological character description is twofold:

- to address obligations identified in the Convention on Wetlands of International Importance (Ramsar Convention) and the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- to provide management agencies with information about the ecological system in the Macquarie Marshes Nature Reserve and U-block component of the Ramsar site and the issues the system faces, to enable the development of mitigation strategies.

1.2.1 Addressing international treaty obligations and legal requirements

The Convention on Wetlands of International Importance, commonly known as the Ramsar Convention, was signed in Ramsar, Iran in 1971. The Ramsar Convention is an intergovernmental treaty with a mission for the conservation and wise use of all wetlands through local, regional and national action and international cooperation as a contribution towards achieving sustainable development throughout the world (Ramsar Convention 2002). By signing this treaty Australia has committed to designating at least one wetland that meets the criteria for inclusion in the List of Wetlands of International Importance. As of 2012 Australia has 64 wetlands listed as Ramsar sites.

The EPBC Act provides the legal basis to protect and manage internationally and nationally important flora, fauna, ecological communities, heritage places and Ramsar wetlands. Under the EPBC Act Australia is obliged to protect the ecological character of Ramsar wetlands and to manage those wetlands in accordance with Schedule 6 (Managing wetlands of international importance) of the Environment Protection and Biodiversity Conservation Regulations 2000 (Commonwealth), which states:

> *The primary purpose of management of a declared Ramsar wetland must be, in accordance with the Ramsar Convention:*
>
> *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) 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* (p.164, regulation 10.02).

Other key purposes for this ecological character description (mostly following McGrath 2006), are to:

1. meet Australia's obligations, by providing information as soon as 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
2. 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
3. assist the administration of the EPBC Act, in particular to:

a) determine whether an action has, will have or is likely to have a significant impact on the ecological character of a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act

b) assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on the ecological character of a declared Ramsar wetland

4. assist any person considering taking an action that may impact on the ecological character of a declared Ramsar wetland to decide whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval

5. inform members of the public who are interested in the Macquarie Marshes Nature Reserve and U-block components of the Ramsar Site and to consolidate current information in a publicly available document

6. assist the Australian and NSW Governments and community organisations in the development of management plans, policies and statutory documents for the Macquarie Marshes Nature Reserve and U-block components of the Ramsar site by providing a guide for the restoration of ecological components and processes and the restoration of resilience.

1.2.2 Providing information about the ecological system

The ecological character description should provide up to date information about the ecological system in the Macquarie Marshes Nature Reserve and U-block component of the Ramsar site. The Ramsar Convention (2008) defines ecological character as the combination of components, processes, benefits and services that characterise a wetland at a given point in time.

The ecological character description should review the issues, both ecological and social, that the Ramsar site faces both in the short and long term. The ecological character description should provide management with the information required to enable the development of an environmental management plan for the site but it should not itself be a management plan.

1.3 Relevant treaties, legislation and policies

In addition to being listed as a Ramsar wetland, the Macquarie Mashes Nature Reserve is listed by the National Trust of Australia (NSW) as a Landscape Conservation Area, on the Australian Heritage Commission’s Register of the National Estate and in the Directory of Important Wetlands in Australia (NPWS 1993). It is also subject to local, regional, state and national policies and legislation and international bilateral migratory bird agreements (listed below).

Table 2: Key statutory and policy instruments for delivering Ramsar obligations in NSW

Level of application	Statutory and policy instruments	Responsibility	Other supporting instruments
International	Ramsar Convention	The Conference of the Parties to the Convention Standing Committee of the Ramsar Convention and the Ramsar Secretariat	Convention on Biological Diversity; Japan–Australia Migratory Birds Agreement; China–Australia Migratory Birds Agreement; Republic of Korea–Australia Migratory Birds Agreement; Convention on the Conservation of Migratory Species of Wild Animals; The Partnership for the East Asian–Australasian Flyway
National (Council of Australian Governments)	National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia	All jurisdictions	
National (Australian Government)	*Environment Protection and Biodiversity Conservation Act 1999*	Australian Government, led by Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)	National Water Initiative including the Australian Government Water Fund; Caring for our Country program
	Water Act 2007	Australian Government, led by Murray–Darling Basin Authority, SEWPaC	
NSW	*NSW Wetlands Policy* (DECCW 2010b)	NSW Government, led by Office of Environment and Heritage (OEH)	*Water Management Act 2000*; *Water Act 1912*; State Water Management Outcomes Plan (2003); *Threatened Species Conservation Act 1995*; *Fisheries Management Act 1994*; *Environmental Planning and Assessment Act 1979*; Draft Floodplain Harvesting Policy; voluntary conservation agreements; wildlife refuges
	NSW Wetland Recovery Program (2005)	NSW Government, led by OEH	
	NSW Rivers Environmental Restoration Program including Riverbank (2007)		
	NSW Ramsar Plan 2006–09 (DEC 2006)		
Macquarie Marshes Ramsar site	Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003	NSW Government, led by Office of Water	*National Parks and Wildlife Act 1974*
	Regional Investment Strategy and Catchment Action Plan	Central West Catchment Management Authority	
	Macquarie Marshes Nature Reserve Management Plan (NPWS 1993)	NSW Government, led by OEH	

2 Macquarie Marshes Ramsar site

2.1 Location

The greater Macquarie Marshes cover an area of approximately 200,000 ha (NPWS 1993) of the floodplain of the lower Macquarie River in central western NSW. The Macquarie River is a large regulated river in the MDB, with a catchment of about 75,000 km^2 (Figure1). The river rises on the western side of the Great Dividing Range, southeast of Bathurst, and extends about 800 km northwest before joining the Barwon–Darling River. As the Macquarie flows onto the Darling Riverine Plain, downstream of Narromine, it develops distributary streams and forms extensive floodplain wetlands. These streams flow north and northwest to join the Bogan and Barwon–Darling Rivers. The main Macquarie River channel continues north, becoming discontinuous and forming the Macquarie Marshes about 30 km north of Warren. The Marshes extend for about 120 km northwards before the river reforms near Carinda and discharges to the Barwon River between Walgett and Brewarrina (Johnson 2005; Figure 2).

The Macquarie Marshes Nature Reserve and U-block are about 100 km north of Warren and 30 km west of Quambone. The boundary for the Macquarie Marshes Nature Reserve component of the Ramsar site is the nature reserve boundary as gazetted 22 January 1971 including additions (Lots 8 and 10) gazetted 17 February 1995 (179 ha) and added to the Ramsar site via an updated RIS in 1998. The gazetted area of the nature reserve in 1995 was 18,143 ha. The boundary of U-block is the cadastral boundary of Lot 47, DP72721 and has a surveyed area of 189 ha, excluding the road reserve (Figure 3).

2.1.1 Land tenure

In January 1971 the Macquarie Marshes Nature Reserve was dedicated under the *National Parks and Wildlife Act 1967* (NSW) covering the area of Crown Land which was originally reserved in 1900 for the preservation of game. In 1919 this area had been committed as a bird and animal sanctuary; in 1943 as a reserve for the preservation of native fauna, and in 1955, as a fauna protection district. At the time of this publication the nature reserve is owned and managed by the Office of Environment and Heritage (OEH) under the *National Parks and Wildlife Act 1974*. All other areas within the Macquarie Marshes (including U-block and the 'Wilgara' components of the Ramsar Site) are either privately owned or leased.

In 1989, under Part 4 of the *National Parks and Wildlife Act 1974*, U-block (197.5 ha including road reserve) was revoked from the Macquarie Marshes Nature Reserve by an Act of Parliament. U-block was exchanged for 179 ha of land adjacent to the northern nature reserve known as Hall's block, being Lot 10 in DP727217 and Lot 8 in DP751622. In February 1995, this land was dedicated as part of the Macquarie Marshes Nature Reserve.

In January 1998, when the Ramsar Information Sheet (RIS) was updated for the Macquarie Marshes Nature Reserve Ramsar site, the Ramsar boundary map was adjusted to show the new boundary of the nature reserve, removing U-block and adding Hall's block.

In 2012 it is acknowledged that U-block should still be part of the Macquarie Marshes Ramsar site, as designated in 1986 and the RIS has been updated in accordance with Resolution VIII.21 Clause 9A of the Ramsar Convention – *the site boundary has been drawn incorrectly and there has been a genuine error.* U-block is now private freehold land and is managed as a grazing property. The road reserve (Warren–Carinda road) that runs through U-block and was included in the original nature reserve Ramsar listing was not added back into the Ramsar site as it has no wetland values.

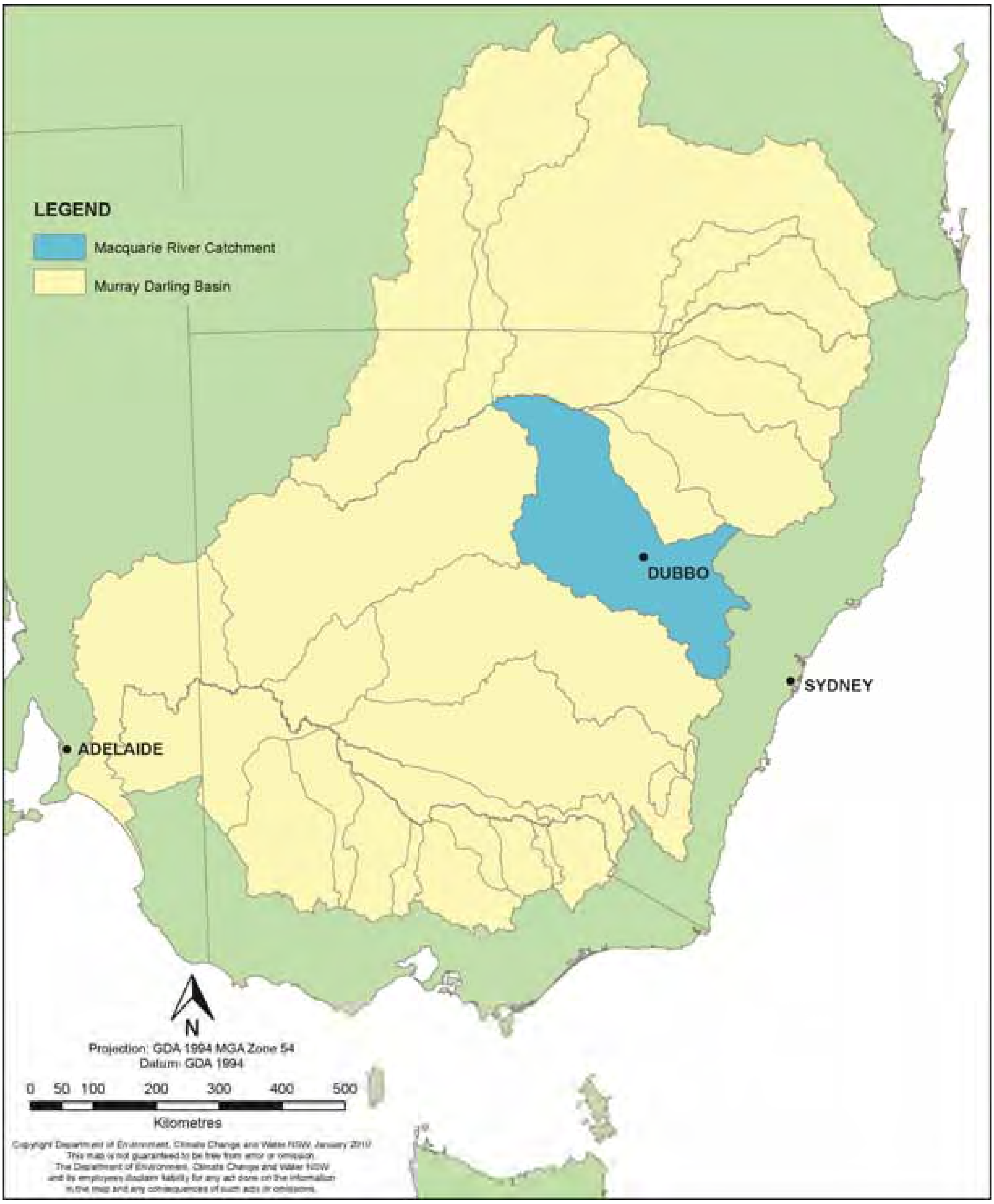


Figure 1: Location of the Macquarie River Catchment in the MDB

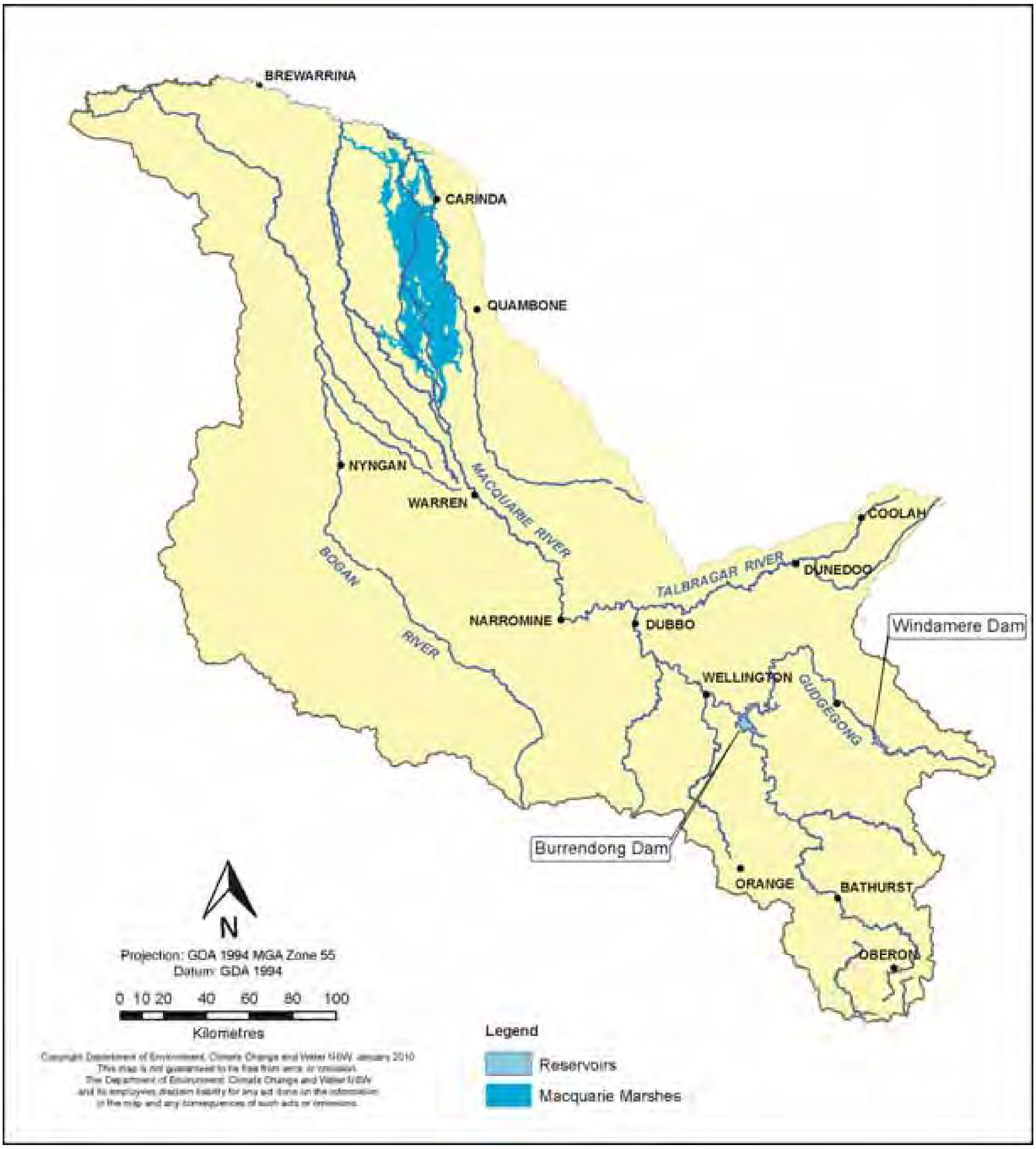


Figure 2: The Macquarie River catchment and the Macquarie Marshes

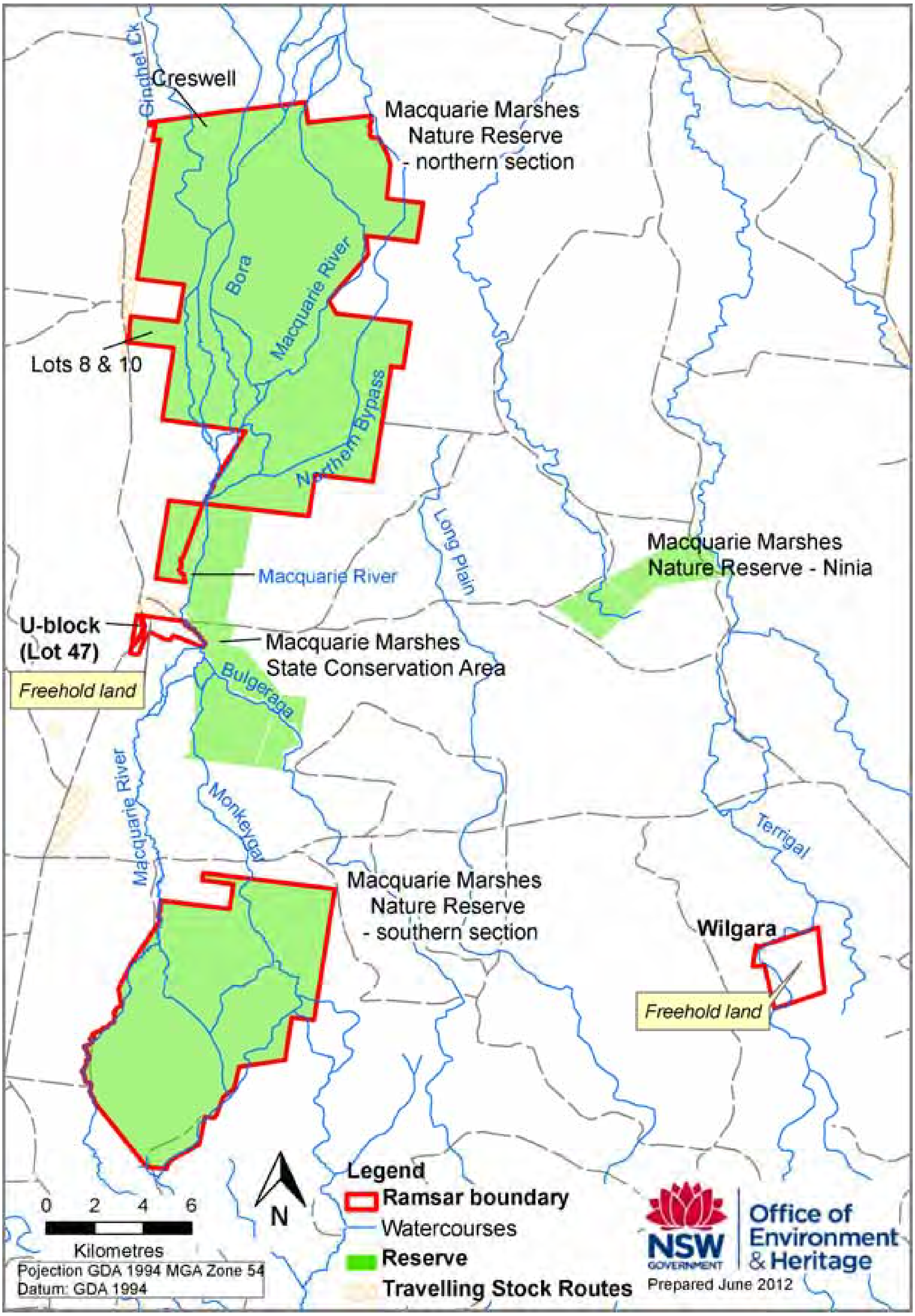


Figure 3: Macquarie Marshes Ramsar site showing the different parts of the Ramsar site – northern nature reserve, southern nature reserve, U-block component and 'Wilgara' component, and their respective tenures

2.1.2 History of land and water use in the Macquarie valley

Changes in land and water use and management in the Macquarie valley have greatly influenced the extent and health of the Macquarie Marshes. The Macquarie Marshes have existed in their current location and maintained their general wetland state for the last 6000 to 8000 years (Yonge & Hesse 2002). Prior to European settlement the indigenous people of the Lower Macquarie used the Marshes (Peckham & Molsher 2005). Grazing by domestic animals and the establishment of cattle stations began in the 1830s and this land use continues. Irrigated agriculture began not long after European settlement in the 1840s in the South Marsh however it was not until the completion of Burrendong Dam in 1967 that large scale irrigation began. By the mid 1990s irrigated agriculture on the lower Macquarie floodplain had reached its peak both in terms of area and water use (MRAC 1994).

Despite concerns about the impacts of Burrendong Dam on the environment of the Marshes, government and community support for irrigation resulted in the approval of construction of the dam in 1946. In 1951 the Macquarie Marshes Investigation Committee (MMIC) suggested that the Marshes should have a primary right to regulated flow from the dam and that water should be supplied to irrigation only after the needs of the Marshes had been met (Johnson 2005) and in 1962 it was announced that 40,000 acre feet (about 50,000 ML) would be set aside annually for the Marshes (National Trust 1985, cited in Johnson 2005).

In 1967, when the dam was about half full, a ‘special release’ was made from Burrendong Dam (WC&IC 1968), in response to Lower Macquarie landholders experiencing dry conditions. These conditions were exacerbated by the dam and irrigation had not yet been developed to a stage where the dam’s water could be used (WC&IC 1968; Sinclair Knight & Partners 1984). In the same year, the Water Conservation and Irrigation Commission (WCIC) also made a commitment to supply a reduced volume of approximately 15,000 acre feet (or 18,500 ML) to the Marshes if required (WC&IC 1968).

The development of irrigation schemes involved the clearing and levelling of land, construction of channel systems and installation of pumps. In many cases levees to protect crops from floodwaters were also constructed. Other interventions ranged from small dams erected by farmers and graziers to give their property a more permanent water supply, through to major interventions such as dam and weir construction by government (Masman & Johnstone 2000).

Six major ‘off-river’ irrigation schemes were established between 1966 and 1975 (Kingsford 2000). These were: Nevertire Scheme (1966), Buddah Lake Scheme (1969), Greenhide Scheme (1970), Narromine–Trangie Scheme (1971), Trangie–Nevertire Scheme (1973), and the Tenandra Scheme (1975).

Development guidelines produced by the Water Resources Commission (WRC) in the late 1970s and early 1980s identified the floodplain between Narromine and Warren as the best land in the valley for irrigation, with flooding and extensive wetlands deemed the only disadvantage (WRC undated a & b, as cited in Johnson 2005). Up until 1979, most irrigation in the Macquarie Valley was based on an individual entitlement to irrigate 162 hectares of land, although the volume of water that could be applied to the land was not specified (Sinclair Knight & Partners 1984). Entitlements to a set volume of water were introduced in 1979 (WRC 1979).The areas being developed for irrigation grew rapidly, more than doubling from the mid 1980s to the mid 1990s, resulting in large areas of the natural floodplain becoming isolated from the river. A floodplain management plan identifies numerous structures that would require modification to optimise the functionality of floodways between Narromine and Oxley Station, to protect property and to improve and maintain the diversity and well-being of riverine and floodplain ecosystems that depend on flood inundation (DECC 2008).

In the late 1960s the WC&IC announced plans to deliver water through the Macquarie Marshes to supply regulated flow for irrigation downstream near Carinda, to compensate for loss of natural flooding in the area (Brereton 1993; Johnson 2005). The allocation of regulated flows to service this irrigation development was subject to the construction of works to convey flows through the Macquarie Marshes 'efficiently' (Brereton 1993). The first stage of the Macquarie Marshes bypass works, including regulators and an 18 kilometre channel, was constructed through the North Marsh in 1973.

After the completion of Burrendong Dam the total annual regulated yield of the Macquarie River was assessed as 406,000 ML in a normal year (Sinclair Knight & Partners 1984). By 1978 the Macquarie River Advisory Committee (MRAC), a group consisting mostly of members of the irrigation industry established by the government to advise on river management, believed that water from the river was over-committed. It was MRAC policy that the issuing of all licences and authorities should be suspended (MRAC 1978).

In 1979 the WRC placed an embargo on applications for licences, and increased the estimated annual regulated yield of the river to 475,000 ML (Sinclair Knight & Partners 1984; WRC 1981). However, the embargo did not halt the growth in water allocations in the Macquarie system. By that time allocations for extraction had risen to 497,500 ML, an over-commitment of 22,500 ML (WRC 1981; Johnson 2005).

By the mid-1980s, prior to the Macquarie Marshes Nature Reserve being Ramsar listed, the river was over-committed by 137,000 ML/year. These estimates did not include access to unregulated river flows ('off allocation' or 'supplementary' flow). Allocations to existing licence holders were increased by about 130,000 ML in 1985 (WRC 1985), despite concerns and objections from other landholders, government agencies and conservation groups. This exacerbated the previously identified problem of over-allocation of water (MRAC 1978; WRC 1981; WRC 1985b, as cited in Johnson 2005).

Since 1985 allocations have continued to rise without an increase in the 475,000 ML of assessed regulated flow. In 2005 the allocation to extractive use in the Macquarie and Cudgegong rivers was 738,793 ML/year. With the addition of 160,000 ML allocated to the environment, the total surface water allocation from regulated and supplementary flow was 898,793 ML (NSW Government 2003), almost twice the river's revised estimated yield of 475,000 ML (Johnson 2005).

2.2 Ramsar criteria

2.2.1 Criteria under which the site was designated

When originally listed as the Macquarie Marshes Nature Reserve Ramsar site in 1986, the site was recognised as internationally important according to the pre-1999 Ramsar criteria 1a, 2b and 3. In 1998, when the RIS was updated, the site was regarded as also meeting criteria 1c, 1d, 2c, 3a and 3b. These criteria equate to the current 2005 Ramsar criteria 1, 2, 3, 4 and 5 (RIS 2000).

2.2.2 Assessment based on current information and Ramsar criteria

There have been changes to the way criteria are applied since the site was listed in 1986 and the RIS last updated in 2000, which influence the application of the Ramsar criteria, including:

- Refinements and revisions of the Ramsar criteria have been made and 7th, 8th and 9th criteria have been added.
- The one per cent population thresholds for birds have been revised (Li & Mundkur 2007; Bamford et al. 2008), which influences the application of criterion 6.

- The bioregionalisation for inland aquatic systems for the implementation of the Ramsar Convention in Australia has changed from IBRA to Australian Drainage Divisions. This affects the application of criteria 1 and 3.
- Threatened species listings have been updated, and there is a focus on nationally and internationally threatened species, which affects criterion 2.

In 2012, all the criteria met at listing are still considered to be met. Criterion 8 is also considered to be met and would likely also have been met at the time of listing had it been assessed. An explanation of how the then Macquarie Marshes Nature Reserve Ramsar site (including U-block) met each criterion at the time of listing (1986) is provided below. This is based on the 2000 RIS update and new information regarding the fish criterion.

Criterion 1: Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The greater Macquarie Marshes were in 1986 and remain one of the largest freshwater wetlands in the MDB. They are a representative example of an inland floodplain wetland of the MDB as they rely on water from a higher rainfall upper catchment and have extensive and changeable wetlands in their semi-arid lowland reaches. They are unique within the MDB in terms of their size and diversity of wetland types (Mussared 1997), and the extent of particular wetland communities. It is estimated that the MDB has over 30,000 wetlands, but the greater Macquarie Marshes is one of only four wetlands that cover an area of 200,000 ha or more (Crabb 1997).

The main wetland communities in the Ramsar site exist as a mosaic and include common reed reed beds, water couch marsh and mixed marsh, lignum shrublands, river red gum forests and woodlands, coolibah woodlands and open water lagoons. The river red gum forest and woodlands, common reed reed beds and water couch marsh are rare examples of these wetland types in the MDB. The extent of these communities is a key feature of the site. In the MDB, it is one of three sites of extensive river red gum (*Eucalyptus camaldulensis*) woodland, one of two sites supporting extensive common reed (*Phragmites australis*) reed beds, and one of two sites with extensive water couch (*Paspalum distichum*) marsh. These communities support significant wetland species diversity including colonial nesting waterbirds, migratory shorebirds, frogs, fish and reptiles (Mussared 1997). The Macquarie Marshes Nature Reserve component of the Ramsar site has supported some of the largest colonial nesting waterbird breeding events in Australian history (Macquarie Marshes Investigation Committee 1951; Marchant & Higgins 1990; Kingsford & Johnson 1998; Kingsford & Auld 2005).

Criterion 2: Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

According to the 2000 RIS, the Macquarie Marshes supported at least four species listed as endangered or vulnerable under the NSW *Threatened Species Conservation Act 1995* (TSC Act): Australasian bittern, brolga, magpie goose and aromatic peppercress. Current EPBC Act listings were not available and therefore were not considered at that time.

It is now known that the Macquarie Marshes Nature Reserve component of the Ramsar site supports at least 35 threatened species (Table 3). Of these species, four are internationally listed as endangered or vulnerable (IUCN Red List, IUCN 2011), five are nationally listed as endangered or vulnerable (EPBC Act) and 34 are listed in NSW as endangered or vulnerable (TSC Act, *Fisheries Management Act 1994*). The Macquarie Marshes Nature Reserve also supports two endangered ecological communities: Coolibah-black box woodland of the northern riverine plains in the Darling Riverine Plains and Brigalow Belt South bioregions (TSC Act) and the aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River (NSW *Fisheries Management Act 1994*).

Table 3: Threatened flora and fauna species in the Macquarie Marshes Nature Reserve (E = Endangered, V = Vulnerable, NT = Near-threatened, LC = Least concern)

Common name	Scientific name	IUCN Red List 2011	EPBC Act (Cth)	TSC Act (NSW)	FM Act 1994 (NSW)
Stripe-faced dunnart	*Sminthopsis macroura*	LC		V	
Squirrel glider	*Petaurus norfolcensis*	LC		V	
Yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	LC		V	
Eastern freetail bat	*Mormopterus norfolkensis*	LC		V	
Little pied bat	*Chalinolobus picatus*	LC		V	
Osprey	*Pandion haliaetus*	LC		V	
Square-tailed kite	*Lophoictinia isura*	LC		V	
Black-breasted buzzard	*Hamirostra melanosternon*	LC		V	
Australian bustard	*Ardeotis australis*	NT		E	
Australasian bittern	*Botaurus poiciloptilus*	E	E	V	
Black-necked stork	*Ephippiorhynchus asiaticus*	NT		E	
Magpie goose	*Anseranas semipalmata*	LC		V	
Freckled duck	*Stictonetta naevosa*	LC		V	
Cotton pygmy goose	*Nettapus coromandelianus*	LC		E	
Blue-billed duck	*Oxyura australis*	NT		V	
Brolga	*Grus rubicundus*	LC		V	
Bush stone-curlew	*Burhinus grallarius*	NT		E	
Australian painted snipe	*Rostratula australis*	LC	V	V	
Black-tailed godwit	*Limosa limosa*	NT		V	
Red-backed button-quail	*Turnix maculosa*	LC		V	
Major Mitchell’s cockatoo	*Cacatua leadbeateri*	LC		V	
Red-tailed black-cockatoo	*Calyptorhynchus banksii*	LC		V	
Glossy black-cockatoo	*Calyptorhynchus lathami*	LC		V	
Turquoise parrot	*Neophema pulchella*	LC		V	
Superb parrot	*Polytelis swainsonii*	V	V	V	
Barking owl	*Ninox connivens*	LC		V	
Hooded robin	*Melanodryas cucullata*	LC		V	
Grey-crowned babbler	*Pomatostomus temporalis*	LC		V	
Brown treecreeper	*Climacteris picumnus*	LC		V	
Painted honeyeater	*Grantiella picta*	NT		V	
Black-chinned honeyeater	*Melithreptus gularis gularis*	V		V	
Diamond firetail	*Stagonopleura guttata*	NT		V	
Silver perch	*Bidyanus bidyanus*	V			V
Murray cod	*Maccullochella peelii peelii*		V		
Aromatic peppercress	*Lepidium hyssopifolia*		E	E	

Criterion 3: Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Within the MDB the Macquarie Marshes Nature Reserve component of the Ramsar site supports one of only three extensive river red gum (*Eucalyptus camaldulensis*) woodlands (approx. 6000 ha), the other two being in the southern half of the MDB on the Murrumbidgee and Murray rivers. These woodlands in the Macquarie Marshes Nature Reserve provide nesting sites and habitat for both waterbirds and woodland birds.

The Macquarie Marshes is also one of only two sites in the MDB (the other being the Great Cumbung swamp) supporting extensive common reed (*Phragmites australis*) reed beds. In 1991 the Macquarie Marshes Nature Reserve supported approximately 3300 ha of common reed in two main reed beds, one in the northern and one in the southern section of the nature reserve (Wilson 1992).

The Macquarie Marshes is also one of only two sites in the MDB (the other being the Gwydir Wetlands) with extensive water couch (*Paspalum distichum*) marsh (approx. 4500 ha). There were 1128 ha of water couch in the Ramsar site's original extent (northern and southern nature reserve) when the Marshes' vegetation was mapped in 1991 (Bowen & Simpson 2010). Most of the remaining water couch occurs on private land outside the nature reserve. It is found within the 'Wilgara' wetland and U-block components of the Ramsar site (Bowen & Simpson 2010).

These wetland vegetation communities provide habitat for 77 waterbird species and 15 frog species, as well as many other birds, mammals and reptiles (Appendix 2).

Criterion 4: Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

The Ramsar wetlands represent highly significant habitat for colonial nesting waterbirds. They are one of the few sites supporting large breeding colonies of straw-necked ibis *(Threskiornis spinicollis)* in Australia and one of only a few sites in NSW where the magpie goose breeds (Kingsford & Thomas 1995). They also support some of the largest breeding colonies of intermediate egret *(Ardea intermedia),* rufous night heron *(Nycticorax caledonicus)* and royal spoonbill *(Platalea regia)* in southern Australia, as well as a rich diversity of other waterbirds including cormorants, herons, spoonbills and ducks, many of which breed there.

In a catchment that has been modified by agricultural activities, these remaining wetlands have become a regionally important refuge for wildlife. They represent an important drought refuge during periods when many other inland wetlands have dried out. The Ramsar site provides important habitat for 17 species of migratory birds covered under the Japan–Australia, China–Australia and South Korea–Australia Migratory Bird Agreements (JAMBA, CAMBA and ROKAMBA). These are the white-bellied sea-eagle (*Haliaeetus leucogaster*), cattle egret (*Ardea ibis*), great egret (*Ardea alba*), caspian tern (*Sterna caspia*), bar-tailed godwit (*Limosa lapponica*), black-tailed godwit (*Limosa limosa*), common greenshank (*Tringa nebularia*), common sandpiper (*Actitis hypoleucos*), curlew sandpiper (*Calidris ferruginea*), Latham's snipe (*Gallinago hardwickii*), marsh sandpiper (*Tringa stagnatilis*), red-necked stint (*Calidris ruficollis*), sharp-tailed sandpiper (*Calidris acuminata*), wood sandpiper (*Tringa glareola*), glossy ibis (*Plegadis falcinellus*), fork-tailed swift (*Apus pacificus*) and white-throated needletail (*Hirundapus caudacutus*).

Criterion 5: Regularly supports 20,000 or more waterbirds.

The justification against criterion 5 provided in the 2000 RIS was inadequate and data has been re-analysed to determine whether this criterion was met at the time of listing.

According to the Convention guidance on designating Ramsar sites, 'a wetland *regularly* supports a population of a given size if:

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

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

The guidance also says that, in establishing the long-term use of a site by birds, '…natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations [e.g. wetlands in arid and semi-arid areas] …the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site… In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.'

The 2000 RIS states that the wetlands of the Macquarie Marshes regularly supported more than 20,000 waterbirds and over 500,000 in large floods. While there are no records of the total numbers of waterbirds using the Macquarie Marshes Ramsar site over time, it is possible to estimate numbers using available information about the location of nesting sites and the habitat requirements of waterbirds, historical data on water inflows to the Marshes and a model of the relationship between inflows and waterbird breeding events.

Sixteen colonial nesting waterbird species have been recorded breeding in the greater Macquarie Marshes. Species in the greatest numbers are the great egret, intermediate egret, little egret, nankeen night heron, glossy ibis, Australian white ibis, straw-necked ibis, little pied cormorant and little black cormorant (Kingsford & Thomas 1995; Kingsford & Auld 2005). Of the 15 known breeding sites in the Macquarie Marshes, six are within the nature reserve and one in the 'Wilgara' part of the Ramsar site. It is therefore assumed that the Ramsar site supports about 50 per cent of colonial nesting waterbirds that breed in the Marshes.

Kingsford and Auld (2003) demonstrated that the nesting of large numbers of colonial waterbirds (specifically ibis, egret, cormorant and night herons) was correlated with flows of more than 200,000 ML at Oxley gauge, which is upstream of the Marshes. These wetland inflows result in inundation of sufficient nesting and feeding habitat for long enough to allow breeding to be completed successfully.

Up to the year 2000, it is probable that the Macquarie Marshes Ramsar site supported more than 20,000 waterbirds in at least two-thirds of the seasons when inflows were large enough to provide suitable breeding conditions. In this period there were seven years where flow volumes exceeded 200,000 ML at Oxley gauge (1988, 1989, 1990, 1993, 1996, 1998 and 2000). Nest counts for colonies within the Ramsar site for these years were 2600, 6200, 37,500, 9300, 2700, 23,800 and 29,100. If the number of nests is used to estimate waterbird numbers (two adults per nest plus chicks), then it is highly likely that 20,000 colonial waterbirds were supported by the Ramsar site in at least five of these years – 1989, 1990, 1993, 1998 and 2000 (Kingsford & Auld 2003).

Other species such as ducks, geese, grebes and shorebirds are also present in high numbers when the Marshes are inundated (Eastern Australian Aerial Waterbird survey), but there is no available estimate of their total numbers in the Ramsar site.

Criterion 8: Is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Due to the location of the Macquarie Marshes in the lower end of the Macquarie catchment, its fish community is a blend of those found in adjacent main channel habitats.

That is, directly upstream and downstream, but also in adjacent systems such as Marthaguy Creek. During high flows, fish are likely to move into the Marshes from these areas (King 2004; Jenkins & Wolfenden 2006). More specifically, the composition (richness, relative abundance and biomass) of a fish community found at a particular site or within a particular creek in the Marshes is likely to be regulated by a combination of local habitat characteristics, recent and historical flows and the degree of longitudinal and lateral connectivity to habitats, including the floodplain (Jenkins et al. 2004).

All native fish species in the Macquarie Marshes and lower Macquarie River typically recruit during spring and early summer. During this critical time appropriate flows are needed to induce spawning, protect eggs and promote larval and juvenile fish survival. Warmer temperatures during this period are important for most species. Appropriate (seasonal) flows are needed during these critical larval rearing stages to prevent wash out of larvae and prey from nursery habitats (Humphries et al. 2002). Restoration of late winter–spring floods would provide optimal feeding and growth conditions for adult fish before spawning (Humphries et al. 2002), as well as providing floodplain habitats with a rich supply of food for larval and juvenile fish (Gehrke et al. 1995).

The Macquarie Marshes support a significant life history stage as recent evidence suggests that native fish move out of the main channel habitats into the floodplain to breed and spawn with the onset of high flows (Balcombe et al. 2007). It is also possible that some species may breed within the main channel during smaller flow events if conditions are right (Humphries et al. 1999).

2.3 Macquarie Marshes Nature Reserve wetland types in 1986

The Macquarie Marshes Nature Reserve and U-block contain a variety of wetlands, ranging from semi-permanent and frequently inundated marshes to ephemeral wetlands inundated by only the largest floods. Core areas of semi-permanent wetlands are made up of reed beds and riparian eucalypt woodlands which are fed by overbank and overland flooding from many small channels.

The Macquarie Marshes are best described as intermittent freshwater marshes (Ts) under the Ramsar Convention, although there are also areas dominated by open water, shrubs and trees. In the 2000 RIS, the Macquarie Marshes Ramsar site was classified as supporting six Ramsar wetland types – N, P, Xf, Ts, W and Tp. However, there are no freshwater lakes greater than 8 ha (P) or permanent freshwater marshes or pools (Tp). Based on mapping done by Wilson (1992) and its analysis using GIS software by Bowen and Simpson (2010), the Ramsar site at the time of listing should be described as supporting the Ramsar wetland types – Ts, Xf, N and W as defined in Table 4.

There has been no specific fine scale wetland mapping in the Macquarie Marshes but there are several vegetation community classifications which provide the basis for wetland types (Paijmans 1981, Wilson 1992, Bowen & Simpson 2010). Figure 4 shows the main wetland types in the Macquarie Marshes Nature Reserve and surrounds in 1981, mapped by Paijmans prior to Ramsar listing.

The wetland types found in the Macquarie Marshes Nature Reserve and U-block are listed in Table 5. The approximate areas listed are from vegetation mapping in 1991 (Wilson 1992). The combination of Paijman’s 1981 mapping and Wilson’s 1991 mapping is the best estimate of wetland types that existed in 1986 at the time of Ramsar listing (Wilson 1992).

Table 4: Ramsar wetland types found in the Macquarie Marshes Nature Reserve in 1986

Ramsar description	Examples from Macquarie Marshes Ramsar site	Wetland type code
Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	Freshwater lagoons, common reed swamps, water couch grasslands, marsh club-rush sedgeland	Ts
Freshwater tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soil	River red gum forest and woodland, coolibah woodlands, black box woodlands	Xf
Seasonal/intermittent/irregular rivers/streams/creeks/ channels	Macquarie River, Bora channel, Ginghet Creek, Monkeygar Creek	N
Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	Lignum shrubland occurs in the northern nature reserve (Salt paddock and a small area in Q-block and in Halls block	W

Photograph 1: Common reed reedbed in the northern section of the Macquarie Marshes Nature Reserve (Photo: Tim Ralph, 2010)

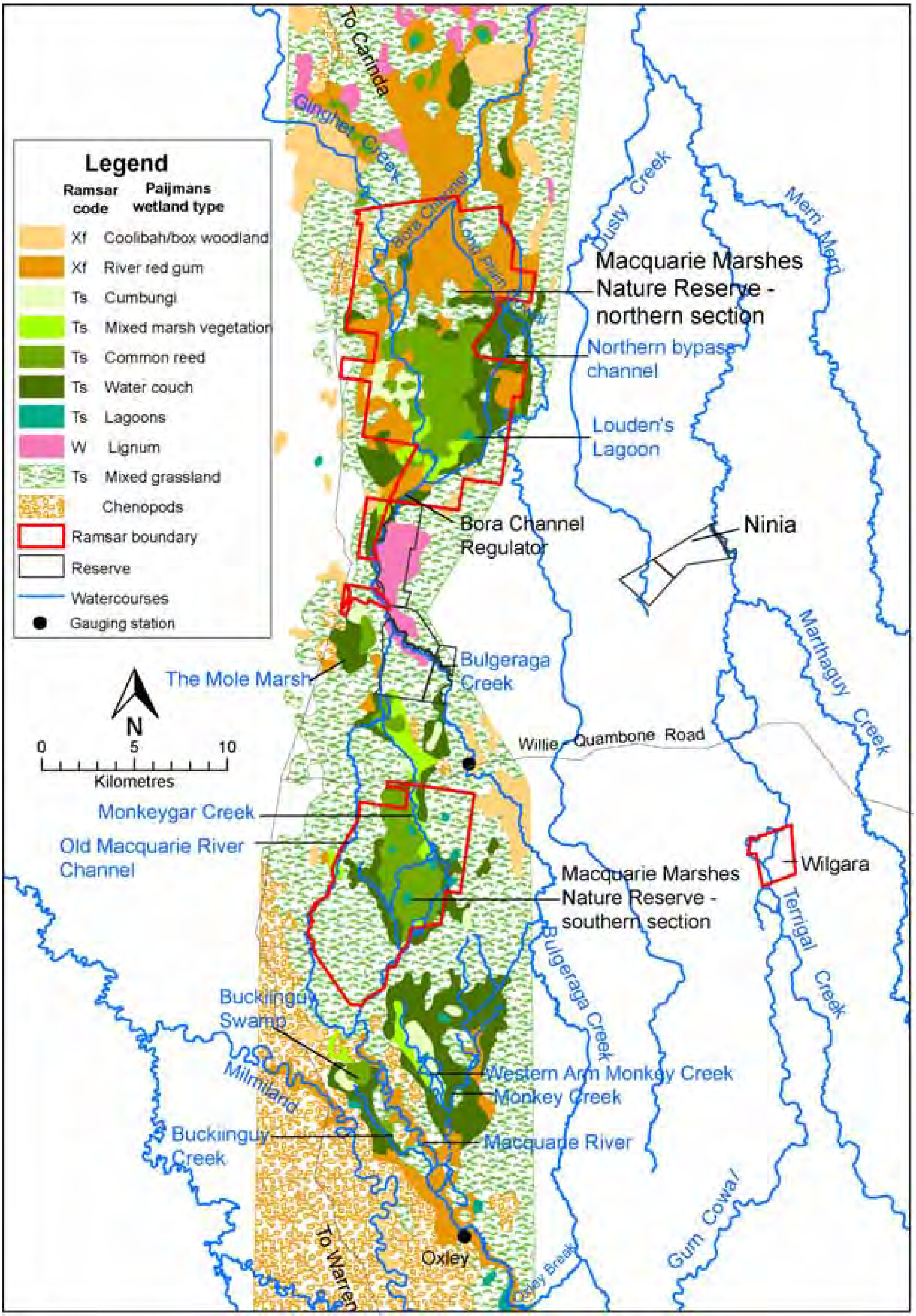


Figure 4: Main wetland types in the Macquarie Marshes Nature Reserve and surrounds in 1981 mapped by Paijmans

Table 5: Wetland types, locations and area in Macquarie Marshes Nature Reserve around the time of Ramsar listing

Wetland type (Ramsar type)	Location	Approx. area (ha) in 1991[#]
River red gum forest and woodland **(Xf)**	Bora Channel (northern section of the Macquarie Marshes Nature Reserve) – extends into adjacent private land	4000
	Macquarie Channel (northern section of the Macquarie Marshes Nature Reserve) – extends into adjacent private land	2000
	Hunt's Woodland (northern section of the Macquarie Marshes Nature Reserve) – extends into adjacent private land	100
	Southern section of the Macquarie Marshes Nature Reserve	210
	U-block	85
Coolibah and/or black box woodland **(Xf)**	Northern section of the Macquarie Marshes Nature Reserve	600
	Southern section of the Macquarie Marshes Nature Reserve	100
	U-block	20
Common reed reed beds **(Ts)**	Louden's Lagoon and northern section of the Macquarie Marshes Nature Reserve	2150
	Southern section of the Macquarie Marshes Nature Reserve	1200
Cumbungi rushland **(Ts)**	Bora Channel (northern section of the Macquarie Marshes Nature Reserve)	260
Water couch marsh **(Ts)**	Louden's Lagoon and northern section of Macquarie Marshes Nature Reserve	910
	Southern section of the Macquarie Marshes Nature Reserve	220
Mixed marsh grassland **(Ts)**	U-block	50
Open water lagoons **(Ts)**	Louden's Lagoon (northern section of the Macquarie Marshes Nature Reserve)	60
	Southern section of the Macquarie Marshes Nature Reserve	30
Lignum **(W)**	Northern section of the Macquarie Marshes Nature Reserve including Salt paddock, Q-block and Halls block	Not mapped but less than 200 ha
Seasonal/intermittent/irregular rivers/streams/creeks **(N)**	Macquarie River, Bora Channel, Monkeygar Creek, Ginghet Creek	–

[#] Approximate areas of vegetation communities, reflecting Ramsar wetland types from Bowen and Simpson 2010

3 Macquarie Marshes Nature Reserve ecosystem components and processes in 1986

Ecosystem components are the physical, chemical and biological parts of a wetland from large scale to very small scale: habitats, species, genes (Ramsar Convention 2005). Ecosystem processes are the dynamic system of local ecological relationships, including relationships between organisms, and relationships between organisms and their environment. They maintain ecosystems and bring about change in ecosystems. They can be biological, chemical or physical processes (Wolfgang 1998).

This section reviews available information for the Macquarie Marshes Ramsar site ecosystem components and processes, and identifies the components and processes that are critical for determining the ecological character of the site at the time of listing. The critical components and processes are summarised in Section 4.

3.1 Soils

The soils of the nature reserve and U-block consist almost entirely of heavy-textured grey-brown and sometimes black silts and clays (mud) to depths of between two and nine metres (Brereton 1994; Ralph 2008; Yonge 2000). Sand content is usually less than 20 per cent and the proportion of organic materials preserved in most areas is generally only 5–10 per cent (Ralph 2008). As these clay-rich soils with mostly uniform texture and colour profiles dry out, they can develop deep cracks that allow water and some litter and other organic material to enter the soil. Cracking mostly occurs in areas of the floodplain away from the main channels, where inundation is the most variable. This leads to gilgai topography, the natural low mounds and shallow depressions formed by shrinking and swelling of clay-rich soils. These soil cracks and holes provide important habitat for invertebrates and small native animals, such as mammals and reptiles.

When floodwaters enter these cracks they lead to deep soil recharge. In the northern Macquarie Marshes Nature Reserve flooding after a long dry period resulted in soil storage of over a metre of water (Bacon 1996). This is the equivalent of 10 megalitres per hectare or some 150,000 ML of soil water storage within the northern section of the nature reserve. A good understanding of how soils respond to flooding in the Marshes may help water managers deliver environmental flows to improve the health of trees such as river red gums, coolibah and black box.

Beyond the area of regular inundation, red-brown texture-contrast soils are characteristic of the palaeochannel sediments which make up the slightly higher ground bordering the modern marsh system. There is also a contrast between the light–medium grey-brown clays at the surface of the modern floodplain and the grey-yellow sandy clays and silty sands found at depths of 3–9 m below the marsh surface (Brereton 1994; Ralph 2008; Yonge 2000). These underlying sediments were laid down by much older river systems which operated on the Macquarie plain before the Marshes came into existence in the Holocene.

3.2 Physiochemical – water

The Pineena database held by the NSW Office of Water includes data on various water chemistry parameters. These data are most comprehensive for the gauging stations at Oxley (south of the Macquarie Marshes) and Carinda (north of the Marshes). There is data on nutrients, conductivity, pH, temperature, heavy metals and some pesticides. No comprehensive analysis of the relationships between these parameters and the functioning of the Macquarie Marshes has been undertaken.

3.3 Wetland vegetation

The list of plant species found in the nature reserve and U-block (Appendix 1) comes from a survey of 280 vegetation sites undertaken in 1991 in the nature reserve (Wilson et al. 1993). There were 324 plant species recorded in the nature reserve with one species, aromatic peppercress (*Lepidium hyssopifolium*) being listed as endangered under the TSC Act and listed as endangered nationally under the EPBC Act.

A compilation of the water regime requirements of wetland and floodplain plants in the MDB has been provided by Roberts and Marsten (2000) and Rogers et al. (2009). Their findings for 17 plant species found in the nature reserve are summarised in Table 6.

Knowledge of the ecological requirements of plant species provides a fundamental basis for understanding the requirements of plant communities, vegetation types and the habitats they provide within the ecological system.

In the Macquarie Marshes several vegetation type classifications have been undertaken often in combination with vegetation mapping. Vegetation types were first mapped by Paijmans (1981) and the 1991 extent and condition was mapped by Wilson (1992). Kidson et al. (2000) identified changes in the distribution of nine tree species in the Macquarie Marshes between 1949 and 1991. Other studies have also examined the extent and/or changes in extent of floodplain vegetation communities around the Macquarie River, including Brander (1987), Bray (1994), Steenbeeke (1996), Kerr et al. (2003) and Shelly (2005).

The most recent vegetation mapping aims to identify the type and magnitude of changes in the extent and condition of all vegetation communities of the Macquarie Marshes and surrounding floodplain in the period 1991 to 2008. This mapping has been completed for the Macquarie Marshes Ramsar site including the Macquarie Marshes Nature Reserve, U-block and 'Wilgara' (Bowen & Simpson 2010; Webb & Fisher 2001).

Paijmans (1981) described and mapped nine wetland vegetation types and one non-wetland vegetation type in the Macquarie Marshes (Figure 4). The 10 vegetation types were based on ground traverses in early 1980 when the Marshes were dry and 1972 aerial photographs when the Marshes were wet. The vegetation types were:

- river red gum forest and woodland
- black box, coolibah and poplar box woodland
- lignum
- reed
- cumbungi with a ground layer of water couch
- water couch
- mixed marsh vegetation
- lagoons (both shallow and deep)
- mixed grassland
- chenopods (non-wetland).

Wilson (1992) mapped vegetation types in the Macquarie Marshes from 1991 aerial photography and ground surveys. The types were determined by their dominant species and structural characteristics such as canopy cover, density and height. This mapping is the best estimate of the vegetation that existed at the time of listing of the Ramsar site in 1986. Bowen and Simpson (2010) updated this map to provide insight into the changes which had occurred in the extent and condition of the mapped vegetation communities between 1991 and 2008. Figures 5, 6 and 7 show the 1991 and 2008 vegetation maps for the Ramsar site.

Table 6: Known water requirements of wetland and floodplain plants in the Macquarie Marshes Nature Reserve

Species	Requirements for maintenance	Requirements for regeneration
River red gum (*Eucalyptus camaldulensis*)	Average flood frequency 1–3 years Average duration 1–7 months, maximum 24 months Flooding required winter–spring Soil drying/aeration between flood cycles	A large flood extending well into summer followed by a wet winter–spring or shallow and brief flooding in winter–spring or in summer
Black box (*Eucalyptus largiflorens*)	Average flood frequency of 2–5 years but can tolerate 7–10 year cycles Average duration 2–4 months, maximum duration of 4 months Flood timing not critical	Maximum flood duration of 1–2 months Flooding in spring–summer will maintain optimal soil moisture for longer periods
Coolibah (*Eucalyptus coolabah*)	Average flood frequency largely unknown although found in areas more frequently flooded, and for longer, than the literature suggests would be the case Duration likely to be 1–2 months Flood timing unknown	Probably shallow flooding in late summer but largely unknown
Lignum (*Muehlenbeckia florulenta*)	Average flood frequency of 1 in 3–10 years Average duration 1–6 months with a maximum duration of 12 months Flood timing probably spring–summer Soil drying/aeration between flood cycles	Flood duration of 2–3 months occurring in spring to summer. Deep inundation greater than 60 cm associated with an absence of Lignum
Water couch (*Paspalum distichum*)	Moist to wet soil conditions for 75% of year Floods can be shallow (5–15 cm), continuous and lasting 4–6 months or can be flooded 2–3 times per year Can recover from 1–3 year dry period but cannot tolerate repeated dry spells Spring–summer flooding important	Germination and seedling requirements unknown, germination cannot take place under water Vegetative regeneration from fragments or buried nodes may be important Moist soil conditions for extended periods essential for both sexual and vegetative reproduction
Common reed (*Phragmites australis*)	Tolerates a range of flood frequencies from permanent inundation to infrequent flooding To maintain vigour 1–2 year flood frequency required Flood depth probably <60 cm, but up to a maximum depth of 200 cm Flood timing not critical, however spring–summer flooding at sites with variable water levels will extend moist soil conditions and enhance growth	Germination and seedling requirements largely unknown but seed germination better in moist rather than waterlogged conditions Seedlings do not tolerate flooding Success of sexual reproduction low Vegetative regeneration from fragments (stem and rhizome) likely to be more important than sexual reproduction

Table 6 continued

Species	Requirements for maintenance	Requirements for regeneration
Cumbungi (*Typha orientalis* & *Typha domingensis*)	Average flood frequency annual although rhizome can survive without flooding for up to 2 years if established Flood duration 8–12 months and more likely to occur where water levels are stable Flood timing winter–spring to early summer	Shallow water (0–5 cm) or saturated mud for germination. Deeper water (5–15 cm) for seedling growth Continuously moist conditions for 3 months in summer and 6 months in winter for seedling establishment
Sedge (*Cyperus exaltus*)	Annual flooding Flood duration 135–200 days at depths <60 cm	Unknown
Common spike rush (*Eleocharis acuta*)	Annual flooding Flood duration 3–10 months at depths <60 cm Flood timing spring–summer	Shallow, moist soil conditions, but to depths of up to 18 cm
Sedge (*Schoenoplectus validus*)	Only found in permanently wet or moist sites Flood duration 350–365 days per year at depths of 20–60 cm	Unknown
Ribbonweed (*Vallisneria americana* or *gigantean*)	Permanent flooding/water Flood duration >8 months Flood timing preferably late winter Requires low turbidity for growth	Seed germination at depths <60 cm, but not under damp conditions alone
Water primrose (*Ludwigia peploides*)	Annual flooding Flood duration 8–10 months to a depth of 1 m Flood timing winter to summer	Seeds can germinate in 5 days given water or wet soil, light and warmth (30°C)
Nardoo (*Marsilea drummondii*)	Annual flooding Flood duration 1–6 months to a depth of <10 cm Flood timing spring–summer	Unknown
Wavy marshwort (*Nymphoides crenata*)	Annual flooding Flood duration 9–10 months to a depth of 1 m Flood timing winter to summer	Unknown
Poison pratia (*Pratia concolor*)	Annual flooding Flood duration 1–3 months to a depth <10 cm Flood timing spring–summer	Unknown
Water ribbons (*Triglochin procerum*)	Annual flooding Flood duration 6 months optimum to a depth of 50 cm – 1.5 m Flood timing winter to summer	Unknown

Mixed marsh is an ecotonal community which was first defined by Paijmans (1981). At the scale of the Paijmans (1981) vegetation mapping ‘mixed marsh’ encompassed all wetland areas that were not dominated by one amphibious wetland species such as common reed, cumbungi or water couch. Wilson (1992) mapped another ecotonal community between grassland and core amphibious wetland as ‘mixed marsh/grassland’.

In 2008 Bowen and Simpson (2009, 2010) defined ‘mixed marsh’ as the Benson (2006) vegetation community ‘Veg type ID: 53 *Sedge-forb shallow freshwater wetland in depressions on floodplains on inland alluvial plains and floodplains*’ (see OEH 2012). Changes in the extent and distribution of this community reflect the wetland’s response to hydrological regimes, and mixed marsh has changed from a coloniser of moist grasslands in wet times (1991) to a community occupying areas formerly supporting other amphibious wetland communities such as water couch in drier times (2008) (Bowen & Simpson 2009, 2010). Because of these changes in community composition (units mapped), direct comparison of area changes of the extent of mixed marsh between 1991 and 2008 should be made with consideration of the ecotonal nature of the community ‘mixed marsh’ (S Bowen, pers. comm., June 2010).

3.4 Aquatic invertebrates

Invertebrates comprise a significant proportion of the biomass in many arid zone river systems (Boulton & Lloyd 1992; Boulton 1999; Timms 1999; Sheldon et al. 2002) and play a critical role in their food webs (Boon & Shiel 1990; Boulton 1999; Bunn & Davies 1999). They are vital to the successful recruitment of native fish (Geddes & Puckridge 1989) and many waterbirds feed on them (Kingsford 1999a). Microinvertebrates (>35μm) feed on algae, bacteria, fungi and protozoans, while macroinvertebrates (>250μm) feed on organic matter, algae and microinvertebrates (Boon & Shiel 1990; Boulton 1999; Bunn & Davies 1999) and thus indirectly affect nutrient cycles and the fluxes of carbon and energy in floodplain wetlands (Baldwin & Mitchell 2000).

In the Macquarie Marshes densities of microinvertebrates in recently inundated floodplain habitats are amongst the highest recorded in the world (Jenkins & Wolfenden 2006). Epibenthic habitats (close to wetland bottom) in temporary floodplains and creeks contain a rich soup of microinvertebrates available as potential prey to macroinvertebrates and fish. The four main types of microinvertebrates found within floodplain and temporary channels in the Macquarie Marshes are rotifers, cladocerans, ostracods and copepods. The latter three types are all microcrustaceans, the preferred prey (particularly cladocerans) for the larvae of most native fish species. After the 2005 inundation, peak densities recorded on floodplain associated with the Bora Creek in the North Marsh and Gum Cowal-Terrigal Creek in the East Marsh were 1140 ostracods/litre, 1043 cladocerans/litre, 3156 copepods/litre and 16,829 rotifers/litre. Considering that densities of 100 cladocerans/litre are reported as adequate to support larval fish (King 2004), the peak densities found in the Macquarie Marshes are extremely high.

More than 50 macroinvertebrate taxa were recorded in the Macquarie Marshes in surveys in 2004 and 2005 but as samples are processed from more extensive surveys in 2006 this number is approaching 100 taxa (Jenkins et al. 2007). During the 2005 flow the highest diversity and abundances of macroinvertebrates were found in floodplain habitats and temporary creeks (Bora Creek and Gum Cowal-Terrigal Creek), compared to constantly flowing creeks. There was a distinct difference in community composition between the creek and floodplain samples. The samples from Bora Creek and Gum Cowal-Terrigal Creek were closer in composition to those from the floodplain than samples from the constantly flowing creeks. Numbers of taxa were unexpectedly high in constantly flowing creeks during the dry period in 2006, suggesting these creeks are important refugia for macroinvertebrates. Abundances were comparable between wet and dry periods in constantly flowing creeks but tended to be higher in dry periods (Jenkins et al. 2007).

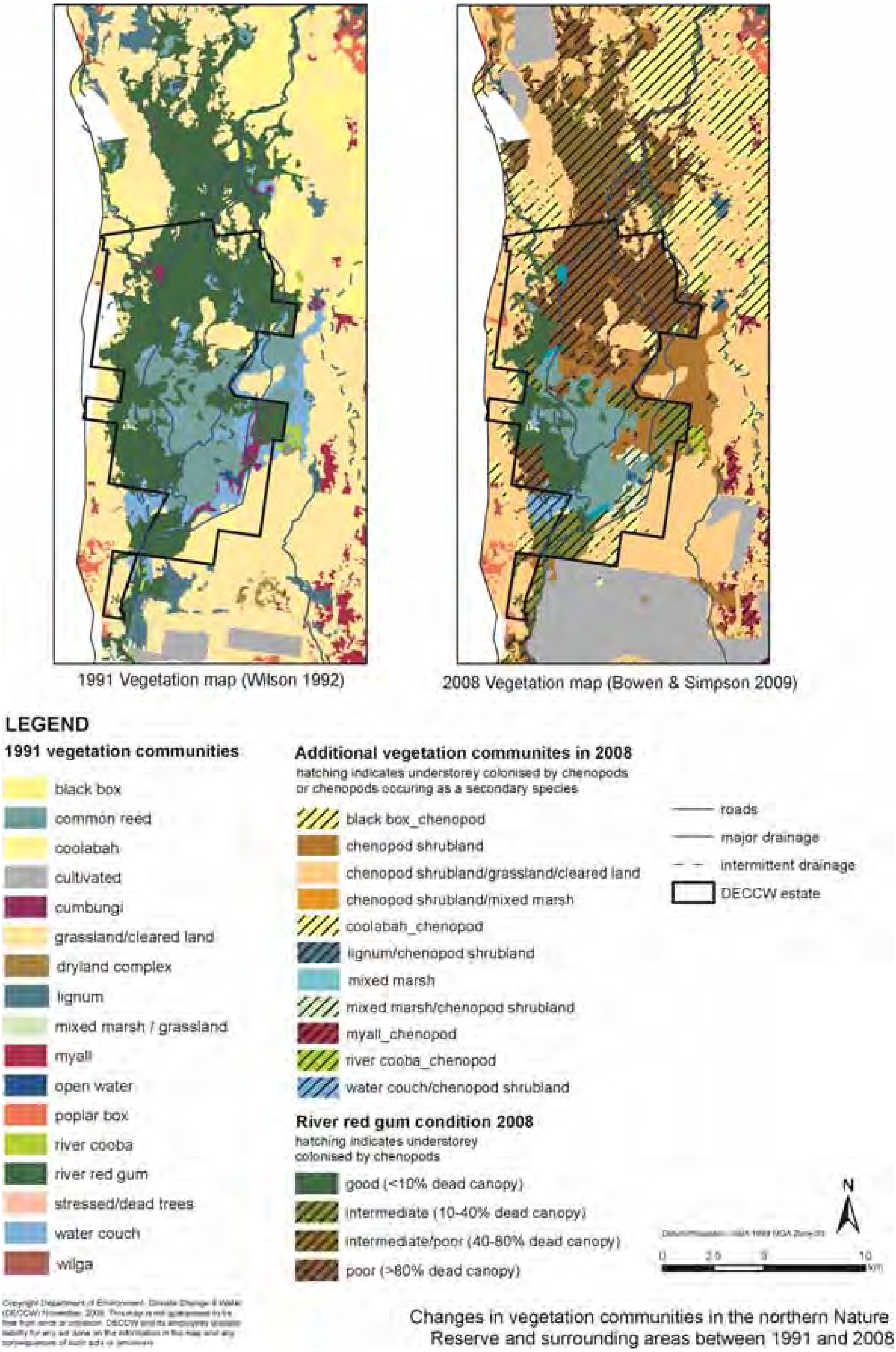


Figure 5: The 1991 and 2008 vegetation maps for the northern section of the Macquarie Marshes Nature Reserve (Bowen & Simpson 2010)

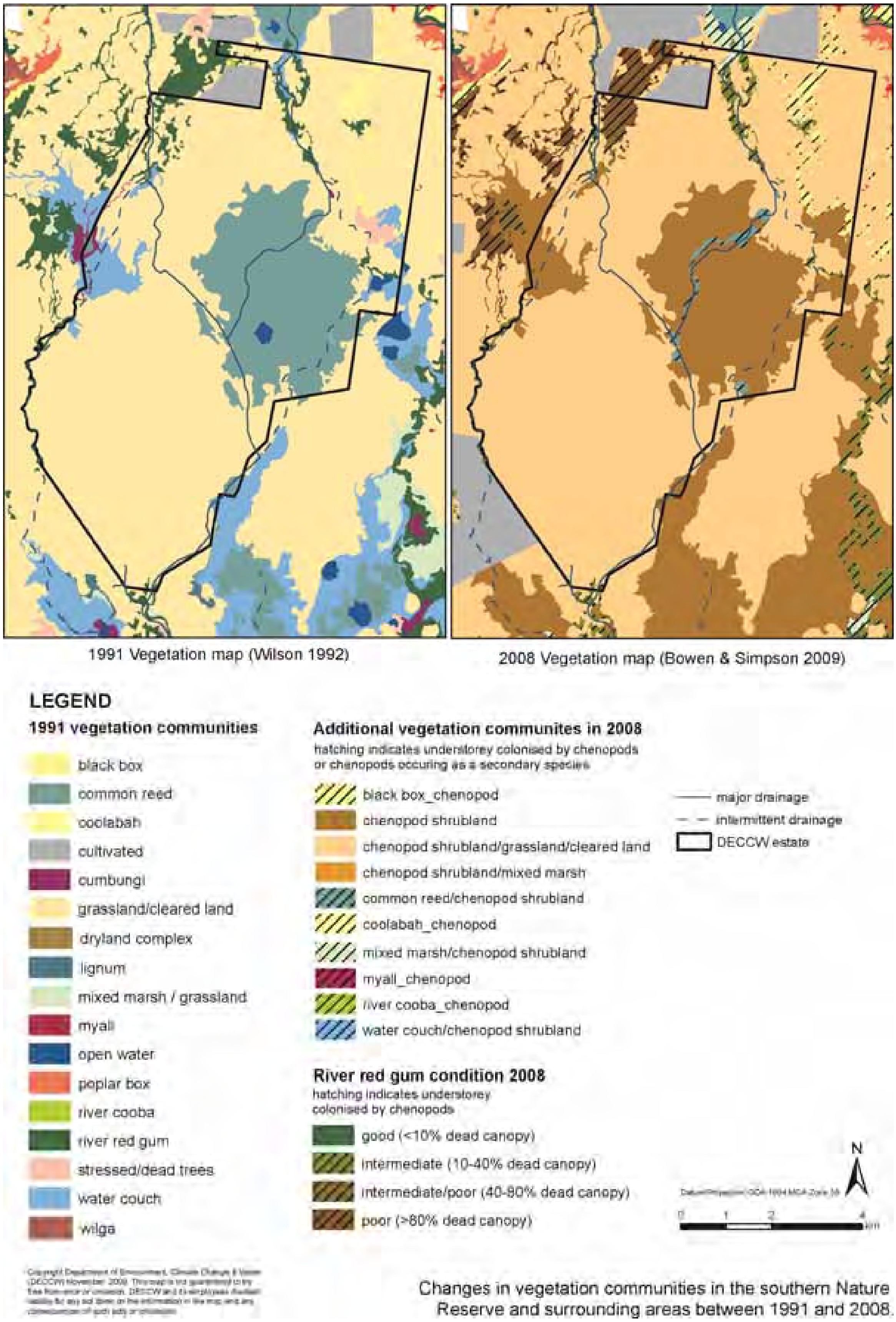


Figure 6: The 1991 and 2008 vegetation maps for the southern section of the Macquarie Marshes Nature Reserve (Bowen & Simpson 2010)

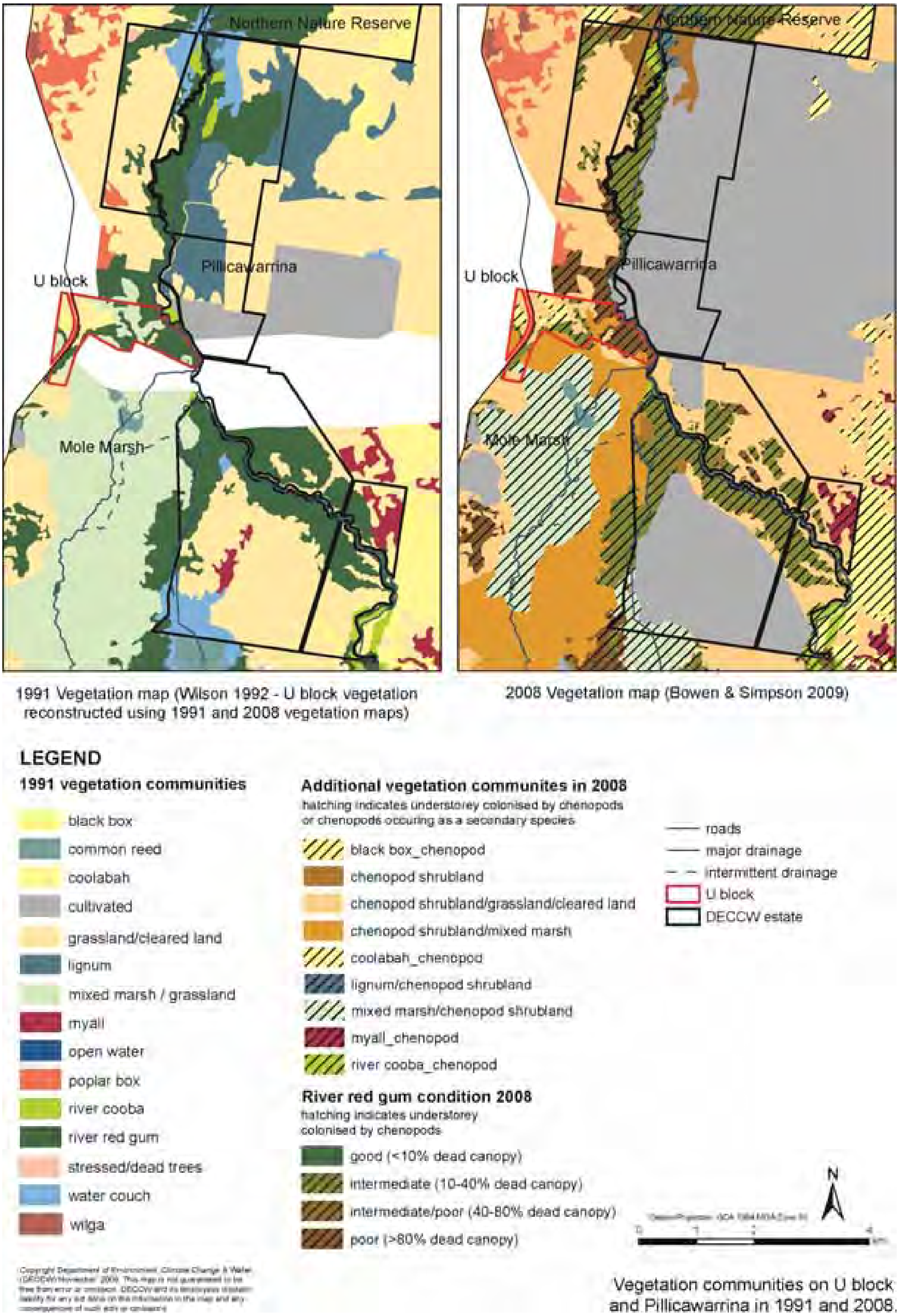


Figure 7: The 1991 and 2008 vegetation maps for U-block (Bowen & Simpson 2010)

3.5 Fish

Based on historical records, 11 species of native fish occurred within the Macquarie Marshes. Within the southern nature reserve 5 native species have been recorded in the recent surveys (Jenkins et al*.* 2009). The 11 native fish species are:

silver perch	*Bidyanus bidyanus*
flyspecked hardyhead	*Craterocephalus stercusmuscarum*
carp gudgeon	*Hypseleotris sp.*
spangled perch	*Leiopotherapon unicolour*
Murray cod	*Maccullochella peelii*
golden perch	*Macquarie ambigua*
crimson-spotted rainbowfish	*Melanotaenia fluviatilis*
bony herring	*Nematolosa erebi*
flathead gudgeon	*Philypnodon grandiceps*
Australian smelt	*Retropinna semoni*
freshwater catfish	*Tandanus tandanus*

All native fish species in the Macquarie Marshes and lower Macquarie River usually recruit during spring and early summer. During this critical time appropriate flows are needed to induce spawning, protect eggs and promote larval and juvenile fish survival. Warmer temperatures during this period are important for most species. Appropriate (seasonal) flows are needed during these critical larval rearing stages to prevent wash out of larvae and prey from nursery habitats (Humphries et al. 2002). Restoration of late winter–spring floods would provide optimal feeding and growth conditions for adult fish before spawning (Humphries et al. 2002) as well as providing floodplain habitats with a rich supply of food for larval and juvenile fish (Gehrke et al. 1995).

The fish community of the Macquarie Marshes is a blend of those found in adjacent main channel habitats. That is, directly upstream and downstream, but also in systems such as the Marthaguy Creek. During flow events, fish are likely to move into the Marshes from these areas. Observations of freshwater mussels in the Marshes, a small obligate parasite on the gills of native fish (Baker et al. 2003) such as the Australian smelt, catfish and silver perch, substantiates their importance as habitat. More specifically, the composition (richness, relative abundance and biomass of pest species) of the fish community found at a particular site or within a particular creek of the Marshes is likely to be regulated by a combination of local habitat characteristics, recent and historical flows and the degree of longitudinal and lateral connectivity to habitats, including the floodplain (Jenkins et al. 2004; T Rayner, pers. comm., 2009).

Murray cod (*Maccullochella peelii peelii)*, which is listed as vulnerable under the EPBC Act, has been recorded in the Macquarie Marshes (Atlas of NSW Wildlife) and was captured in intensive fish surveys in 2006 (Jenkins et al*.* 2007). Murray cod is the largest freshwater fish found in Australia. It is a long lived predator species that is highly territorial and aggressive. It occurs naturally in the waterways of the Murray–Darling Basin in a wide range of warm water habitats that range from clear, rocky streams to slow flowing turbid rivers and billabongs (DEH 2003).

There is also one threatened species and one endangered ecological community in the Macquarie Marshes listed under the NSW *Fisheries Management Act 1994*. Silver perch, *Bidyanus bidyanus*, is listed as a vulnerable species (DPI 2005). Silver perch was recorded in 2008 in the Marshes in a formal survey for the first time since 1989 (S Davis, pers. comm., 2009). Silver perch inhabits warm, sluggish, standing waters with cover provided by woody debris and reeds as well as fast-flowing, turbid waters (Koehn & O'Connor 1990). Little is known about its ecological requirements in the wild although some information is available from breeding in captivity. Recruitment of silver perch appears to be localised and opportunistic (Morris et al. 2001). Whilst spawning can occur during non-flood conditions, spawning activity and recruitment success may be significantly increased during floods and higher flows. The larvae and juveniles use floodplain habitats. Adults and juveniles feed on small aquatic insects, molluscs, earthworms and green algae, while larvae feed on zooplankton (Merrick 1996).

The Macquarie Marshes is located in the area covered by the endangered ecological community listed under the NSW *Fisheries Management Act 1994* as the 'aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River'. This community covers all native fish and aquatic invertebrates and the natural rivers, creeks, lagoons, billabongs, wetlands, lakes, tributaries, anabranches and effluents in which they live. The key threatening processes listed that affect the Macquarie Marshes are in-stream structures and other mechanisms that alter natural flow, exotic species and degradation of native riparian vegetation.

In surveys in 2003, three native fish species were captured: western carp gudgeon, *Hypseleotris klunzingeri*, Midgley's carp gudgeon, *Hypseleotris* sp., and flathead gudgeon, *Philypnodon grandiceps* (Jenkins et al. 2004). More intensive surveys in 2006 captured seven native species: carp gudgeon, golden perch, bony herring, Australian smelt, rainbow fish, Murray cod and spangled perch (Jenkins et al. 2007).

Three exotic fish species are abundant in the Marshes (goldfish *Carassius auratus*, European carp *Cyprinus carpio*, gambusia *Gambusia holbrooki*) with a fourth species, redfin perch (*Perca fluviatilis*) captured less frequently (Gehrke 1997).

3.6 Frogs

There are 15 frog species recorded in Macquarie Marshes Nature Reserve (Appendix 2). None are considered threatened species in NSW. Of the 15 species, eight are burrowing frogs, four are marsh or grass fogs and three are tree frogs. It is not known how common or rare they are or any specific detail about their breeding, habitats and food needs in the Marshes.

In general terms most frogs in the MDB need flooding in spring or summer to initiate breeding and a water depth of between 10–50 cm for anywhere from 30 to 180 days depending on the species. Provided the habitat is available this ensures conditions are suitable for egg laying, algal growth for feeding tadpoles and time for metamorphosis (Young 2001).

There is a small amount of ecological information about two frog species that occur in the Marshes from research by Healey et al. (1997) in wetlands near Wagga Wagga. The eastern sign-bearing froglet (*Crinia parinsignifera*) was only found in wetlands with water couch and its preferred habitat was the creeping or trailing stems only found in water couch with good water availability. The most important microhabitat for the long-thumbed frog (*Limnodynastes fletcheri*) was beds of tall spike rush (*Eleocharis sphacelata*).

There are some indications that frog populations are declining in the Marshes. The number of red-bellied black snakes in the Marshes was once one of the highest in Australia but in the last 20 years there has been a dramatic decline in both the number and condition of these snakes (Phillips 2006). Frogs are this snake's main source of food in the Marshes, and declining snake numbers could be an indicator of declining frog populations. Frog eggs are an important food source for fish, and tadpoles are an important food source for turtles and waterbirds.

3.7 Reptiles

There are 60 reptile species in the Macquarie Marshes, none of which are considered threatened in NSW (Appendix 3, Atlas of NSW Wildlife): three turtles, 40 lizards and 17 snakes. While most snakes and lizards do not depend on water, several are wetland specialists. The red-bellied black snake diet includes fish, tadpoles, frogs, lizards, snakes, mammals and the occasional aquatic invertebrate (Greer 2006). Shine (1983) found that frogs made up 88 per cent of the diet of De Vis's banded snake, a small snake found commonly in the Marshes. As discussed previously the number and condition of red-bellied black snakes in the Marshes have declined dramatically over the last 20 years.

The three turtle species, broad-shelled turtle, eastern snake-necked turtle and short-necked turtle are water-dependent and only leave the water to lay their eggs. To breed successfully turtles need good reserves of fat that can only be obtained during floods. Their main foods are fish, yabbies, aquatic invertebrates and algae. Unlike frogs that need a flood to trigger their breeding, turtles need a flood to provide ample food before they can lay eggs. They lay their eggs in a shallow burrow of wet soil next to water. Changes to floodplain soils through compaction or earthworks can have a big impact on their ability to dig burrows, and predation by foxes can cause up to 95 per cent mortality of eggs and young.

3.8 Birds

There have been 233 bird species recorded in the Macquarie Marshes Nature Reserve including 77 waterbirds, 19 birds of prey, 6 night birds, 17 parrots, 5 pigeons and 109 bush or land birds (Appendix 2). Twenty-five of these are listed as either endangered or vulnerable in NSW under the TSC Act and two – the superb parrot and the Australian painted snipe – are listed nationally as vulnerable under the EPBC Act (Atlas of NSW Wildlife).

3.8.1 Waterbirds

Between 10,000 and 300,000 adult waterbirds rely on the Macquarie Marshes each season (Kingsford & Thomas 1995) for their breeding, feeding and habitat requirements. In the entire Macquarie Marshes, 77 waterbird species have been recorded (Atlas of NSW Wildlife, www.bionet.nsw.gov.au/; Appendix 2).

The Australian painted snipe has been recorded in the nature reserve and sighted in marsh adjacent to U-block and is listed as nationally vulnerable (EPBC Act). Australian painted snipe are known to use water couch for feeding and mixed marsh for nesting in the Macquarie Marshes (T Hosking, pers. comm., May 2010). Nine species of waterbirds in the Macquarie Marshes Nature Reserve are listed under the NSW *Threatened Species Conservation Act 1995* (www.environment.nsw.gov.au/threatenedspecies/). Of these species, the black-tailed godwit, cotton pygmy-goose, blue-billed duck (1989: n = 18), freckled duck (1983: n = 15), magpie goose (1996: n = 25), Australasian bittern, black-necked stork, and brolga (1988: n = 49; 1989: n = 50) have been recorded during annual aerial survey. Cryptic species such as the Australian painted snipe and species in low numbers are often missed during aerial surveys (Kingsford 1999b).

Seventeen species are listed on international migratory bird agreements with Japan (JAMBA), China (CAMBA) and the Republic of Korea (ROKAMBA). These include the following wetland dependent species: cattle egret, great egret, Caspian tern, bar-tailed godwit, black-tailed godwit, common greenshank, common sandpiper, curlew sandpiper, Latham's snipe, marsh sandpiper, red-necked stint, sharp-tailed sandpiper, wood sandpiper and glossy ibis.

The Macquarie Marshes provide important habitat for waders; however, little is known of the relative importance and pattern of use of different wetlands and the specific habitat needs of different species. It is likely that mudflats that become exposed as water dries back are important habitat for migratory waders.

3.8.2 Woodland birds

Many once common woodland bird species are now considered to be declining in southeastern Australia. Reid (1999) listed 20 woodland bird species whose numbers have declined significantly since the 1980s (Appendix 2). Eighteen of these species are found commonly in the Macquarie Marshes. The brown treecreeper, grey-crowned babbler, hooded robin and diamond firetail are listed as vulnerable under the NSW TSC Act.

The main reasons for a decline in woodland bird species are loss of habitat, fragmentation of woodland vegetation and simplification or degradation of the remaining woodland vegetation (Ford et al*.* 2001). Large intact woodlands with native shrubs and groundcover plants are now extremely rare in southeastern Australia particularly on fertile soils such as the Marshes' soils (Yates & Hobbs 1997).

Research by Oliver and Parker (2006) in the NSW central Murray catchment found that woodland bird abundance and species richness was the highest in woodland patches larger than 100 ha that were less than 1 km from other patches of woodland with high habitat complexity (canopy cover, shrubs, groundcover, litter and logs) and good tree health. They also found that river red gum woodlands and forests had the highest total bird abundance and species richness when compared with white cypress pine, black box, yellow box, grey box, buloke, myall and tree planting sites.

This research may explain why 18 of the 20 declining woodland bird species are found in the Macquarie Marshes. River red gum forest and woodlands are an important and extensive plant community in the Marshes. There is a need to find out more about the relationship between this plant community and woodland birds (Blackwood et al. 2010).

3.8.3 Waterbird breeding

The Macquarie Marshes are renowned for their large scale waterbird breeding events, some of the largest in Australia's recorded history (Macquarie Marshes Investigation Committee 1951; Marchant & Higgins 1990; Kingsford & Auld 2005). Waterbird breeding in the Marshes was first recorded in 1896 and was referred to in numerous documents and maps throughout the 1900s. In 1954 Cooper made some detailed observations, followed by Carrick, who studied ibis breeding in the Marshes throughout the 1950s and recorded this in 1962 (Brereton 1993; Carrick 1959; Carrick 1962; Cooper 1955). It was not until 1986 that detailed waterbird breeding records were kept for every flood event.

Of all the waterbirds that breed in the Marshes, colonial nesting species are the most prominent and have been the most studied. Sixteen species have been recorded breeding, with great egret, intermediate egret, little egret, rufous night heron, glossy ibis, Australian white ibis, straw-necked ibis, little pied cormorant and little black cormorant occurring in the largest numbers (Kingsford & Thomas 1995; Kingsford & Auld 2005).

In the 16 years for which detailed waterbird breeding records have been kept (1986–2001) colonies of more than 500 nests occurred in nine of those years. More than 10,000 waterbirds bred every 2–3 years while large breeding events of larger than 40,000 nests occurred about every eight years (Kingsford & Auld 2003). Since 1986 colonial nesting waterbirds have been recorded breeding in 15 locations throughout the Macquarie Marshes (Figure 8 and Table 7), nine in the North Marsh (five of these in the northern section of the nature reserve), five in the East Marsh (one in 'Wilgara' Ramsar site), and one in the South Marsh (none in the southern section of the nature reserve).

Photograph 2: Intermediate egret stepping onto nest in river red gum, Bora Channel colony, northern section of the Macquarie Marshes Nature Reserve (Photo: Bill Johnson, 1993)

In the 2000 flood in the Macquarie Marshes the area inundated was more than 200,000 ha and 13 known breeding locations were used (Figure 8). Two locations in the northern section of the nature reserve were not used – Hunt's Woodland, a river red gum breeding site and Louden's Lagoon, a common reed and marsh club-rush site.

There have only been four waterbird breeding events in the Marshes since 2000. In 2008, a relatively small flood supported a successful nesting of approximately 2000 egrets, and cormorants bred in river red gum forest at P-block (Macquarie). This was not expected with such low flows and was the first record of colonial nesting waterbirds breeding at only one location in the Marshes. In March 2010, a small colony of egrets successfully bred at P-block. In 2010–11 there was a large scale waterbird breeding event in response to substantial inundation of the Marshes. Within the Ramsar site, mixed colonies of approximately 25,000 pairs of waterbirds successfully bred at the P-block and Bora North colony sites (D Love, pers. comm., March 2011). In 2011–12 also there were approximately 50,000 pairs of waterbirds breeding in the Ramsar site.

Because of such large waterbird breeding events, the need to restore and maintain waterbird breeding sites has become a major focus of management of the Marshes. This can only be achieved by understanding the ecological components and processes required for breeding waterbirds in the Marshes, such as flow regime, nesting sites and food availability.

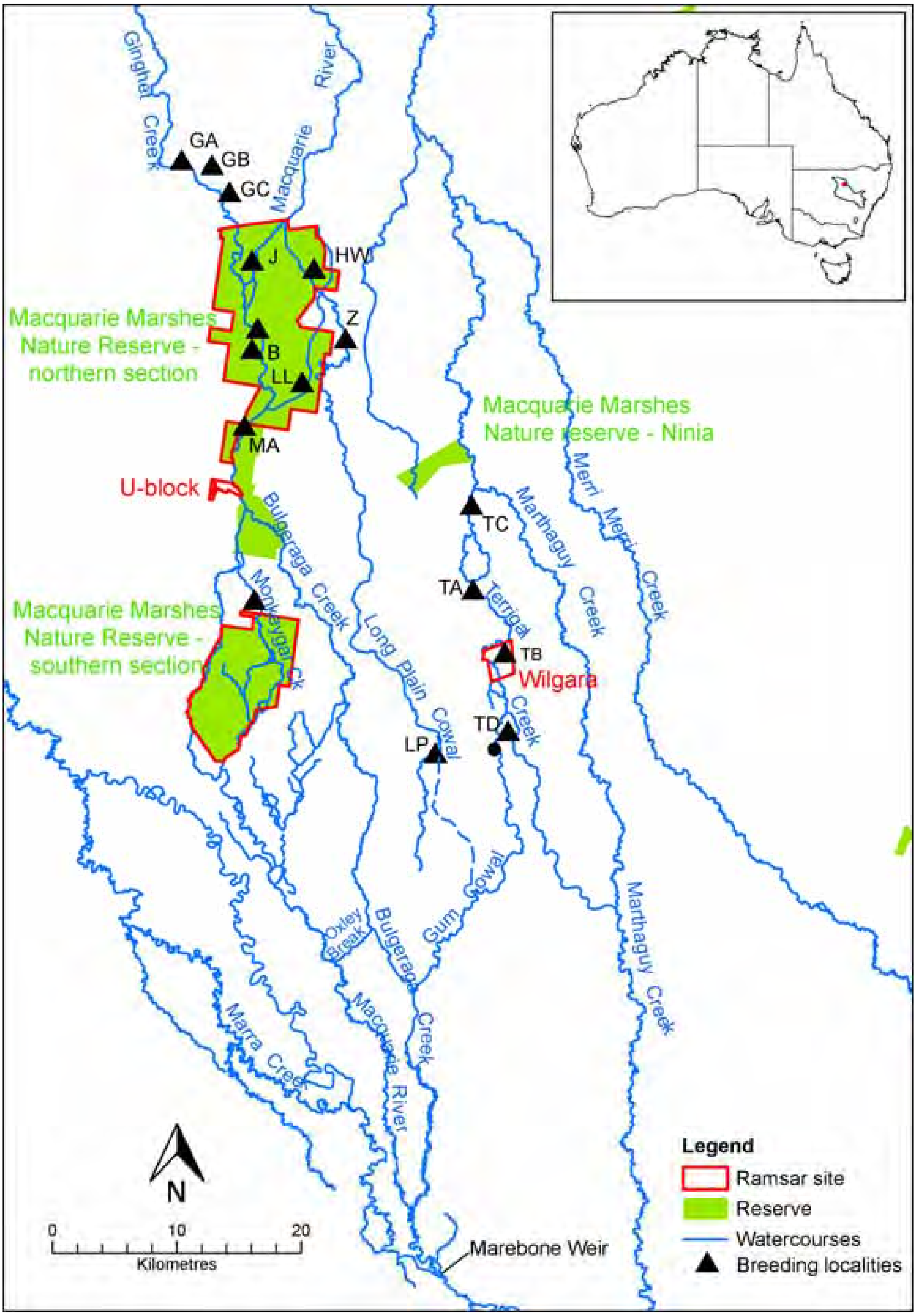


Figure 8: Map of the known breeding localities of colonial nesting waterbirds in Macquarie Marshes since 1986 (after Kingsford & Auld 2003)
[Ginghet colonies (GA, GB, GC), J-block (J), Hunt's Woodland (HW), Bora colonies (B), Zoo Paddock (Z), Louden's Lagoon (LL), Macquarie (MA), Monkeygar (Willancorah) (M), Terrigal colonies (TA, TB, TC, TD) and Long Plain cowal (LP)]

Table 7: Nesting vegetation, colony sites, breeding colonial species and measures of colony size within the Macquarie Marshes between 1986 and 2000 (after Kingsford & Auld 2003; unpubl. data)

Colony location	Colonial nesting species	Year last bred	Colony size		
			Mean (SE)	Median	Max.
Reed nesting vegetation					
*Louden's Lagoon	glossy ibis, straw-necked ibis, Australian white ibis	1998	490 (364)	200	5,400
Monkeygar (Willancorah)	glossy ibis, straw-necked ibis, Australian white ibis, royal spoonbill, darter	2000	5,790 (2,446)	2,000	36,300
Reed and lignum nesting vegetation					
Zoo Paddock	glossy ibis, straw-necked ibis, Australian white ibis, intermediate egret, great egret, cattle egret, little egret, rufous night heron	2000	4,973 (2,687)	250	37,100
*J Block	little black cormorant, little pied cormorant, glossy ibis, straw-necked ibis, Australian white ibis	2000			280
*South Marsh A (Lake Willancorah)	straw-necked ibis, Australian white ibis	1960s			
*South Marsh B (Lagoon)	straw-necked ibis, Australian white ibis	1960s			
Reed, lignum and woodland vegetation					
Terrigal A	little pied cormorant, little black cormorant, great egret, cattle egret, intermediate egret, little egret, glossy ibis, straw-necked ibis, Australian white ibis, rufous night heron, Pacific heron, pied heron, white-faced heron, darter, royal spoonbill, yellow-billed spoonbill	2000	1,808 (1,034)		16,000
^Terrigal B	little pied cormorant, little black cormorant, great egret, cattle egret, intermediate egret, little egret, glossy ibis, straw-necked ibis, Australian white ibis, yellow-billed spoonbill	2000	541 (541)		8,625
Ginghet A	little black cormorant, little pied cormorant, intermediate egret, glossy ibis, straw-necked ibis, Australian white ibis, rufous night heron	2000	19 (19)		300
Ginghet B	glossy ibis, straw-necked ibis, Australian white ibis, royal spoonbill	2000	450 (312)		4,200
*Macquarie	straw-necked ibis, Australian white ibis, royal spoonbill	2000			1,030

*Nesting site within Macquarie Marshes Nature Reserve section of Ramsar site
^Nesting site within 'Wilgara' section of Ramsar site

Table 7 continued

Colony location	Colonial nesting species	Year last bred	Colony size		
			Mean (SE)	Median	Max.
Woodland and forest vegetation					
*Bora Colonies	little pied cormorant, little black cormorant, cattle egret, great egret, intermediate egret, little egret, rufous night heron, Australian white ibis, straw-necked ibis, glossy ibis, Pacific heron, royal spoonbill, yellow-billed spoonbill, darter	2000	1,327 (355)	848	3,550
*Hunt's Woodland	little pied cormorant, little black cormorant, great egret, intermediate egret, little egret, cattle egret, rufous night heron, glossy ibis, royal spoonbill, yellow-billed spoonbill	1990	457 (232)	0	3,190
Ginghet C	little black cormorant, little pied cormorant, intermediate egret, great egret, cattle egret, little egret, rufous night heron, yellow-billed spoonbill	2000	134 (134)		2,150
Long Plain Cowal	little pied cormorant, little black cormorant, great egret, intermediate egret, rufous night heron, Pacific heron, Australian white ibis, royal spoonbill, yellow-billed spoonbill, darter	2000	4,880	4,880	4,880
Terrigal C	great egret, intermediate egret, rufous night heron	2000	158 (156)		2,500
Terrigal D	little pied cormorant, little black cormorant, great egret, intermediate egret, little egret, rufous night heron, Pacific heron, white-faced heron	2000	459 (424)		6,800
Garrawilla	straw-necked ibis, Australian white ibis, glossy ibis, rufous night heron, great egret, intermediate egret	2000			8,500

*Nesting site within Macquarie Marshes Nature Reserve section of Ramsar site

3.8.4 Flow regime

Colonial waterbirds usually breed in response to large floods that inundate the Macquarie Marshes (Kingsford & Johnson 1998). The minimum flow requirement for successful colonial nesting waterbird breeding in the entire Marshes is flooding of sufficient volume and duration to inundate colony sites and feeding areas for at least five consecutive months between August and March. As a general guideline this needs between 180,000 ML and 300,000 ML depending on antecedent conditions. In the past this volume has supported successful breeding of about 4000 pairs of egrets and 10,000 pairs of ibis in the four most secure colony sites: Bora, Willancorah, Zoo Paddock and Gum Cowal-Terrigal (Figure 6).

Although smaller flows often do not support successful colonial nesting waterbird breeding, they do allow other water dependant species to breed. Evidence also suggests that they are critical for maintaining wetland vegetation for habitat and aquatic invertebrates and fish for food (Jenkins & Wolfenden 2006). River regulation is estimated to have decreased colony sizes by about 100,000 nests every eleven years, decreasing the frequency of breeding events (Kingsford & Johnson 1998).

3.8.5 Nesting sites

Nesting sites for breeding waterbirds vary between species and apart from a few ground nesters they require some form of vegetation. The Macquarie Marshes provide a diverse range of waterbird nesting sites. The following is a list of the basic vegetation forms recorded for nesting waterbirds in the Macquarie Marshes.

Live trees: The following species require live trees for nesting: great egret, cattle egret, intermediate egret, little egret, white-faced heron, pied heron, rufous night heron, great cormorant, little pied cormorant, little black cormorant and yellow-billed spoonbill. In the Macquarie Marshes river red gum is the most utilised live nesting tree, with river cooba also an important species. The only NSW breeding record for pied heron was in river cooba in the Macquarie Marshes (Johnson, pers. comm., 2009). Two waterbird breeding sites in the northern section of the Macquarie Marshes Nature Reserve, Bora Creek and Hunt’s Woodland are characterised by river red gum and river cooba.

Live or dead trees: Two species nest in either live or dead trees: darter and white-necked (Pacific) heron. They most commonly nest alongside live tree nesters and have been recorded breeding at Bora Creek and Hunt’s Woodland in the northern section of the Macquarie Marshes Nature Reserve.

Tree hollows: Australian wood duck is the only obligate tree hollow nester recorded in the Marshes. It uses a number of different tree species including river red gum, coolibah and black box throughout the Macquarie Marshes Nature Reserve.

Tree hollows and/or ground nesting: Grey teal, Australasian shelduck and Pacific black duck use either tree hollows or ground nests depending on availability. They are commonly recorded breeding throughout the Marshes and use tree species including river red gum, coolibah and black box.

Shrubs and/or reed nesting: The following species require shrubs or reeds for nest sites: blue-billed duck, freckled duck, hardhead, musk duck, pink-eared duck, magpie goose, little bittern, Eurasian coot, dusky moorhen, black-tailed native-hen, purple swamphen, glossy ibis, Australian white ibis, straw-necked ibis, royal spoonbill. For most of the ducks, Eurasian coot and black-tailed native-hen, nest sites are hidden within the shrubs and reeds but for ibis and royal spoonbill the shrubs and reeds are flattened to provide platforms for nests. Magpie geese have only been recorded breeding on cumbungi. The most important plant species in the Marshes for these waterbirds are lignum, common reed, cumbungi and marsh club-rush.

Ground, floating or island nesting: The following waterbird species use either ground nests or nests constructed from vegetation that is either free floating or on small islands: Australasian shoveler, black swan, plumed whistling-duck, black-fronted dotterel, red-kneed dotterel, masked lapwing, brolga, whiskered tern, great crested grebe, hoary-headed grebe, Australasian grebe, black-winged stilt. The most important plant species for these waterbirds are cumbungi, common reed and several sedge and rush species.

3.8.6 Food availability

Food availability both prior to and during nesting and egg-laying is critical for successful waterbird breeding. There is generally a lag time between the commencement of a flood and the commencement of waterbird breeding. Most waterbirds need to increase their fat reserves before egg-laying and then require suitable food types for their young. Microinvertebrates play a critical role in the Marshes' food web particularly for breeding waterbirds. By feeding on algae, bacteria, fungi and protozoa, microinvertebrates maintain nutrient cycles and the flux of carbon and energy. In turn, microinvertebrates are vital to the successful recruitment of native fish by providing their first food source after hatching (Geddes & Puckridge 1989). Many waterbirds such as pink-eared ducks feed exclusively on microinvertebrates (Kingsford 1999a).

In the Macquarie Marshes, densities of aquatic microinvertebrates in recently inundated floodplain habitats are amongst the highest in the world and floodplain soils contain a substantial egg bank that produces a massive pulse in microinvertebrate biomass within the first 28 days after flooding (Jenkins & Wolfenden 2006). This underpins food webs in the Marshes and eventually enables waterbirds to breed successfully.

Herbivorous waterbirds such as the magpie goose have been recorded feeding on seeds of water couch in the Marshes both prior to and during breeding (Johnson, pers. comm., 2009). The availability of water couch seed may underpin the success of breeding for the magpie goose in the Marshes as they require not only reed or cumbungi for nest construction, but also large areas of aquatic grasses for food for young (Marchant & Higgins 1990).

3.8.7 Non-breeding habitat

Understanding what happens to waterbirds outside their breeding sites is also important for management. The mobility of waterbirds is well known but their ecological requirements outside of breeding are not. Kingsford and Auld (2003) used satellite transmitters to track the movements of two breeding straw-necked ibis in the 2000 flood in the Marshes. They found these birds spent most of their time foraging within five kilometres of their nest site but occasionally travelled 20–30 kilometres away. Three weeks after the completion of breeding they had left the Marshes, with one ibis located in southwest Queensland and the other in the Tully River region in north Queensland. The reasons for moving so far are not really understood, but for many species of colonial nesting waterbirds parts of northern Australia are their non-breeding habitat.

3.9 Mammals

There are 29 native mammal species recorded in the Macquarie Marshes Nature Reserve (Appendix 2). These include four kangaroo species, three possums and gliders, nine native mouse and rat species, 12 bat species and an echidna, plus there are eight introduced species (Atlas of NSW Wildlife). Six of the native species are listed as vulnerable under the NSW TSC Act.

Little is known of the ecological requirements of most of these mammals. The narrow-nosed planigale, a small marsupial mouse, is found only in cracking grey soils. Most other mammals are closely associated with the woodlands and grasslands of the Marshes.

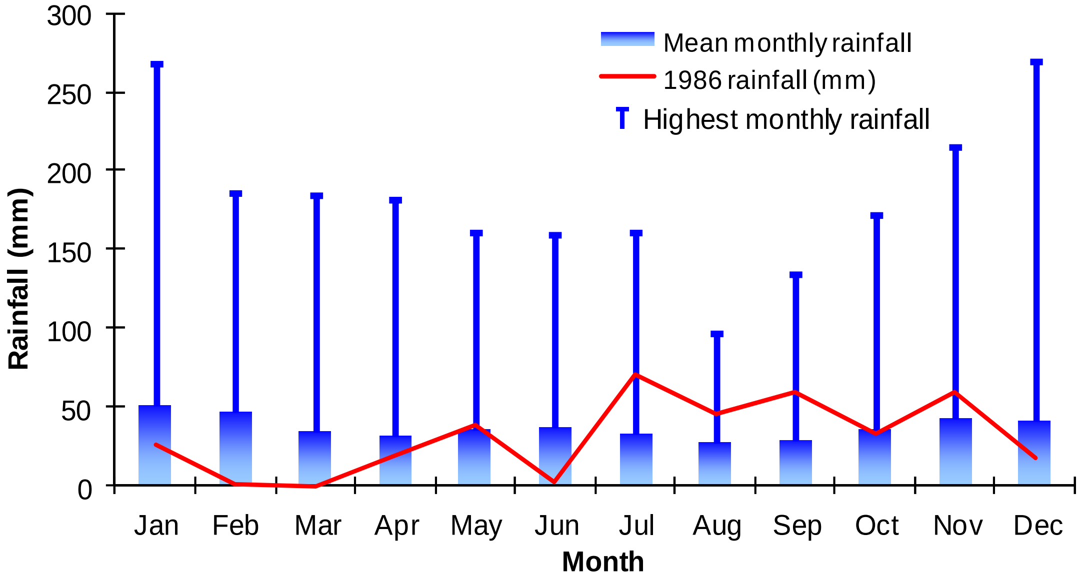
Some information is available about the water rat from other wetlands in the MDB. They live in permanent water bodies and can tolerate a range of water quality including high salinity. However, they cannot tolerate cold water (<5°C) or high levels of turbidity. As they collect most of their food from water (aquatic insects, fish, yabbies, mussels and frogs) turbidity levels can affect their ability to find food. They normally only breed once a year but when water and food are abundant they can breed up to three times a year. They nest at the end of tunnels in banks or sometimes hollow logs and riverine vegetation is an important feature of their habitat as it offers protection from predators.

Water rats were once commonly seen in the Macquarie Marshes Nature Reserve but sightings of them are now rare (Jones, pers. comm., 2008). In recent times they have only been found in river red gum woodlands with cumbungi (Shelly 2005). Water quality, food availability and riverine vegetation are important for their survival but it is not known which of these may be linked to their decline in the Marshes. If the Marshes are to be managed to ensure water rats remain a feature, a better understanding of their habitat requirements is needed.

3.10 Climate

The hydrology of rivers and wetlands is predominantly related to the climate of the catchment in which the system lies. The Macquarie Marshes has a semi-arid climate with hot summers and cool to mild winters and winter nights that can be cold. Mean monthly maximum temperatures for the period 1907 to 1975 at Quambone, located immediately east of the Macquarie Marshes, range from 16.6°C to 18.8°C in winter, to between 33.4°C and 34.6°C in summer. Mean monthly minimum temperatures range from 4.0°C to 5.2°C in winter, to between 18.2°C and 19.9°C in summer (BoM 2010).

Rainfall at the Macquarie Marshes tends to be uniformly distributed throughout the year, with a mean annual rainfall of 444.2 mm at Quambone for the period 1900 to 2008. However, rainfall is extremely variable, and this is particularly evident in the period between November and January when the highest monthly rainfall is in excess of 200 mm (Figure 9), which is up to five times greater than the mean monthly rainfall (BoM 2010). In addition, rainfall at the Macquarie Marshes also varies considerably between years. Annual rainfall at Quambone has ranged between 126 mm in 2002 and 1022.8 mm in 1950. In 1986, at the time of listing, the Macquarie Marshes Nature Reserve and U-block rainfall was above the long-term average for July, August and September and below average for December, January and February. Annual rainfall in 1986 was 371.5 mm (Figure 10) (Thomas et al*.* 2011).



Source: Bureau of Meteorology (BoM 2006)

Figure 9: Mean monthly rainfall and highest monthly rainfall at Quambone for the period 1900 to 2008

Despite substantial local rainfall in some years, the supply of water to the Macquarie Marshes is more dependent on rainfall within the catchment than localised rainfall. A pronounced climatic gradient exists from upstream to downstream along the Macquarie catchment, from highland regions with higher rainfall and less evaporation, to lowland areas with less rainfall and higher evaporation. The upper Macquarie catchment near the headwaters of the Macquarie River are sub-humid, with mean annual rainfall in the order of 600–1000 mm per year and mean annual potential evapotranspiration from 1400–1600 mm (BoM 2006). Mean annual rainfall figures at Bathurst and Mudgee, located in the upper Macquarie catchment, are in the order of 633.1 mm and 675.5 mm, respectively (Figure 10). This contrasts with the lower section of the Macquarie catchment in the region of the Macquarie Marshes, which receives on average only around 400–500 mm of rainfall per year and has around 2000–2400 mm of mean potential evapotranspiration per year.

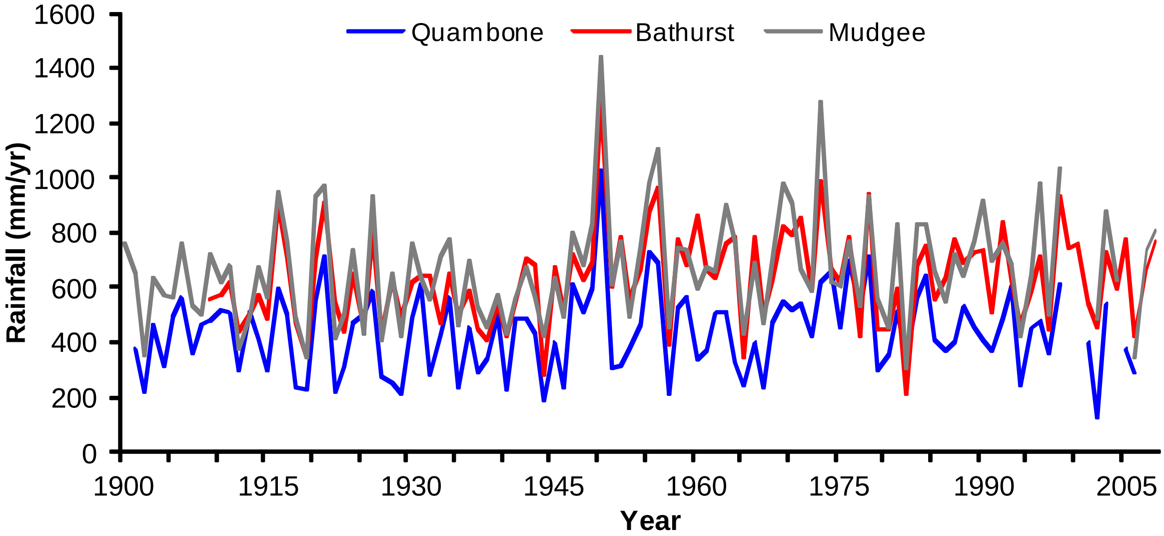


Figure 10: Local annual rainfall at Quambone between 1901 and 2008; Bathurst between 1909 and 2008; and Mudgee between 1900 and 2008

3.11 Geomorphology

Geomorphology describes the processes of change to landforms. Studies of the geomorphology of the Macquarie system indicate a long history of fluvial change related to climate and hydrology, with channels and marshes being formed and abandoned over timeframes ranging from several thousands of years to less than one hundred years. The Macquarie Marshes have existed in their current location and maintained their general wetland state for the last 6000 to 8000 years (Watkins & Meakin 1996; Yonge & Hesse 2002).

In the Macquarie Marshes geomorphology and hydrology are closely related. Downstream declines in discharge and stream power lead to the formation of distributary channels and broad, low-energy wetlands (Ralph & Hesse 2010; Yonge & Hesse 2009). At geological time scales hydrology is contributing to the morphology of the Macquarie Valley, while at a contemporary scale, geomorphology influences the hydrology of the Macquarie River and the Macquarie Marshes.

Geologically the upper Macquarie catchment is mainly composed of north–south aligned palaeozoic volcanic and sedimentary rocks of the Lachlan fold belt and north–west dipping mesozoic sediments of the Great Australian Basin. Neogene and quaternary sediments have filled the alluvial valley in the middle catchment and the lowland riverine plain (Oremland & Taylor 1978; Watkins & Meakin 1996).

The Macquarie alluvial plain, which includes the lower Macquarie River and Macquarie Marshes, is located in the southern portion of the Upper Darling Riverine Plain and is one of the low-gradient alluvial floodplains in the region that converge on the Barwon–Darling River. The majority of the surface of the plain is covered by cainozoic alluvium with depths of up to 100 m and includes several small inliers of palaeozoic rocks which are exposed as crests of buried hills (Watkins & Meakin 1996).

The Macquarie Marshes occur in an area of anastomosis, distributary development and extensive channel breakdown with floodplain wetlands on the lower reaches of the Macquarie River (Ralph 2008). The core wetlands of the Macquarie Marshes and the nature reserve Ramsar site are associated with the modern channel of the Macquarie River and its primary distributaries, while the alluvial plain consists of an arrangement of active and abandoned channels. Semi-permanent wetlands occur in regularly inundated areas on the alluvial plain, while dryland vegetation is associated with areas receiving irregular or no inundation. The modern floodplain of the Macquarie Marshes is broad and flat, reaching up to 25 km in width. The Marshes have a low longitudinal gradient of 0.0002 to 0.0004 and have a typical difference in vertical relief of less than two metres (Ralph 2008).

The modern river system is dominated by silt and clay-sized sediments that are accreting over alluvial materials deposited on the Macquarie Alluvial Plain by the late quaternary. Between two and nine metres of silts and clays have been deposited during the Holocene and mostly overlie the sandy clay palaeochannel sediments in the central parts of the Macquarie Marshes (Brereton 1994; Ralph 2008). Low alluvial ridges and shallow depressions on the alluvial plain are also indicative of palaeochannels and tend to border the western and eastern sides of the of the modern marsh area. In addition, some palaeochannels have been reoccupied through the capture of floodwaters and/or the diversion of younger channels into their paths (Ralph 2008).

The South Marsh, of which the southern section of the Macquarie Marshes Nature Reserve Ramsar site is a part, is characterised by low-sinuosity distributary channels and marsh channels, extensive unchannelised plains and a few small areas of active reed beds (Ralph 2008). The South Marsh contrasts with the North Marsh. The North Marsh is characterised by larger reed beds that receive water from a few main streams with many interconnected floodplain-surface channels (Ralph 2008).

Throughout the Macquarie Marshes, finer spatial scale geomorphological features include small channels, low levees, flood basins, depressions, shallow scour-lines and gilgai. These features may affect the distribution of floodwaters, particularly small–moderate magnitude events, across the floodplain and in turn affect processes of channel and floodplain sedimentation and erosion (Beadle 1948; Ralph 2008). Floodwaters may reconverge through small channels at the downstream limits of wetlands, but flow may also not be maintained with channels repeatedly breaking down into reed beds.

3.12 Hydrology – water distribution

Flows to the Macquarie Marshes come primarily from the Macquarie River fed by the major tributary rivers: the Fish, Cudgegong, Bell, Little and Talbragar rivers. The Macquarie River splits into several distributaries before reaching the Macquarie Marshes: the Marra, Crooked and Duck creeks and the Macquarie River. The Marthaguy and Merri Merri creeks flow in independently from the east while Marra Creek flows predominantly northwest from the Macquarie River. The main supply of water to the Macquarie Marshes comes down the Macquarie River, bifurcating after Marebone weir into the main channel of the Macquarie River and Marebone Break (Figure 11).

Once water reaches the Macquarie Marshes, the complex distributary system of creeks that supplies the Macquarie Marshes, branches out to different parts of the floodplain. Flows from Marebone Break separate into three creek systems: the Bulgeraga Creek, Gum Cowal/Terrigal Creek and the Long Plain Cowal (Figure 11). The Terrigal Creek system flows north through the 'Wilgara' Ramsar site and is then joined by the Marthaguy and Merri Merri creek system. The Bulgeraga Creek and Long Plain Cowal flow north towards the main channel of the Macquarie River. The Macquarie River branches into Monkeygar Creek and Buckiinguy Creek.

Monkeygar Creek channelisation eventually gives way to floodplain and marsh, allowing water to easily flow over the banks during floods. The Buckiinguy Break, the Old Macquarie River, Monkeygar Creek and Monkey Creek all have small distributary marsh channels that supply the floodplain making up the Macquarie Marshes. There are two major water systems in the southern section of the nature reserve. The Macquarie River (known locally as the Old Macquarie River) flows north along the western boundary of the southern section of the nature reserve. The Macquarie River loses its channel in the floodplain of the southern section of the nature reserve before reforming as the Old Macquarie channel downstream. The Monkeygar Creek system flows north through the eastern section of the southern nature reserve. The Old Macquarie River no longer flows regularly and the Monkeygar system is the major water carrier in the area. An erosion channel, known as 'The Breakaway', has formed, which flows in a westerly direction from the Monkeygar Creek to the Old Macquarie River. Another channel off The 'Breakaway' is now increasingly carrying water from the Monkeygar into the Old Macquarie River, bypassing the erosion control structures that were put in place in 2002 (NPWS 2004).

The Old Macquarie River, Monkeygar Creek and Bulgeraga Creek join just upstream of the U-block and reform the Macquarie River, which then flows into the northern section of the nature reserve. It continues to the north before again breaking down in an anastomosing system. The braided channels of Bora Channel and subsequently Ginghet Creek run through the western half of the northern nature reserve, while the Macquarie breaks down in the main reed bed then reforms in the northern part of the reserve. During high flows, water flows through the Macquarie Marshes can reach the Darling River. The northern section of the Macquarie Marshes Nature Reserve has a constructed channel that bypasses the Macquarie Marshes on its eastern side (Bypass Channel) which takes low flows downstream most of the time. During large floods the Long Plain Cowal also provides flows to the northern section of the nature reserve (Figure 11).

The Macquarie Marshes are a representative example of an inland floodplain wetland in the MDB relying on water from a higher rainfall upper catchment and having extensive and changeable wetlands in the semi-arid lowland reaches. They are unique in terms of both their size (approximately 200,000 ha) and their diversity of wetland types. Any change to the process of water distribution to the Marshes will inevitably mean changes for the wetlands receiving that flow.

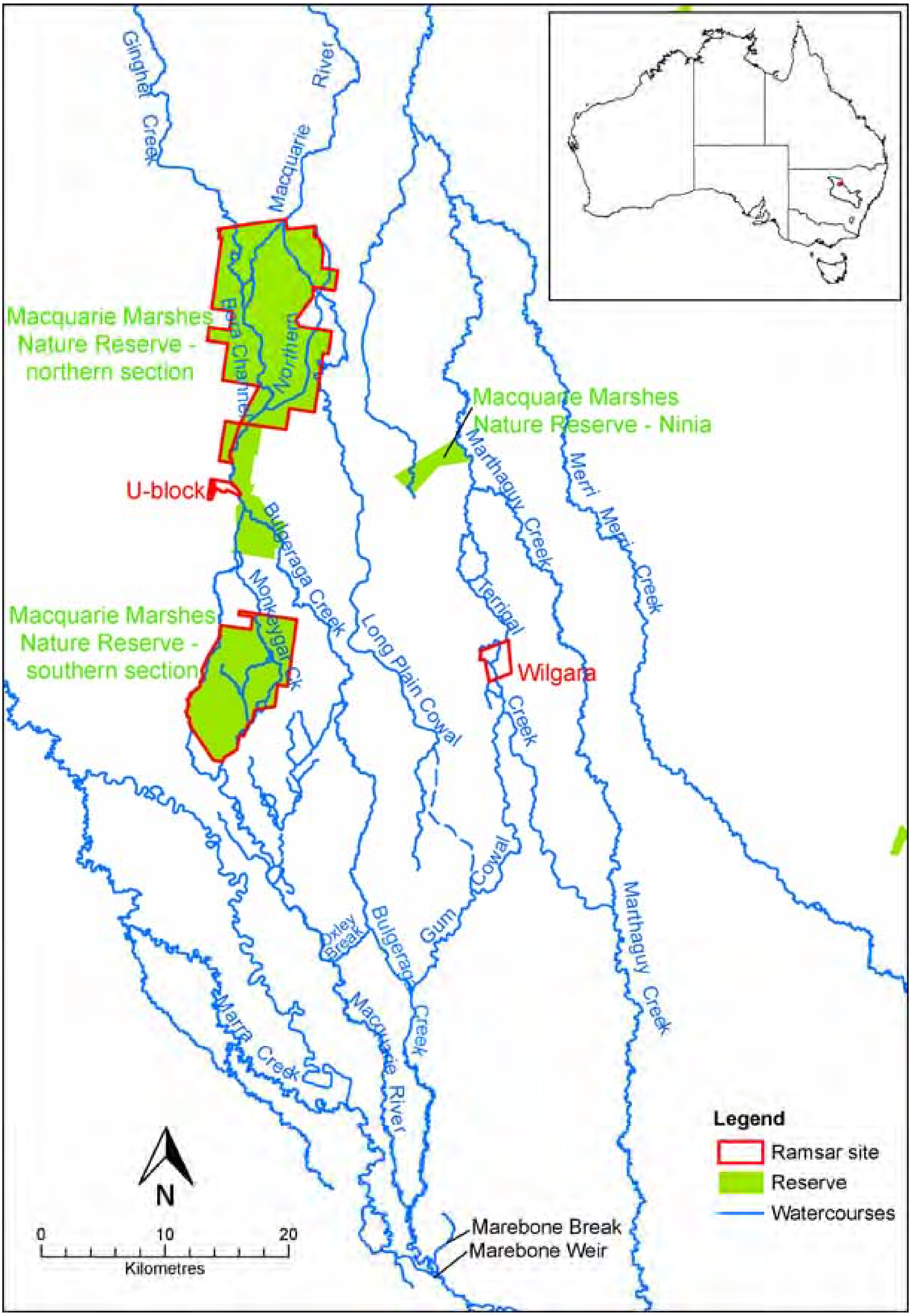


Figure 11: Location of the Macquarie Marshes Ramsar site (green) within the Macquarie–Bogan Catchment. Dashed lines show path of flows during large floods

3.13 Hydrology – flow regime

The natural flow regime of a river is driven by climate and available runoff, the latter being primarily influenced by geology, topography and vegetation cover in the upstream catchment. The main components of flow regime are size, frequency, duration, timing and rate of change of flows (LeRoy et al. 1997; Puckridge et al. 1998). Flow size (magnitude) is the amount of water moving past a fixed point in a certain time; frequency refers to how often a flow of a certain size occurs; duration is the length of time of a flow; timing refers to the regularity and predictability of flows; and rate of change refers to how quickly flows change from one size to another (LeRoy et al. 1997). Catchment topography, key components of the flow regime (e.g. bank-full discharge volume and stream power) and riparian vegetation usually determine the type, size and number of river channels in a fluvial system.

Flow regime organises, drives and defines physical and ecological processes in rivers (Bunn & Arthington 2002; LeRoy et al. 1997). Natural flow regimes vary between different regions, and between different rivers. For example, some rivers have little natural flow variability, some have high variability that may be seasonally predictable, and others have high, unpredictable variability, with high or low flows occurring at any time of year (LeRoy et al. 1997; Puckridge et al. 1998). The variability of natural flows creates diversity of river and floodplain forms and habitats, essential for maintaining the ecological function and health of riverine and floodplain ecosystems (LeRoy et al. 1997; Ward 1998).

Flow can be described broadly at three scales. Flow pulses are single events, their influence generally lasting for less than a year. The sequence of flow pulses becomes the long-term pattern of flooding and drying, or flow history and influences the system at scales ranging from months to centuries. The term ‘flow regime’ refers to a statistical generalisation of flow over a period of time (Puckridge et al. 1998; Arthington & Pusey 2003; Thoms et al. 2004).

Long-term average flows are misleading when applied to riverine and wetland ecosystems such as the Marshes that need relatively frequent small and medium flows in addition to large floods (Johnson 2005). For example, if the regulated flow regime comprises constant low flows in channel habitats, the long-term average may show reasonable volumes of water in the system, yet the wetland will remain dry as the low flows fall below the commence-to-flow thresholds for overbank flooding of floodplain habitats.

Flow to the Macquarie Marshes is delivered by the Macquarie River. Gauges on the river at Dubbo, Warren and Oxley measured flow between 1914 and 2000. Total flow is highly variable, reflecting the variable rainfall in the catchment (see Figures 12, 13 and 14).

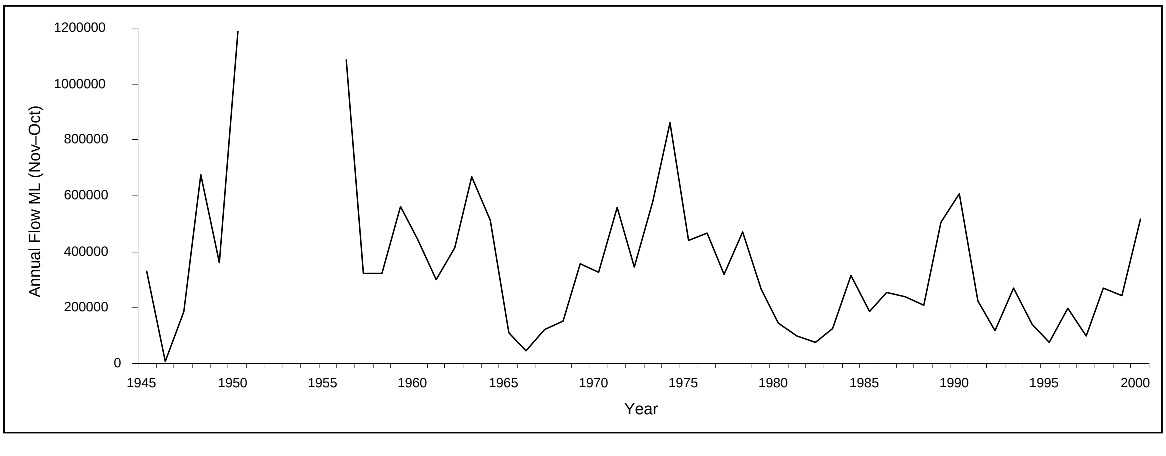


Figure 12: Total annual flow (Nov–Oct) at Oxley 1945–2000; gaps indicate missing data

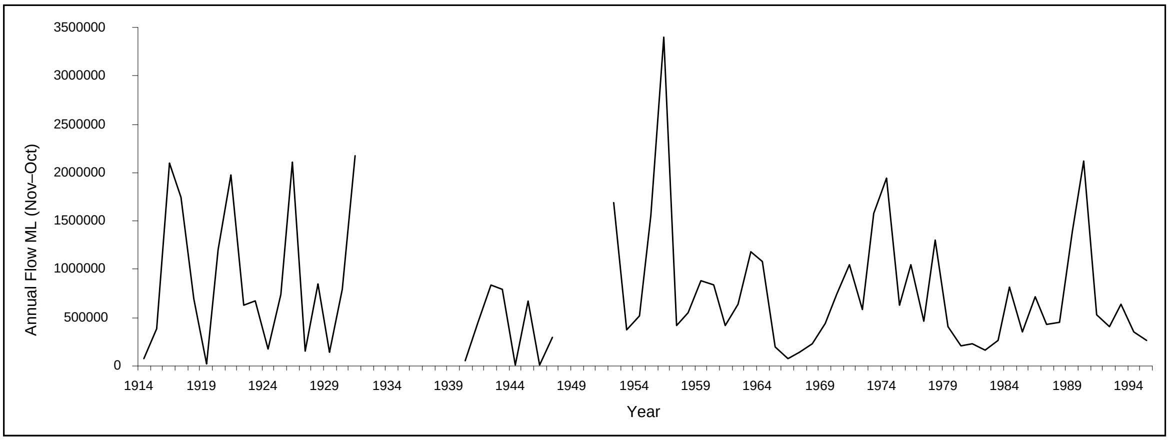


Figure 13: Total annual flow (Nov–Oct) at Warren 1914–1995; gaps indicate missing data

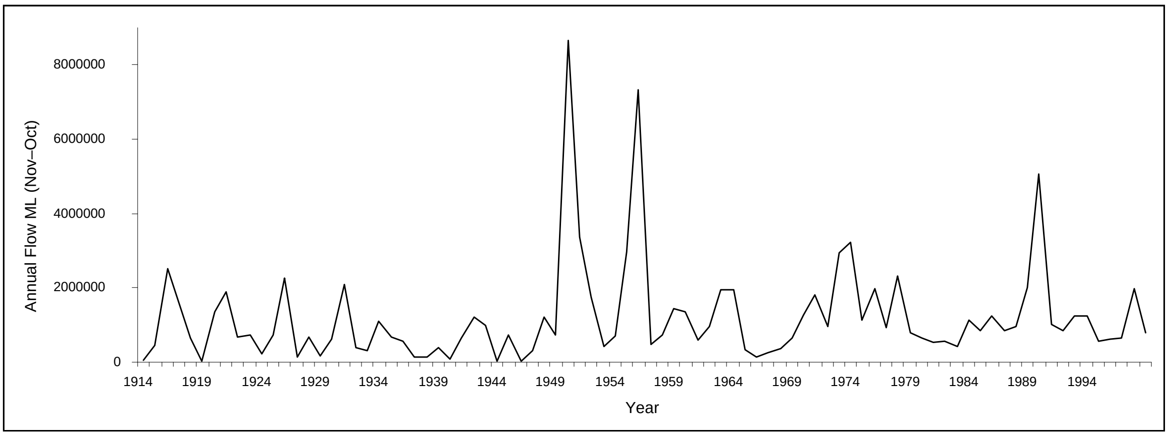


Figure 14: Total annual flow (Nov–Oct) at Dubbo 1914–1999

There is little analysis of the flow regime of the Macquarie River and its relationship with the Marshes. It is known that the area flooded in the Macquarie Marshes is highly variable among years and that flood extent is tightly correlated with annual flow at the Oxley gauge (R^2=0.859, p<0.001) but not with local rainfall (p=0.497) (Kingsford & Thomas 1995).

Flow regime in the Macquarie River has a long history of natural variability. In particular, intra-seasonal, interannual and interdecadal climatic fluctuations may cause significant hydrological variability (Ralph & Hesse 2010). Flow regime is known to be strongly influenced by Indo–Pacific fluctuations in sea surface temperature, air pressure and rainfall, related to the Madden–Julian Oscillation (Kessler & Kleeman 2000), El Niño–Southern Oscillation (ENSO, Chiew et al. 1998; Walker et al. 1995), Interdecadal Pacific Oscillation (IPO, Power et al. 1999; Verdon & Franks 2005; Verdon et al. 2006) and Pacific Decadal Oscillation (PDO, Power et al. 1999; Verdon et al. 2004). Figure 15 shows the relationship between flows at Oxley gauge and the Southern Oscillation Index (SOI) and the Interdecadal Pacific Oscillation Index (IPOI). In particular it is evident that large flow events generally coincide with positive phases of the SOI, which is a measure of El Niño–Southern Oscillation intensity, and negative phases of the IPOI, which is a measure of the intensity of the Interdecadal Pacific Oscillation.

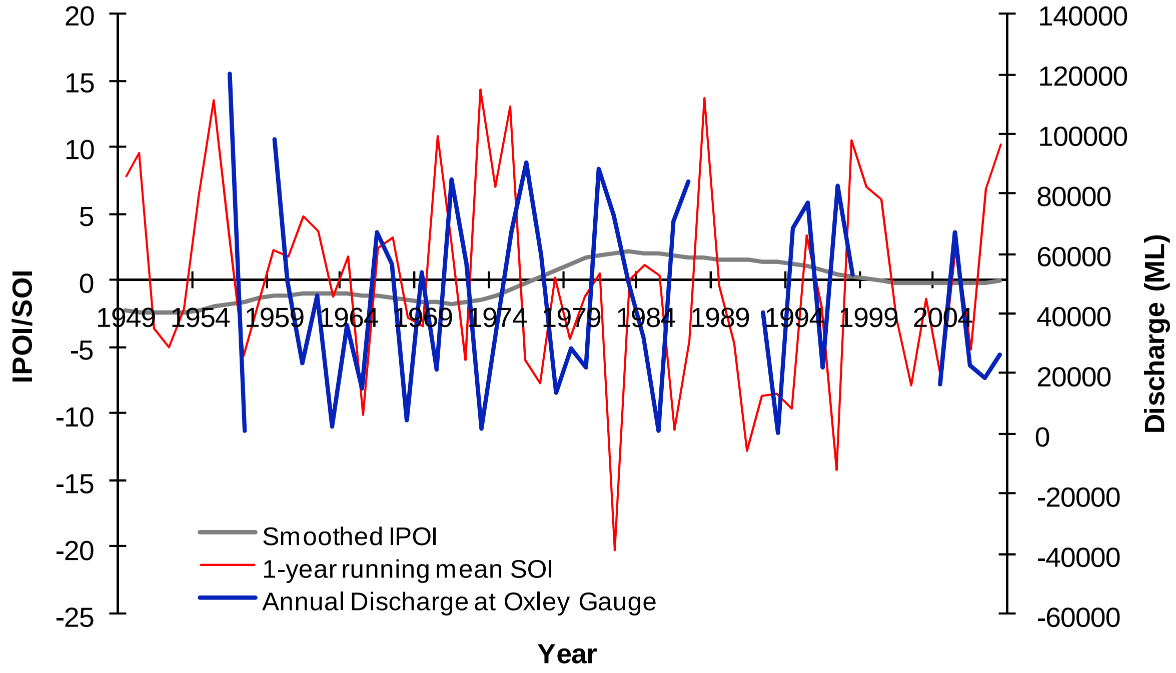


Figure 15: Relationship between annual discharge at Oxley gauge (ML), El Niño–Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO)

While there is little available information on the main components of flow regime, including size, frequency, duration, timing and rate of change of flows, there is some information available about the extent of flooding or inundation at the Macquarie Marshes. Annual inundation as an integrated response to water and vegetation was mapped in the Macquarie Marshes using one near spring landsat image (MSS and TM imagery) per year over 28 years (1979–2006). Annual inundation within the Macquarie Marshes study area (an area larger than the Macquarie Marshes Nature Reserve and U-block) was highly variable and ranged from 4333 to 131,458 ha. Between 1979 and 2006, the five ranked larger floods mapped were in 2000, 1989, 1990, 1998 and 1984. Half of the twelve smallest inundations occurred consecutively after the 2000 flood. There was no significant linear trend in inundated area over time but there was a correlation between magnitudes of antecedent flows (cumulative 30 days and 180 days prior to image acquisition) and inundated areas (Thomas et al. 2011). Figure 16 shows the area of inundation (ha) in the Macquarie Marshes Nature Reserve and the flow of water (ML) measured at the Oxley gauge 30 days prior to the inundation mapping period.

Describing the flow regime of a river or wetland is an important step in setting management and restoration goals because it plays such a central role in determining the composition, structure and function of aquatic, wetland and riparian ecosystems (Richter et al. 1996). However this concept does not mean a return to pre-regulation and pre-development flow regimes as this information is not available for the Macquarie River and Marshes. It does advocate the retention or re-introduction of flow variability as a specific aim of river and Ramsar site management.

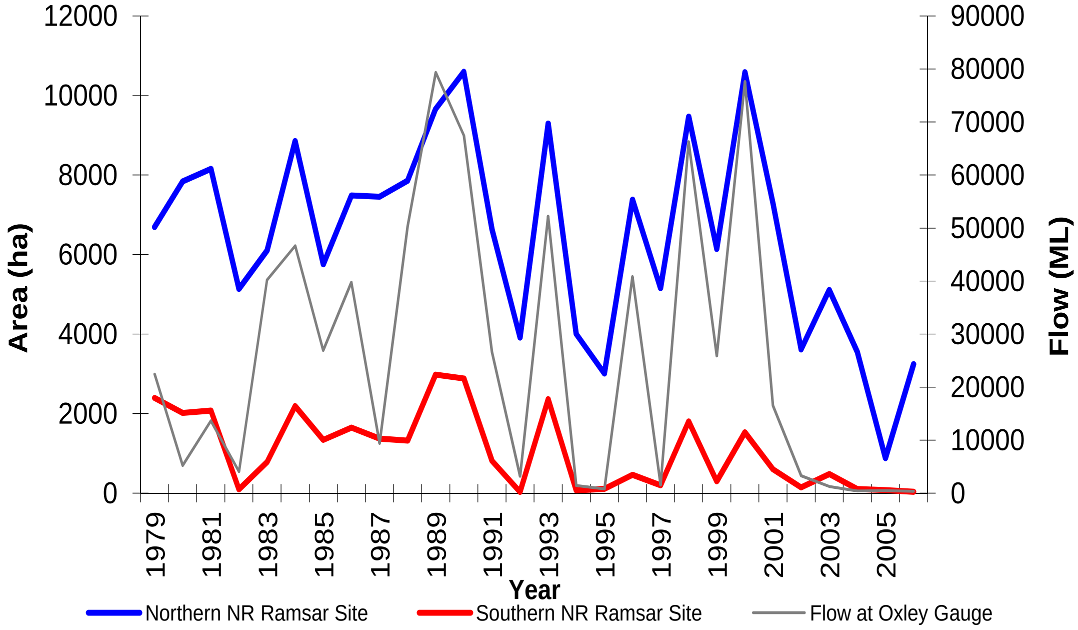


Figure 16: Area of inundation (ha) in the Macquarie Marshes Nature Reserve and the flow of water (ML) measured at the Oxley gauge 30 days prior to the inundation mapping period

3.14 Hydrology – groundwater

The watertable in the Macquarie Marshes rises and falls with floods and droughts (Brereton 1993). Following the floods of 1999–2000 groundwater levels in parts of the north Marsh were observed to be within 1–2 metres of the surface. In 2006, following five years without significant floods in the Marsh, the groundwater level in the same areas was observed to be between 6–8 metres below the surface (Jones, pers. comm., 2007). This shows a clear link between surface water flooding and major recharge events to the groundwater system in the lower Macquarie River (CSIRO 2008).

Large amounts of salt are bound in saline clays and dissolved in saline groundwater in the quaternary aquifers and in the underlying regolith beneath the Macquarie Marshes. Recent mapping of groundwater shows a thin resistive layer only a few metres thick, with fresh pore water over-lying this very large salt store throughout the Marshes (BRS 2009).

Use of saline groundwater has been proposed as causing the loss of semi-permanent wetland in the North Marsh, particularly river red gum woodland and forest (Bacon 1996; Hogendyk 2007). The Australian Nuclear Science and Technology Organisation was commissioned to provide insight into groundwater–surface water interactions in the Macquarie Marshes and to identify sources of water used by riparian vegetation, to provide an improved understanding of wetland responses to water stresses (Hollis et al. 2009). The report concluded that because of the high EC values of the saline groundwater it is not likely to be a source of water for transpiration. The report goes on to say:

> *The original hypothesis that trees may access groundwater during drought thereby lowering the water table would likely be untrue in those areas of the Macquarie Marshes where we have identified high salinity, shallow groundwater bodies – preliminary data suggest that in these areas, trees only access fresher soil waters from the unsaturated zone. When this source of water is less available (during periods of extended drought or when the extent of upstream diversions substantially reduces the frequency and degree of overbank flow) the trees become stressed.*
>
> (Hollis et al. 2009)

On-ground works that increase the permanence of water bodies within the Marsh are also likely to have local impacts on groundwater. Maintaining the Macquarie Marshes over the long term depends on providing enough freshwater to maintain a thin layer of freshwater for plants to utilize (BRS 2009).

Brereton (1994) reported that river red gums were dying in Hunt’s Woodland, an important waterbird breeding area in the northern section of the Macquarie Marshes Nature Reserve. He concluded that this was probably due to the combination of its location on a shallow saline groundwater aquifer, constant flows due to altered flow regime in the Macquarie River, and water ponding caused by the construction of the northern by-pass channel. In 1991 gates were placed on the siphons that ran under the by-pass channel to prevent water ponding in Hunt’s Woodland. During the subsequent decade little water reached this area in the North Marsh and by 2006 approximately 30 per cent of the trees in Hunt’s Woodland were dead and the remainder stressed by lack of freshwater (DNR 2007).

3.15 Energy and nutrient cycling

Organic matter, nutrients and aquatic biofilms comprised of algae, bacteria and fungi underpin the secondary production of microinvertebrates, macroinvertebrates, fish and waterbirds in arid zone floodplain food webs. Organic matter and nutrients build up in floodplain sediments and depositional patches in river and creek channels as leaf litter is deposited and via the senescence and decomposition of terrestrial and aquatic plants and animals.

During dry phases organic material is broken down and retained within the soil. Flooding events inundate these soils releasing nutrients to the water. Loss of flooding in the Macquarie Marshes has diminished the reservoir of organic matter and dormant biota in floodplain sediments. Research by Jenkins and Wolfenden (2006) has shown that soils not flooded since 1990 (14 years) had lost significant amounts of organic matter and microinvertebrate diversity and density compared to those soils last flooded in 2000 (four years) and 2003 (one year).

Recent work by Kobayashi et al. (2010) investigated longitudinal spatial patterns in water quality, dissolved inorganic and organic matter, phytoplankton, zooplankton, bacteria, primary production and respiration in relation to flow pulses in channels of the Macquarie Marshes. Overall, two distinct ecological zones were identified within the Marshes – these being the upstream zone with relatively high levels of dissolved oxygen, turbidity and diatoms, and the downstream zone with relatively high levels of nutrients, dissolved organic matter, cyanobacteria, planktonic bacteria, protozoans and cladocerans.

4 Ecosystem benefits and services

Ecosystem benefits and services are the economic, social and cultural benefits that people receive from ecosystems, and the ecological services that are very important even though humans may not benefit directly (Millennium Ecosystem Assessment 2005a). By describing benefits and services the relationship between the ecological system and the social system is also described and the issues the ecological system faces are highlighted. Table 8 outlines the four main categories of ecosystem benefits and services as defined by the Millennium Ecosystem Assessment (2005a, 2005b). Farming, stock watering, irrigation, primary production and aquatic food provision do not occur within the nature reserve now but have been included as services/benefits, recognising that up until 1990, blocks of the nature reserve were leased for grazing, and recognising the connectivity of the nature reserve and the broader Macquarie Marshes and the role of the nature reserve in the provision of water and carbon downstream of the Ramsar site. Cattle and sheep grazing continues to be a primary service of U-block.

Table 8: Wetland ecosystem benefits and services of the Macquarie Marshes

Ecosystem service or benefit	Description	Ecosystem component or process	Relevant Ramsar criteria
Provisioning services			
Domestic farm water supply	The Macquarie River and Marshes provide suitable domestic farm water supply	Hydrology	Criterion 1 – a benefit from a natural wetland
Stock watering	Provide suitable water supply and quantity for production of healthy livestock	Hydrology	Criterion 1 – a benefit from a natural wetland
Irrigation	Provides suitable water supply for irrigation of crops, pastures, parks, gardens and recreational areas	Hydrology	Criterion 1 – a benefit from a natural wetland
Primary production	Provides fertile land and water for primary production, in particular cattle and sheepgrazing and broad scale agricultural crops such as cotton and wheat	Hydrology Geomorphology Wetland vegetation	Criterion 1 – a benefit from a natural wetland
Provision of aquatic foods for human consumption	Some provision of aquatic foods such as fish and yabbies suitable for human consumption	Hydrology Geomorphology Fish, aquatic invertebrates	Criteria 1, 3 & 7
Genetic resources	Largely unknown role in preserving a natural reservoir for biological diversity and providing genetic resources that can support colonisation, contribute to maintaining intra-species diversity and allow for research and development	All plant and animal species	Criteria 2, 3 & 7

Table 8 continued

Ecosystem service or benefit	Description	Ecosystem component or process	Relevant Ramsar criteria
Regulating services			
Maintenance and regulation of hydrological cycles and regimes	The Marshes regulate hydrological processes and cycles, including retaining and retarding flows, maintaining groundwater–surface water balances through recharge / discharge processes and providing habitats and refugia for wetland dependent species	Hydrology Geomorphology Wetland vegetation	Criteria 1, 3 & 4
Maintenance and regulation of climate	Largely unknown role in regulation of greenhouse gases, temperature, precipitation and other climatic processes	Wetland vegetation	Criterion 1 – a benefit from a natural wetland
Maintenance and regulation of local climate	Possible influence on local climatic effects, for example, through evaporation of water that can help to form mist, fog and rain and provide a local cooling effect	Hydrology Geomorphology Wetland vegetation	Criterion 1 – a benefit from a natural wetland
Biological control of pest species and diseases and support of predators of agricultural pests	Provision of habitat for animals that can control pests and diseases. Some waterbirds, frogs and fish reduce the abundance of disease vectors by eating mosquitoes or their larvae. The Marshes also provide habitat for predators that control agricultural pests such as ibis feeding on grasshoppers	Birds Frogs Fish	Criteria 1, 3 & 4
Pollution control and detoxification through trapping, storage and treatment of contaminants	Role in slowing flow, trapping and assimilating sediments, nutrients and other contaminants, and 'buffering' the amount of contaminant transfer that may occur during flow events. Diffuse sources of pollution include stormwater runoff from urban or agricultural land, irrigation areas, degraded landscapes or urban stormwater management systems. Point sources include discharges from sewage treatment plants or industry	Hydrology Geomorphology Wetland vegetation	Criterion 1 – a benefit from a natural wetland
Natural hazard reduction	Role in reducing flood water impacts (for example, reducing peak levels and velocity), storm protection, riverbank stabilisation and reduction in fire intensity and frequency when wet	Hydrology Geomorphology Wetland vegetation	Criterion 1 – a benefit from a natural wetland

Table 8 continues overleaf…

Table 8 continued

Ecosystem service or benefit	Description	Ecosystem component or process	Relevant Ramsar criteria
	Cultural services		
Science and education	Provides features with educational and scientific interest for scientific research and wetland education programs	Hydrology Geomorphology All plant and animal species	Criteria 1, 2, 3, 4 & 5
Aesthetic amenity	Provision of 'iconic' natural scenery and attractive landscapes that people can view, enjoy or otherwise appreciate in a semi-arid environment. It also supports wetland characteristics of high value such as waterbird communities	Hydrology Geomorphology All plant and animal species	Criteria 1, 3, 4 & 5
Spiritual and inspirational	The Marshes are an iconic natural area with significant cultural values. Many people have significant links with the Marshes through historic connections, land and water management roles, living and/or working in the near vicinity, or they are involved with an environmental or a primary production group. Aboriginal cultural values relate to the deep history of Aboriginal interaction with the wetlands and the values, interests and aspirations of contemporary Aboriginal communities with custodial relationships to the wetlands. Aboriginal cultural values relate to specific places, specific plants and animals, and also the wetlands landscape as a whole	Hydrology Geomorphology All plant and animal species	Criteria 1, 2, 3, 4 & 5
	Supporting services		
Nutrient cycling	The Marshes provide a critical service in the uptake, transformation, processing, storage, movement and re-uptake of compounds that promote biological growth or development, including repeated pathways of particular nutrients or elements from the environment through one or more organisms back to the environment. This includes primary production and the carbon, nitrogen and phosphorus cycles	Hydrology Geomorphology All plant and animal species	Criteria 1, 3 & 5
Sediment trapping, stabilisation and soil formation	Provides trapping and stabilisation of sediment and accumulation of organic matter that allows the formation of fertile self mulching clays in the Marshes	Hydrology Geomorphology All plant and animal species	Criteria 1 & 3

Table 8 continued

Ecosystem service or benefit	Description	Ecosystem component or process	Relevant Ramsar criteria
Supporting services continued			
Biodiversity	Supports a high diversity of wetland and semi-arid zone species, communities, habitats, and geomorphic features	Hydrology Geomorphology All plant and animal species	Criteria 1, 3 & 5
Distinct or unique wetland species	Supports species which may be common but are also notable or otherwise important, such as keystone or indicator species. These may also include iconic species such as those species which are especially important to a community, often in a symbolic sense or by association (such as colonial waterbirds)	Plant and animal species	Criteria 1, 3 & 5
Threatened species and communities	Supports listed threatened species and endangered ecological communities (see Table 3)	Plant and animal species	Criterion 2
Ecological connectivity	Supports another wetland or wetland aggregation, terrestrial ecosystem, or species transfer/movement, including supporting another wetland's hydrological processes, providing a pathway for seed dispersal and interconnected habitat for waterbirds, migratory birds and woodland birds	Hydrology Geomorphology All plant and animal species	Criteria 1, 2, 3, 4 & 5

5 Critical ecosystem components, processes, benefits and services

According to the national framework for describing ecological character (DEWHA 2008) the critical components, processes, benefits and services are a subset that are:

- important determinants of the site's unique character
- important for supporting the Ramsar criteria under which the site was listed
- sensitive to change over short or medium time scales (<100 years), and
- those for which change will cause significant negative consequences if it occurs.

In this ECD the critical components and processes that have been selected are those core attributes that define the site's character (values for which the site was Ramsar listed) and enable the ecological system to function. For example, extensive river red gum woodlands are a critical component of the northern Macquarie Marshes Nature Reserve but it is hydrology and in particular flow regime which is critical for their functioning. If extensive river red gum woodlands are maintained then so are waterbird breeding areas, woodland bird habitat, native fish habitat and many other wetland plant and animal species. The same argument applies to each of the vegetation communities.

Critical benefits and services have been identified to highlight not only the most important ecological services but also the social services. These social services are often overlooked in ecological character descriptions but they are important to understand as they provide the basis for a successful management plan and communication strategy.

The critical ecosystem components, processes, benefits and services listed here reflect our current understanding and should be further developed as both management and science gain a better understanding of the complexity of the Macquarie Marshes ecological and social system.

5.1 Wetland types and vegetation

The Macquarie Marshes Nature Reserve was listed as a Ramsar site because of its diversity of wetland types. River red gum woodland, common reed reed beds and water couch marsh are critical, as their occurrence justifies the site against Ramsar criterion 3. Wetland vegetation has been divided into semi-permanent wetland vegetation and floodplain wetland vegetation to distinguish vegetation communities reliant on frequent flooding from vegetation communities requiring less frequent flooding. Table 9 lists the critical components, processes, benefits or services in 1986 and ecological requirements of wetland types and vegetation communities as described by Paijmans (1981) and Wilson (1992).

5.2 Aquatic ecological community

Waterbird breeding is dependent on adequate food being available both for adult birds to reach breeding condition, and chicks to be fledged (Marchant & Higgins 1990). Critical food supply is provided by the aquatic ecological community. This community covers all native fish and aquatic invertebrates (NSW *Fisheries Management Act 1994*). Aquatic invertebrates also play a critical role in energy and nutrient cycling which maintains biological diversity in the Marshes (Jenkins & Wolfenden 2006; Geddes & Puckridge 1989). Table 10 on page 54 lists the basic requirements for maintaining this aquatic community and the nationally listed threatened species, Murray cod (EPBC Act).

Table 9: The ecological requirements of critical components, processes, benefits and services – wetland types and vegetation in Macquarie Marshes Nature Reserve and U-block

Critical component	Critical process, benefit or service	Ecological requirements [1]	Location	Approx. area (ha) in 1991 [2]
Semi-permanent wetland vegetation				
River red gum woodland and forests	Hydrology – flow regime Primary production	Provide water to inundate for at least 5 months between July and February, at least 7 years in 10. Ensure appropriate grazing management.	Bora Channel Macquarie Channel Hunt's Woodland Southern reserve U-block	4000 2000 100 210 85
Common reed reed beds	Hydrology – flow regime Geomorphology Primary production	Tolerates a range of flood frequencies from permanent inundation to infrequent flooding. To maintain vigour 1–2 year flood frequency is required. Ensure appropriate grazing management. Information is not available about the preferred timing of flooding.	Louden's Lagoon Southern reserve	2150 1200
Cumbungi rushland	Hydrology – flow regime Geomorphology	Provide water to inundate between July and December for at least 8 years in 10. Ensure appropriate grazing management.	Bora Channel Old Macquarie Channel	260 20
Water couch marsh	Hydrology – flow regime Geomorphology Primary production	Provide water to inundate for at least 6 months of the year, 8 years in 10. Ensure appropriate grazing management. Spring/summer flooding provides optimal conditions for growth (Rogers & Ralph 2010).	Louden's Lagoon / northern reserve Southern reserve	900 220
Mixed marsh grassland	Hydrology – flow regime Geomorphology Primary production	Provide annual flooding for at least 8–10 months to a depth of 1 metre between July and February.	U-block	50
Lagoons	Hydrology – flow regime Geomorphology	Many of the deep lagoons are semi-permanent requiring annual flooding, while shallow lagoons dry out more regularly. Duration of inundation is not known, however draw down does expose shorelines and provide habitat for shorebirds.	Louden's Lagoon Southern reserve	60 30

Table 9 continues overleaf…

Table 9 continued

Critical component	Critical process, benefit or service	Ecological requirements [1]	Location	Approx. area (ha) in 1991 [2]
Floodplain wetland vegetation				
Coolibah woodland and black box woodland	Hydrology – flow regime Primary production	Provide water to inundate 3–4 years in 10 between December and April. Ensure appropriate grazing management.	Northern reserve Southern reserve U-block	600 100 20
Lignum	Hydrology – flow regime Primary production	Provide water to inundate for at least 3 months between September and March, at least 5 years in 10. Ensure appropriate grazing management.	Salt Paddock	200

[1] Roberts & Marsten 2000 and Rogers et al. 2009
[2] Bowen and Simpson 2010

Table 10: The ecological requirements of critical components, processes, benefits and services – the aquatic ecological community in the Macquarie Marshes

Critical component	Critical process, benefit or service	Ecological requirements
Aquatic invertebrates	Hydrology – flow regime Energy and nutrient cycling Threatened species and communities	Provide water to inundate for at least 3–5 months in late winter or spring (Jenkins 2006). Floods should occur every 1–2 years in core areas to sustain diverse and productive colonisation sources and no longer than every 10 years. Beyond this threshold the dormant stages of crustaceans decline (Jenkins et al. 2007). Crustaceans underpin successful recruitment of native fish and waterbirds.
Fish species diversity	Hydrology – flow regime Threatened species and communities	Provide water to inundate for at least 3–4 months in late winter or spring. Floods should occur every 1–2 years in core areas. High (natural) flows in channel habitats in late winter–spring will induce spawning, protect eggs and promote larval and juvenile fish survival. Warm temperatures are important. High stable water levels should continue for two months after the flood pulse with a gradual recession to prevent wash out of larvae and prey from nursery habitats (Jenkins 2006).
Murray cod (EPBC Act)	Hydrology – flow regime Threatened species and communities	Found in waters up to 5 m deep and in sheltered areas with cover from rocks, timber or overhanging banks. Migrates upstream usually when flooding and prior to spawning in late spring and early summer when the water reaches a temperature of 16–21°C. This change in temperature provides the stimulus for spawning (Kearney & Kildea 2001).

5.3 Birds

The Macquarie Marshes regularly support many thousands of birds including waterbirds and waders. Waterbird abundance and diversity, waterbird breeding and the ability to support many threatened bird species were critical for listing in 1986 and met Ramsar criteria 2, 3, 4 and 5. Table 11 lists the broad ecological requirements of birds in the Macquarie Marshes Nature Reserve including U-block.

5.4 Provisioning service – primary production

At the time of Ramsar listing and up until 1990, the Macquarie Marshes Nature Reserve was divided into leased blocks that were used for grazing. The nature reserve is no longer used for primary production, however cattle and sheep production continues to be an important primary industry for landholders that neighbour the reserve and for U-block.

There is some evidence, both scientific and anecdotal, that grazing by cattle can have both beneficial and detrimental effects on wetland vegetation. For example, river red gums germinate more successfully in grassy conditions but tree establishment benefits from the removal of grass by cattle grazing (Dexter et al. 1986). Middleton (1990) reported that water couch does not tolerate grazing when water stressed (that is when dry), or persistent grazing when under water, however there is emerging evidence that managed grazing at the right time can promote water couch dominance (Wilson et al. 2009). Water couch and common reed are frost sensitive and dry off every winter. Careful grazing promotes water couch and common reed which in turn provides habitat for birds (Garry Hall, pers. comm., April 2010). There is anecdotal evidence that common reed does not tolerate grazing under dry conditions or when new shoots are emerging, but responds well to grazing at other times.

5.5 Supporting service – threatened species and communities

The Macquarie Marshes Nature Reserve including U-block supports four internationally endangered or vulnerable species (IUCN Red List 2011), three nationally endangered or vulnerable species (EPBC Act) and 34 species regarded as endangered or vulnerable in NSW (TSC Act, *Fisheries Management Act 1994*). They are listed in Table 3 under the criteria for Ramsar listing.

Table 11: The ecological requirements of critical components, processes, benefits and services – birds in Macquarie Marshes Nature Reserve and U-block

Critical component	Critical process, benefit or service	Ecological requirements
Waterbird abundance and diversity	Hydrology – flow regime Energy and nutrient cycling Threatened species and communities	Maintain all critical components listed under wetland types/vegetation communities. Maintain critical components listed under aquatic ecological community.
Waterbird breeding	Hydrology – flow regime Energy and nutrient cycling Threatened species and communities	Maintain all critical components listed under wetland types/vegetation communities. Maintain critical components listed under aquatic ecological community. The minimum flow requirement for successful colonial nesting is flooding of sufficient volume and duration to inundate colony sites and feeding areas for at least five consecutive months between August and March (Kingsford & Auld 2005).

Table 11 continues overleaf…

Table 11 continued

Critical component	Critical process, benefit or service	Ecological requirements
Migratory birds and waders	Hydrology – flow regime Energy and nutrient cycling Threatened species and communities	Little is known of their ecological requirements in the Marshes. Provide open water lagoons for migratory waders visiting during summer. Maintain all critical components listed under wetland types/vegetation communities. Maintain critical components listed under aquatic ecological community.
Australian painted snipe (EPBC Act)	Hydrology – flow regime Threatened species and communities	Breeding habitat requirements may be quite specific: shallow wetlands with areas of bare wet mud and both upper and canopy cover nearby. Nest records are all, or nearly all, from or near small islands in freshwater wetlands (Rogers et al. 2005). Maintain critical components listed under wetland types/vegetation communities.
Superb parrot (EPBC Act)	Hydrology – flow regime Threatened species and communities	Mainly inhabits and breeds in forests and woodlands dominated by eucalypts, especially river red gums and box eucalypts such as yellow box or grey box (Webster 1998). Maintain critical components listed under wetland types/vegetation communities.
Australasian bittern (IUCN Red List 2011)	Hydrology – flow regime Threatened species and communities	Favours wetlands with tall dense vegetation (common reed, cumbungi, tall rush) and forages in still, shallow water up to 0.3 m deep, often at the edges of pools or waterways, or from platforms or mats of vegetation over deep water (Marchant & Higgins 1990). Maintain critical components listed under wetland types/vegetation communities.

6 Macquarie Marshes conceptual models

Conceptual models provide a representation of the current knowledge and understanding of a resource, in this case a wetland type. They integrate the current understanding of ecosystem components, processes and benefits, identify threats and illustrate connections between indicators and ecological processes (Gross 2003). Models can be used as a basis for discussion or planning, and can also help to illustrate gaps in knowledge, and prioritise areas that require further research or monitoring.

The conceptual models for the inter-relationships among components and processes that operate in the Macquarie Marshes and its catchment are provided by a flow diagram and two conceptual diagrams in Figures 17a, b and c. The diversity of wetland types and the hydrological variability in the Marshes make it difficult to develop a single conceptual model. The relationship between geomorphological features, soils, hydrological variability and vegetation community is represented in Figure 17a. The soil, channel morphology and flooding are the key drivers. Vegetation communities are derived from the period, regularity, depth and duration of inundation; in turn these provide habitat for waterbirds (Kingsford 2006).

Figures 17b and 17c show the relationships between the critical components and processes and their responses in wet and dry phases. It is intended to continue developing these models.

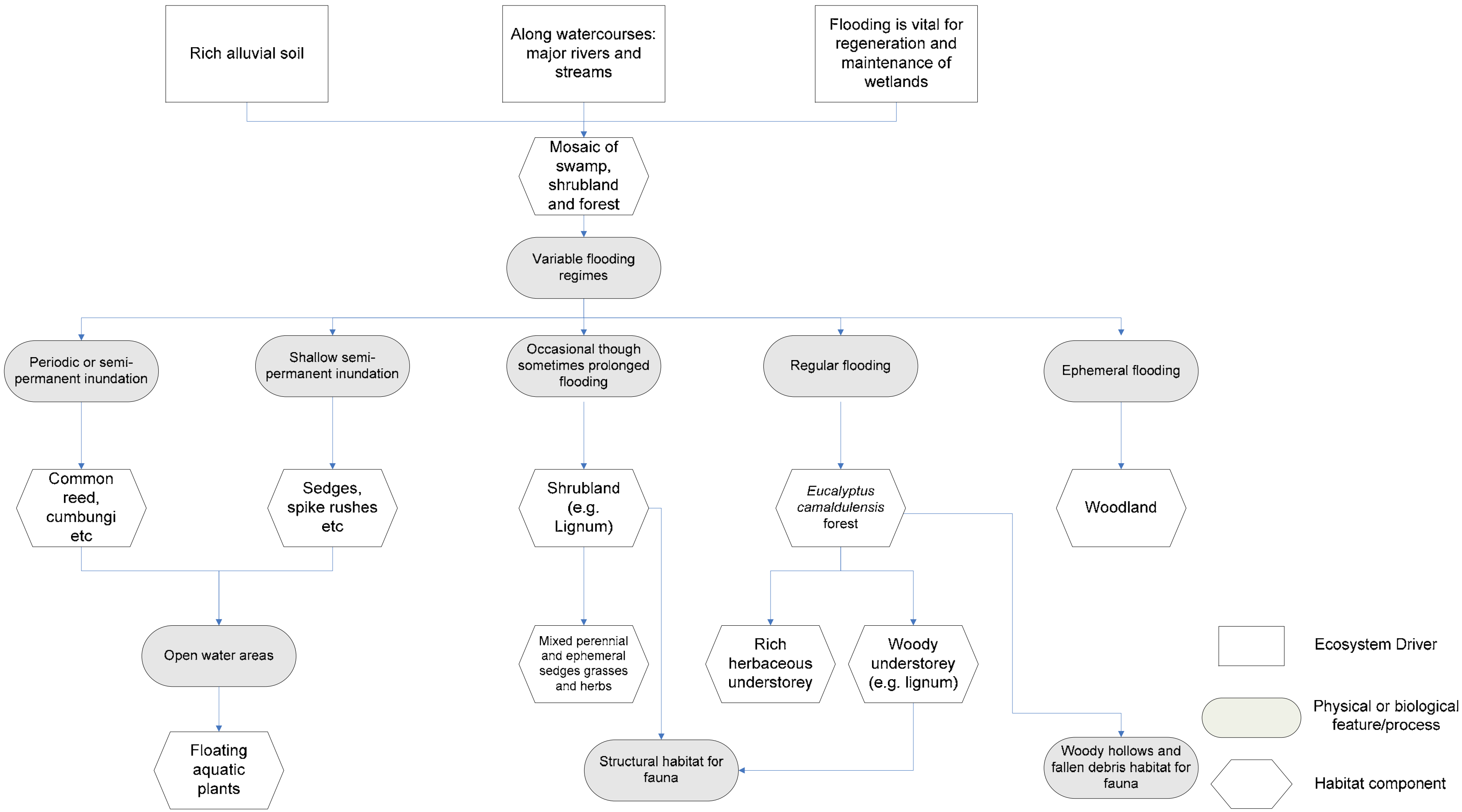


Figure 17(a): Flow chart describing the relationships among critical components and processes in the Macquarie Marshes

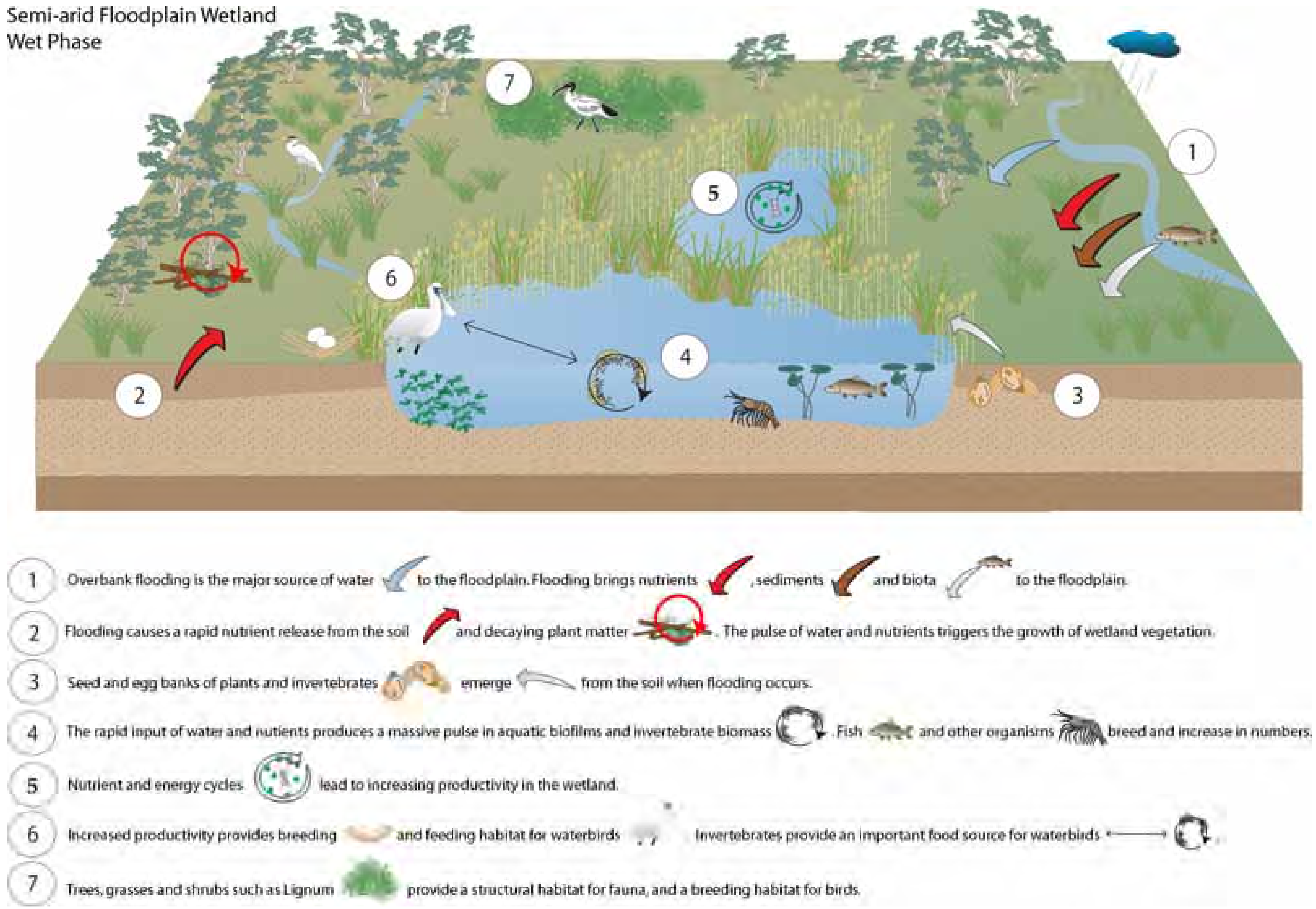


Figure 17(b): Conceptual diagram of relationships among critical components and processes in the Macquarie Marshes during a wet phase

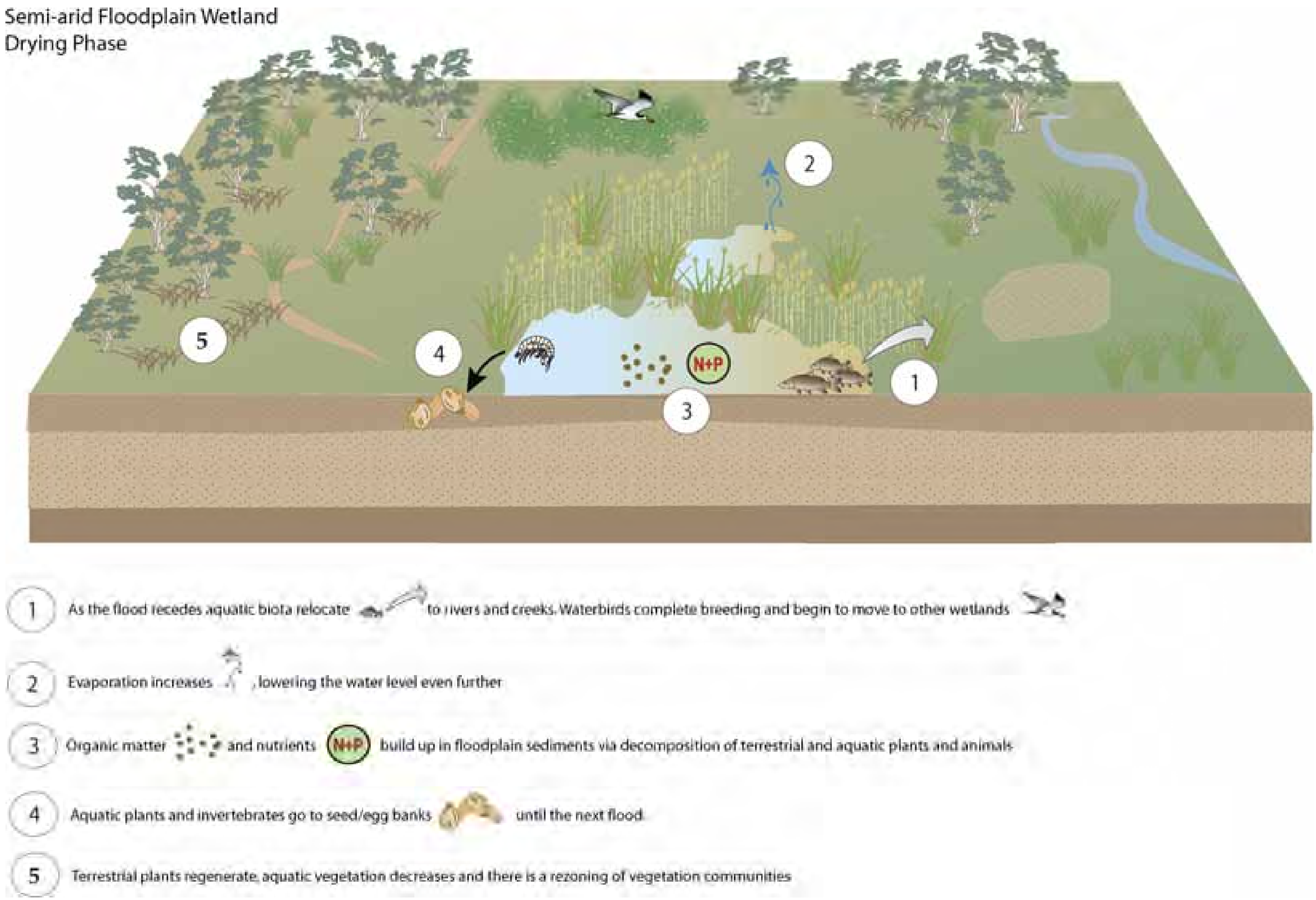


Figure 17(c): Conceptual diagram of relationships among critical components and processes in the Macquarie Marshes during a dry phase

7 Limits of acceptable change

Understanding the range of natural variation in wetland ecosystem components and processes is important for describing the ecological character of wetlands and determining when ecological character may have changed. This is particularly important for Australian Ramsar wetlands given they often have a wide range of natural variability. For the purposes of implementing Article 3.2 of the Ramsar Convention, change in ecological character is defined as 'the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (DEWHA 2009).

Limits of acceptable change (LACs) in components and processes can be identified by values that lie outside the range of known values (estimate of variability), for those critical ecosystem components or processes for which adequate temporal baseline data exists. For the Macquarie Marshes Nature Reserve Ramsar site, such suitable indicators for which benchmark values have been established are vegetation communities, the diversity, abundance and breeding of waterbirds, and the diversity of native fish and aquatic invertebrates. In cases where knowledge of natural variability is limited or lacking, a percentage has been listed to estimate limits of acceptable change for the mapped area of the species or community. These percentages are based on available information and expert opinion and take into account error which is a normal part of mapping wetland vegetation communities, but they are relatively subjective. When better information becomes available about variability they should be revised and updated. For nationally threatened species, LACs for vegetation have been used as a surrogate, as vegetation is an indicator of habitat availability. It is noted that use of vegetation as a surrogate does not guarantee a population is maintained. Other factors including pest species such as foxes and cats may also be impacting on species.

Hydrology is a critical component and key driver of the Ramsar site, however, a LAC has not been set for hydrology because a baseline hydrological model for the level of development around the time of listing (1986) was not available. Should a model of the hydrology for this time become available a LAC could be set.

Table 12 summarises the baseline values, and their known ranges of natural variation (best estimate for circa 1986), used to develop LAC indicators. It also provides an indication of the level of confidence in the LAC. Level of confidence in the LAC is based on the adequacy and reliability of the baseline information and knowledge of natural variability for each critical component or process. Low confidence indicates that the baseline data may be limited and/or we are uncertain of the natural range of variability. Medium confidence means that there is some data available but its direct applicability to the LAC is not certain, and that the variability is understood to a certain extent. High confidence relates to LACs where the baseline data is considered to be adequate and reliable and where the range of natural variability is understood, such that the LAC is based on data. No LAC has been set where baseline information is not available. It is suggested that LACs should be reviewed as better knowledge becomes available.

When interpreting LACs for the purpose of determining whether there has been a change in ecological character or for other purposes, the following qualifications should be considered and applied as appropriate:

- Exceeding or not meeting a limit of acceptable change (LAC) does not necessarily indicate there has been a change in ecological character.
- While the best available information has been used to prepare this ecological character description and define limits of acceptable change for the site, in many cases only limited information and data are available for these purposes.
- The LACs in Table 12 may not accurately represent the variability of the critical components, processes, services and benefits under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Table 12: Limits of acceptable change for critical components, processes, services and benefits in Macquarie Marshes Nature Reserve

Ecological components and processes	**Baseline condition and range of natural variation**	**Limits of acceptable change (LACs)**	**Confidence in LAC**
	Hydrology		
Hydrology	Models of the flow regime are available for pre- Burrendong dam flows and for current levels of development (DECCW 2010a; CSIRO 2008).The frequency, magnitude, timing and duration of flows are critical for driving ecological processes in the Marshes and supporting critical components and services. A hydrological model for the Macquarie Marshes for the level of development around the time of Ramsar listing is not available.	No data is available to set a LAC. If data become available a LAC should be set.	
	Semi-permanent wetland vegetation		
River red gum woodland and forests	The extent of river red gum communities is estimated to be 6071 ha in the northern section of the nature reserve, 212 ha in the southern section of the nature reserve and 85 ha in U-block (Wilson 1992). River red gum are long lived trees and their extent in the Macquarie Marshes is not known to have changed in recent years; however, there is no information on natural variability in this community. As such, an objective, statistically based LAC cannot be determined and a figure of 20% change has been selected based on expert opinion. There is no baseline information on the condition of these communities for the time of listing.	Extent of river red gum woodland and forest to be no less than: • 4850 ha in the northern section of the nature reserve • 170 ha in the southern section of the nature reserve • 68 ha in U-block. The LAC is based on expert opinion and takes account of variation in survey and/or mapping techniques. Should better knowledge become available this LAC should be revised.	Low
Cumbungi rushland	The area of cumbungi rushland in 1991 was 260 ha (Bowen & Simpson 2010). Cumbungi exhibits a large range of natural variation where it has been recorded throughout the Murray–Darling Basin. It has been recorded for more than 100 years in the Marshes (Young 2001).	That cumbungi is present in the Ramsar site and greater Macquarie Marshes. When better knowledge of variation in the extent of cumbungi in the Macquarie Marshes becomes available this LAC should be revised.	Low

Ecological components and processes	**Baseline condition and range of natural variation**	**Limits of acceptable change (LACs)**	**Confidence in LAC**
Semi-permanent wetland vegetation continued			
Common reed reed beds	The area of reed bed in 1991 was reported by Bowen and Simpson (2010) to be 2147 ha in the northern section of the nature reserve and 1207 ha in the southern section of the nature reserve. In the greater marshes it was reported to be 5476 ha (Bowen & Simpson 2010). Reed beds have been recorded, in their general location within Macquarie Marshes, for more than 100 years. They are an important nesting habitat for colonial waterbirds and are therefore critical to the Ramsar values of this site throughout their distribution in the greater marshes. Reed beds appear to tolerate both long floods and long periods of dry. Scientific evidence indicates that there is some natural variability in reed beds' condition and extent in response to frequency and timing of inundation, fire and grazing management (Paijmans 1981), but this has not been quantified. There is no information available on natural variability in the extent of reed beds. As such, an objective, statistically based LAC cannot be determined and a figure of 20% change has been selected based on expert opinion.	Extent of reed bed to be no less than: • 1720 ha in the northern section of the nature reserve • 965 ha in the southern section of the nature reserve • 4380 ha in the greater marshes. The LAC is based on expert opinion and takes account of variation in survey and/or mapping techniques. Should better knowledge become available this LAC should be revised.	Low
Water couch marsh	The area of water couch marsh in 1991 was 908 ha in the northern section of the nature reserve and 220 ha in the southern section of the nature reserve (Bowen & Simpson 2010). Water couch does not survive long dry periods (Blanch et al. 1999; Bennett & Green 1993), and its extent will vary considerably over wetting and drying periods. Natural variation in the extent of water couch marsh is unknown but it is likely to be variable (Paijmans 1991). As such, an objective, statistically based LAC cannot be determined and a figure of 25% change has been selected based on expert opinion.	Extent of water couch marsh to be no less than: • 681 ha in the northern section of the nature reserve • 165 ha in the southern section of the nature reserve. When better knowledge of variation in the extent of water couch marsh in the Macquarie Marshes becomes available this LAC should be revised.	Low

Table 12 continues overleaf…

Table 12 continued

Ecological components and processes	**Baseline condition and range of natural variation**	**Limits of acceptable change (LACs)**	**Confidence in LAC**
	Semi-permanent wetland vegetation continued		
Mixed marsh vegetation	The area of mixed marsh in 1991 was 50 ha in U-block. It was identified by Wilson (1992) as mixed marsh/grassland. No mixed marsh was mapped in the nature reserve at this time (Bowen & Simpson 2010). Mixed marsh is considered to be an ecotonal community between grassland and amphibious wetland in the Macquarie Marshes. In 1991 mixed marsh was a coloniser of moist grasslands as there was more frequent inundation of the marshes (Thomas et al. 2011). From 2001–2008 mixed marsh occupied areas formerly supporting water couch because it can tolerate a wider range of hydrological regimes (Bowen & Simpson 2010). Its natural variation is unknown, but it does not survive long dry periods. As such, an objective, statistically based LAC has not been set.	A LAC has not been set for mixed marsh because of the limited understanding of its variation. When better knowledge of the extent of mixed marsh in the Macquarie Marshes becomes available a LAC should be set.	
Lagoons and fringing vegetation	The area of lagoons (open water habitats) in the nature reserve Ramsar site in 1991 was 83 ha (Bowen & Simpson 2010). The extent of shoreline habitats and fringing vegetation is unknown. The area of lagoons varies naturally with wetting and drying cycles, which is important for shorebird habitats; however, the rate and frequency of variation is unknown. Variation in the area and condition of fringing vegetation is also unknown. As such, an objective, statistically based LAC has not been set.	A LAC has not been set for lagoons and their fringing vegetation. When better knowledge of variation in the area of lagoons (linked to the hydrological models) and their shorelines becomes available a LAC should be set.	
	Floodplain vegetation		
Lignum shrubland	Expert opinion is that approximately 200 ha of lignum shrubland occurs within the northern section of the nature reserve. It also occurs as a common understorey species in woodlands (R Jones, pers. comm., 2010). Less than 20 ha was mapped in the nature reserve part of the Ramsar site by Bowen & Simpson (2010). The baseline extent of lignum shrubland and natural variation in the extent of lignum shrubland is unknown. Lignum understorey is difficult to map accurately. As such, an objective, statistically based LAC has not been determined.	No LAC has been set for lignum. Should better knowledge become available a LAC should be set for lignum shrubland.	

Ecological components and processes	Baseline condition and range of natural variation	Limits of acceptable change (LACs)	Confidence in LAC
Floodplain vegetation continued			
Coolibah / black box woodland	In 1991 the area of coolibah / black box woodland in the northern section of the nature reserve was 600 ha, in the southern section it was 100 ha and in U-block it was 20 ha (Bowen & Simpson 2010). Coolibah and black box are long lived trees with little natural variation in their extent expected; however, there is no information on natural variability in this community. As such, an objective, statistically based LAC cannot be determined and a figure of 20% change has been selected based on expert opinion. There is no baseline information on the condition of the coolibah / black box woodland for the time of listing.	Extent of coolibah / black box woodland to be no less than: • 480 ha in the northern section of the nature reserve • 80 ha in the southern section of the nature reserve • 16 ha in U-block. Should better knowledge become available this LAC should be revised.	Low
Aquatic ecological community			
Aquatic invertebrates (microinvertebrates, microcrustaceans & macroinvertebrates)	There is no information available for around the time of Ramsar listing. Experimental manipulation of floodplain soils has found that during inundation, microcrustacean (cladocerans, ostracods and copepods) densities in floodplain habitats in the Macquarie marshes are from 1000–10,000/litre (Jenkins 2006). A LAC has been set for the density of microcrustaceans that occurs during inundation of floodplains based on the lower range recorded in these experiments. Recent macroinvertebrate surveys have found more than 100 species utilise the Marshes when they are wet (Jenkins et al. 2007). However, there is no information available on variation in macroinvertebrate species. There is inadequate knowledge to set LACs for aquatic invertebrate species richness.	Densities of microcrustaceans after floodplain inundation should be no less than 1000/litre. When better knowledge of variation in the richness of aquatic invertebrates species becomes available this LAC should be revised.	Low

Table 12 continues overleaf…

Table 12 continued

Ecological components and processes	Baseline condition and range of natural variation	Limits of acceptable change (LACs)	Confidence in LAC
Aquatic ecological community continued			
Native fish (species richness)	Historical records indicate that 11 native fish species utilised the Macquarie Marshes. Seven species were captured in 2006 (Jenkins et al. 2007). There is a lack of underlying knowledge of variability in fish species richness and the relationship with ecological character. Data are also insufficient at this time to define fish abundances. A LAC for fish species richness has been defined based on expert opinion.	No less than seven endemic species present in two consecutive years. When better knowledge of variation in native fish, abundance and/or composition, becomes available this LAC should be revised.	Low
Waterbirds and waterbird breeding			
Waterbirds (species richness)	The average number of waterbird species recorded during annual aerial surveys in the northern third of the Macquarie Marshes between 1983 and 1989 was 20 (±1.76 SE, range 14–26) (Kingsford 1999a). NB. The annual aerial survey only covers part of the northern nature reserve. There is no survey of the whole Ramsar site. A LAC for waterbird species richness has been defined based on the lower end of the range of species recorded between 1983 and1989.	No fewer than 14 species in two consecutive years.	Low
Waterbirds (abundance)	Average number of waterbirds recorded in annual surveys of the northern third of the Macquarie Marshes is estimated to be 22,500 (±11,020 SE, range 3462–87,340) between 1983 and 1989 (Kingsford 1999a). Waterbird numbers are known to vary substantially in response to the flooding of the marshes. There is limited understanding of what would constitute a decline in waterbird abundance, such that the site’s ecological character is changed. Expert opinion is that a 50% reduction in the average number of waterbirds recorded in aerial surveys of the northern section of the nature reserve in five consecutive years may reflect a significant change. The LAC for waterbird abundance has been defined based on expert opinion. It is only for part of the Ramsar site.	No less than 11,000 waterbirds are recorded in the annual aerial surveys of the northern section of the nature reserve in five consecutive years.	Low

Ecological components and processes	Baseline condition and range of natural variation	Limits of acceptable change (LACs)	Confidence in LAC
	Waterbirds and waterbird breeding		
Colonial waterbirds (breeding frequency)	Between 1986 and 2000, the longest period without breeding of colonial waterbirds (at least 500 nests) in the Macquarie Marshes was two years (Kingsford & Auld 2005). During the same period, large colonial waterbird breeding events (>40,000 nests) occurred about every eight years (Kingsford & Auld 2005). NB. Records of colonial waterbird breeding events are good, however, many sites are outside the Ramsar boundary, but still considered critical to the ecological character of the site.	No more than two consecutive years without breeding of colonial waterbird species (at least 500 nests) in the Macquarie Marshes. Colonial waterbird breeding events of about 40,000 pairs or more should occur at least once every ten years.	Medium
Colonial waterbirds (species richness)	Fourteen species of colonial waterbirds have been recorded breeding in the Macquarie Marshes Nature Reserve during large floods (Kingsford & Auld 2005). There is limited understanding of how changes in species richness will impact on the ecological character of the site and at what point this would constitute a change in ecological character. A LAC has been set based on expert opinion, but confidence is low as to whether it represents an appropriate limit.	No less than 14 species of waterbirds are recorded breeding in the Macquarie Marshes during large flood events.	Low
Colonial waterbirds (breeding sites)	Four sites within the nature reserve were used by colonial waterbirds for breeding during large floods between 1986 and 2000: Louden's Lagoon, Hunt's Woodland, J-block and Bora colonies. There are estimated to be another 12 nesting sites in the greater marshes that have been used during this period. All breeding sites are important for the ecological character of the Ramsar site. Expert opinion is that breeding habitat must be in good condition to be used. Key habitats for breeding sites are common reed reed beds, rive red gum forest and woodland, and lignum.	No overall reduction in breeding sites for colonial waterbirds in the greater marshes. See LACs for river redgum, common reed reed beds and lignum.	Low

Table 12 continues overleaf…

Table 12 continued

Ecological components and processes	**Baseline condition and range of natural variation**	**Limits of acceptable change (LACs)**	**Confidence in LAC**
	Waterbirds and waterbird breeding continued		
Migratory waterbirds (species richness)	Seventeen species listed under JAMBA, CAMBA and/or ROKAMBA have been recorded in the nature reserve. There is no data on variation in species richness. There is limited understanding of how changes in species richness will impact on the ecological character of this site and at what point this would constitute a change in ecological character.	No LAC has been set. When better knowledge of variation in migratory waterbirds species richness becomes available a LAC should be set.	
	Threatened species		
Murray cod (EPBC Act)	The Murray cod has not been recorded in the Macquarie Marshes since 1975. There is inadequate data to establish a baseline. Current research being undertaken in the Macquarie River is looking at the movement of adult fish, the type and location of spawning sites, spawning behaviour, parental protection of eggs and larvae, effects of coldwater pollution, and the timing and duration of the breeding season. Results of this research will improve our knowledge of this species in the Marshes.	No LAC has been set. A LAC should be set if adequate baseline information becomes available.	
Australian painted snipe (EPBC Act)	Australian painted snipe is a cryptic species that is often overlooked. There are three records of this species being observed in the Marshes in the NSW Wildlife Atlas from 1978–1979. In 2010 a snipe was observed in Mole Marsh adjacent to U-block. They utilise water couch marsh, mixed marsh, reed and lagoons in the Macquarie Marshes. There is inadequate data to set a LAC for this species. Experts have recommended that vegetation may be used as a surrogate. NB. Use of vegetation as a surrogate does not guarantee the population is maintained. Other factors including pest species such as foxes and cats may also be impacting on this species.	See LACs for water couch, mixed marsh, common reed, and lagoons and fringing vegetation. Should better knowledge become available a LAC should be set for the Australian painted snipe.	Low

Ecological components and processes	Baseline condition and range of natural variation	Limits of acceptable change (LACs)	Confidence in LAC
	Threatened species continued		
Australasian bittern (IUCN Red List)	The Australasian bittern is a shy and cryptic bird. There are 16 records for the Macquarie Marshes in the NSW Wildlife Atlas from 1969–1981, predominantly in the southern section of the nature reserve in association with Monkeygar Creek, lagoons and reed beds. The Australasian bittern feeds on animals in and around the margins of wetlands including: fish, crayfish, frogs, insects, snakes, lizards and occasionally small birds and mammals. Plant matter can also form part of the diet (NSW Scientific Committee 2010). There is inadequate data to set a LAC for this species. Experts have recommended that vegetation may be used as a surrogate. NB. Use of vegetation as a surrogate does not guarantee the population is maintained. Other factors including pest species such as foxes and cats may also be impacting on this species.	See LACs for common reed, and lagoons and fringing vegetation. Should better knowledge become available a LAC should be set for the Australasian bittern.	Low
Superb parrot (EPBC Act)	There is one NSW Wildlife Atlas record of the superb parrot in the Macquarie Marshes from July 2003: ‘several birds were observed flying in the northern nature reserve’. The main habitat of this species is river red gum woodlands. Baseline data is inadequate to set a LAC for this component.	No LAC has been set. Should further information become available, a LAC may be set in the future.	

8 Threats to the Macquarie Marshes

The Macquarie Marshes Nature Reserve and U-block were Ramsar listed in 1986 and many of the threats that existed then are still issues in 2011; however, there are now new threats such as climate change. The threats to the Ramsar site cannot be separated from the threats to the entire Marsh, particularly where they concern water availability and water management. Table 13 summarises the actual or likely threats to the Macquarie Marshes Nature Reserve and U-block components of the Ramsar site.

The greatest threat to the Ramsar site and the greater Macquarie Marshes is the alteration of the natural flow regime through river regulation, which has changed the seasonality of flows and the size of flows to the Macquarie Marshes. This includes upstream extraction of water, which has reduced the size of flows reaching the Marshes, and development of structures that alter flow paths within the Marshes and along the Macquarie River and its distributaries. This threat applies at a landscape scale and cannot be resolved by the managers of the Ramsar site alone. Many other threats listed below are also contingent on resolving water management issues.

Table 13: Threats to Macquarie Marshes Nature Reserve Ramsar site

Actual or likely threat	Potential impact on ecological character	Likelihood	Timing of threat
Current water management	Insufficient flow size frequency, and duration and change to flow timing leading to loss and declining health of wetland vegetation, waterbird habitat, aquatic ecological community and waterbird breeding sites	Certain/high	Immediate to medium term
Water management structures	Water diversion leading to loss and declining health of wetland vegetation, waterbird habitat, aquatic ecological community and waterbird breeding sites	Certain/high	Immediate to medium term
Dryland salinity in the catchment	Impact on aquatic organisms, reducing diversity and possibly abundance	Medium	Long term
Fire management	Declining health of wetland vegetation, in particular common reed and river red gum woodlands	Medium	Long term
Pest management	Declining health of wetland vegetation, lower breeding success of waterbirds and declining water quality	Certain	Short to long term
Impacts of climate change	Reduced water availability leading to loss and declining health of wetland vegetation, waterbird habitat, aquatic ecological community and waterbird breeding sites	Medium	Long term
Channel erosion	Deeply incised channels and disconnected floodplains, particularly in the southern reserve	Certain/high	Immediate to long term
Lack of understanding complex systems	Largely unknown	Medium	Long term

8.1 Current water management – water availability

In the regulated Macquarie–Cudgegong system, the total share component of access licences plus the environmental water allowance is now about 899,453 ML. This consists of 14,265 ML for domestic and stock access licences; 22,681 ML for local water utility access licences; 19,419 ML for regulated river (high security) access licences; about 632,428 ML for regulated river (general security) access licences; and 50,000 ML for regulated river (supplementary water) access licences (NSW Government 2003).

The existing environmental water allowance (EWA) under the *Water Sharing Plan for the Macquarie Cudgegong Regulated Rivers (2004)* is 160,000 ML (NSW Government 2003; column graph in Figure 3.4). The EWA accrues water at the same rate as the general security entitlement (e.g. a 10 per cent allocation to general security will accrue16,000 ML to the EWA account).

In addition, more than 48,100 ML of general security entitlement, 1452 ML of supplementary access entitlement and 184 ML of unregulated entitlement have been bought by the NSW RiverBank, the Rivers Environmental Restoration Program and NSW Wetland Recovery Program (WRP) in the Macquarie valley. The Commonwealth Environmental Water Holder has also purchased water in the Macquarie valley and as at the end of March 2012 had purchased 90,253 ML of general security entitlement and 1888 ML of supplementary access entitlement.

The available water determination (AWD) and allocation of shares to general security access licences indicates the amount of water available from regulated flows for the irrigation industry and the environment.

Measurements of water availability and use are often given as averages. For example, the average surface water availability in the Macquarie–Cudgegong Regulated Rivers Water Source is 1,448,000 ML/year, and average total diversions are 391,900 ML/year (NSW Government 2003). The long-term average annual flow to the Macquarie Marshes, measured at Marebone Weir, is 440,000 ML/year (Macquarie–Cudgegong RMC 2001); however, long-term averages, especially in a highly variable system such as the Macquarie, can be misleading when managing at the shorter time scales relevant to agricultural systems and river and wetland ecosystems.

For the semi-permanent wetlands of the Marshes the sustained lack of flows has been especially damaging. From 2001 to 2010, surface runoff was similar to that of the 1930s, which was very dry. However, between 1930 and 1950, at least seven moderate to large floods were recorded in the area now included in the northern section of the Macquarie Marshes Nature Reserve, in 1934, ’37, ’40, ’41, ’43 and ’48. More than half the area now included in the Macquarie Marshes Nature Reserve was classified as ‘flooded channel country’, ‘swampy plain’ or ‘usually inundated’ (Department of Lands 1941, circa 1950). The system is now under the additional pressure of Burrendong Dam harvesting flows from the largest and historically most reliable water supply in the catchment. Also, the river now supports a large irrigation industry as well as many other industries and larger urban populations. For the irrigation industry, which between 1980 and 2001 had an average 88 per cent allocation to general security shares, a sudden shift to nine years of low flows and an average allocation of less than 13 per cent is equally serious.

8.2 Current water management – water allocation

The process of allocating water for extraction and the environment is called the available water determination (AWD) and is undertaken by the NSW Office of Water after a resource assessment. Under this process Burrendong and Windamere dams are assessed for the amount of water stored in the dams plus the likely future minimum inflows (which are based on the lowest inflows recorded since records were first kept). Essential water requirements (e.g. riparian, stock and domestic, town water) for the current and following year are calculated. Any water that is additional to that needed for ‘essential water requirement’ is made available for extractive and environmental use and is distributed under rules in the WSP for the Macquarie–Cudgegong Regulated Rivers (NSW Government 2003). This process allocates all available water and is updated periodically throughout the year as inflows occur. In the case of Burrendong Dam it is assumed that two years of average inflow will fill the dam while in Windamere it is assumed that this will take seven years (DECCW 2010a).

In 2007 the Water Sharing Plan for the Macquarie-Cudgegong Regulated Rivers was suspended because insufficient reserves in storage meant that the ability to deliver essential requirements was not assured. Access to the environmental and extractive carry-over accounts was suspended, although later reinstated as the resource availability improved, while high security users and town water supplies experienced restricted allocations (DECCW 2010a).

The rules determining the environmental share of inflows were developed during a period of relatively high water availability. In a relatively wet period, environmental share with general security equivalency served the needs of the environment reasonably well; however, in the drier climate phase experienced between 2001 and 2010, general security allocation was very low and we have seen dramatic changes in marsh health as a result of unprecedented reductions in both base flows and flood events.

8.3 Current water management – river regulation

A study by Brereton et al. (2000) looking at the impacts of river regulation in the Macquarie found that flow timing had changed since the construction of Burrendong. There has been a shift in the timing of flooding primarily from winter–spring to spring–summer. The impacts of this change are not fully understood but it is known that winter–spring floods are required for maintaining healthy river red gums. They are also needed to provide optimal feeding and growth conditions for adult fish before spawning (Humphries et al. 2002), as well as floodplain habitats with a rich supply of food for larval and juvenile fish (Gehrke et al. 1995). The impacts of changes to flow timing may be critical for some species and need to be investigated.

Many changes to the condition of the river contribute to the degradation of native fish and aquatic invertebrate habitat. River regulation has changed the flow conditions that many native fish depend on (MDBC 2003). Changed flow patterns and degraded riparian zones increase bank erosion and turbidity and sedimentation within channels, filling pools and smothering habitats, including macrophytes, woody debris and gravel substrates (MDBC 2003). Constant low flows reduce ecosystem productivity by removing the boom (wet) and bust (dry) cues that trigger and sustain aquatic cycles (Jenkins & Wolfenden 2006).

8.4 Water management structures – river and floodplain

Structures including banks, weirs, regulators and diversion channels in the Marshes are the subject of much discussion and some controversy. Hogendyk (2007) found a number of levee banks upstream of the North, South and East Marsh which were acting to trap water and spread it to irrigate pasture for grazing. Steinfield and Kingsford (2008) mapped the majority of water management structures on the Macquarie floodplain between Warren and Carinda and identified 338 km of levees, 1648 km of channels, 54 off-river storages and 664 tanks that could affect flows across the floodplain. They found in the southern section (between Warren and Marebone Weir) most water management structures were for flood protection and the provision of water for irrigation, while in the northern section (from Marebone Weir to Carinda) most structures were primarily for stock and domestic supply, erosion control and diverting flows around wetlands. Ralph et al. (2009) documented 100 instream structures in the marshes and used digital terrain mapping to ascertain the types of impacts these structures were having on the river and marsh channels.

Water management structures affect several aspects of flow regime including flow size, duration and timing, but it is the impact diverting water for other purposes has on the flow size that currently causes the most environmental concern.

Some structures threaten fish directly. Fish larvae are usually poor swimmers, and travel with currents. Many researchers suggest that larval and juvenile fish are directly extracted from the river by pumping of water for irrigation and town supply. Collaborative research is being carried out between NSW DPI (Fisheries), the Australian Cotton Cooperative Research Centre and Murrumbidgee Irrigation, to investigate this (Cameron & Baumgartner 2005). Marebone Weir has an undershot design that is now known to cause high mortality in larval and juvenile fish; for example, 95 per cent in golden perch (Baumgartner et al. 2006). Releases of cold, poor quality water from the bottom of Burrendong dam affect aquatic habitat adversely for many kilometres downstream. Habitat degradation needs to be tackled at the whole river scale, as do attempts to control introduced fish, particularly carp (Humphries et al. 2002).

Photograph 3: View downstream at Marebone Weir. Irrigation supply channel on left, Macquarie River centre, and Marebone Break on right (Photo: Grenville Turner, 2007)

8.5 Water management structures – Burrendong dam

Burrendong dam has insufficient outlet valve capacity to meet high simultaneous demand for extractive and environmental water. The maximum rate of release from the dam is 8200 ML per day, and peak summer extractive demand is typically between 4000 and 7000 ML per day. Although environmental requirements have legislative precedence, in the past, extractive requirements have been given priority for valve space (Keyte & Johnson 1997, 1998, 1999, 2000). The ability to deliver a high flow for the Marshes between August and March is compromised by the outlet valve capacity (DECCW 2010a).

Photograph 4: Burrendong dam at less than 5% capacity, February 2007 (Photo: Grenville Turner, 2007)

8.6 Increasing salinity

Increasing river salinity is a potential long-term concern. Dryland salinity within the upper Macquarie River catchment now affects 3850 ha of land in five main locations (EPA 1995). In the Salinity Audit of the MDB Ministerial Council (MDBMC 1999), river salinities are predicted to rise. The average salinity for the Macquarie River was 620 EC in 1998, and is predicted to increase to 1290 EC in 2020, 1730 EC in 2050 and 2110 EC in 2100. From 800 EC it becomes increasingly difficult to manage irrigation and damage to tree crops has been known to occur. At 1500 EC, irrigation of most leguminous pastures and forage crops is very risky. Water starts to taste salty at 1700 EC (MDBMC 1999). Direct adverse biological effects are likely to occur in river, stream and wetland ecosystems as salinity rises.

In addition to dryland salinity in the upper part of the catchment, the Macquarie Marshes occupy a natural sump in the landscape where they have accumulated large amounts of salt over a long period of time. This salt is bound in saline clays and dissolved in saline groundwater in the quaternary aquifers and in the underlying regolith. The BRS (2009) mapping shows a thin resistive layer only a few metres thick, with fresh pore water overlying a very large salt store throughout the Marshes. The water table in the Macquarie Marshes rises and falls with floods and droughts (Brereton 1993). On-ground works that increase the permanence of water bodies within the Marsh are also likely to have local impacts on groundwater. Maintaining the Macquarie Marshes over the long term depends on providing enough freshwater to maintain a thin layer of freshwater (BRS 2009) for plants to utilise.

8.7 Clearing

There has been no clearing of vegetation within Macquarie Marshes Nature Reserve although clearing of wetland vegetation has occurred since the 1960s throughout the Marshes, with black box and coolibah woodland, river red gum woodland and lignum shrublands most affected. Some of this clearing occurred at known waterbird breeding sites. Clearing is regulated by the *Native Vegetation Act 2003*. It is unlikely to directly threaten the Macquarie Marshes Nature Reserve and U-block component of the Ramsar site as clearing is prohibited except for fire and boundary management. However, there may be indirect impacts such as changes to floodplains, erosion, increased sedimentation and water availability as a result of vegetation clearing within the catchment.

8.8 Fire management

Record keeping of wildfires in the Macquarie Marshes Nature Reserve began with the establishment of the reserve in 1971. Prior to the effects of river regulation in the late 1960s, fires occurred every one or two years, burning out within a day or two because of subsurface moisture, in contrast to more recent fires which are hotter and continue burning, affecting the roots of the reed beds (Barry Lamph, pers. comm., 2008).

Eighteen wildfires in total have been recorded since 1947 in and adjacent to the nature reserve in the Macquarie Marshes. The six largest fires occurred in the North Marsh area and were in excess of 1000 ha (Brookhouse 1999).

Photograph 5: Fire in reed beds in northern Macquarie Marsh Nature Reserve in 1992 (Photo: Bill Johnson, 1992)

Lightning has been the major ignition source, resulting in 90 per cent of on-reserve ignitions. The true rate of lightning ignitions may be understated due to the low rate of detection of short duration fires and the level of reporting of such. Most fires caused by lightning occurred between November and March. Wildfires in the wet grasslands and riverine forests were rare events as seasonal flooding coincided with the main period of lightning occurrence. Large fires occurred in these vegetation types in 1947, 1966, 1994 and 1995, when flooding did not occur due to droughts. Fires in the Macquarie Marshes Nature Reserve may be becoming more frequent. While reed beds can withstand frequent low intensity fire, red gum vegetation is particularly susceptible to fire, especially in the drier period from November to March. Management of the river's flow regime should perhaps take into account the higher risk of fire during that period in order to reduce the impact on red gums.

8.9 Pest management

Feral pigs are common on the lower floodplain and among the reed beds. They prey on eggs and young of ground-nesting birds and disturb marsh soil and vegetation. They are regularly controlled by OEH. Foxes and feral cats also affect native fauna (Brock 1998). In addition, European carp cause erosion in the Marshes, damaging aquatic vegetation and resuspending nutrients such as phosphorus (Brock 1998), and compete with native fish.

The invasion of exotic species is changing some vegetation complexes. There is a moderate infestation of lippia, with high levels of infestation along some waterways, especially along the North Marsh bypass channel (Figure 9). Lippia is particularly a threat to water couch areas, as its prostrate growth form can completely cover the ground (Brock 1998). Controlling invasive native species is also a routine management activity on U-block, with ongoing benefits for the current vegetation.

8.10 Climate change

Climate change is projected to impact water availability and water security within the MDB and threatens the delicate ecological balance between hydrology and biota in the Macquarie Marshes Nature Reserve and U-block component of the Ramsar site. For the purposes of this report, the climate change definition adopted is that used in the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report, as it incorporates both climate change attributed to natural climate variability and that associated with the enhanced greenhouse effect:

> *Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.*
>
> (IPCC, cited in Swart et al. 2007, p. 28)

Climate change will affect rainfall, temperature and carbon dioxide levels in different ways throughout Australia. Both climatic and hydrological cycles are strongly influenced by the Madden–Julian Oscillation (MJO), El Niño–Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) or Pacific Decadal Oscillation (DPO).In eastern Australia an extended period of below average rainfall was experienced between 1890 and 1948. Consumptive water use on the Macquarie River has been largely adapted to the wetter decades of post 1949 (Herron et al. 2002).

It is estimated that changes in rainfall due to climate change will reduce stream flow in the east-central MDB (which includes the Macquarie River) from 0–20 per cent by 2030 and from 5–45 per cent by 2070 (CSIRO 2008). This will result in water shortages, particularly in winter rainfall systems, and reduced recharge of groundwater systems. Other climate change factors that will affect this area are increases in atmospheric carbon dioxide (CO_2) and increased temperatures. Increased CO_2 and higher temperatures have the potential to increase tree growth rates by 25–50 per cent in southern Australia. However, rainfall reduction and increased fire frequency may offset these increases.

A study undertaken on the water resources of the Macquarie River catchment, combining climate change and decadal variability, found that the most likely impacts of climate change were reductions in mean annual Burrendong dam storage, Macquarie Marsh inflows and irrigation allocations of 0–15 per cent by 2030 and 0–35 per cent by 2070. The study also predicted only a five per cent probability of flow increases occurring in 2030 and 2070 (Jones & Page 2001).

CSIRO (2008) indicates that climate change is likely to have a significant influence on water availability and the flow regime of the Macquarie River by 2030. Water availability is projected to decrease by a median value of 8 per cent (range of –24% to +23%), while there is likely to be an increase in the period between winter–spring flood events, and a decrease in the flood volume per event and per year. The response of flora and fauna species to these hydrological changes is likely to be varied; however, some species are particularly vulnerable to reduced water availability, such as floodplain trees, colonial nesting waterbirds and fish that rely on flows to trigger spawning (Rogers et al*.* 2009).

Reforestation of the Macquarie River catchment, including commercial forestry, salinity management, carbon sequestration and biodiversity conservation (estimated as a 10 per cent increase in tree cover in the headwaters of the Macquarie River) is predicted to lead to a 17 per cent reduction in inflows to Burrendong dam (Herron et al. 2002).

The combined potential effects of climate change, decadal variability and reforestation on flows in the Macquarie River are significant for the Macquarie Marshes. Yet to be considered are the effects of changing rainfall patterns, such as the likelihood of less runoff due to longer dry spells between rainfall events.

8.11 Lack of understanding of complex systems

The knowledge that exists about the Macquarie Marshes has increased understanding of various parts of the system but has not helped much when it comes to understanding how the system works as a whole. It may not be enough to provide more water and graze more appropriately if there are complex ecological interactions that provide the right conditions for waterbirds to breed. For example, there is some evidence that increased microinvertebrate density and diversity is also linked to waterbird breeding. Microinvertebrates are prey for fish, frogs and some species of waterbirds in the early months of a large flood. Some months into a flood waterbirds such as egrets, herons and cormorants begin to remove microinvertebrate predators allowing microinvertebrates to increase again (Maher 1991). This happens towards the end of the flood and so allows a mass of resting eggs to be deposited by microinvertebrates.

The knowledge that food availability for breeding waterbirds is dependent on high densities of microinvertebrates which are in turn dependent on regular flooding, available organic matter and then the removal of their predators by waterbirds, is the beginning of understanding the complexity of the system. There are many more interactions in the Marshes that require better understanding to maintain waterbird breeding on a system-wide scale.

The basic ecological requirements for breeding waterbirds in the Macquarie Marshes are known – the preferred vegetation for nest sites, the flow regime needed to flood colony sites, and the food items needed for successful breeding. What is not known is how to maintain or restore these features. How often and how long do floods need to be to maintain nest trees and microinvertebrate populations?

9 Changes since Ramsar listing

The Macquarie Marshes Ramsar Site was listed in 1986 prior to the legal imperative to describe ecological character. Changes that have occurred over the two decades since listing are only now being documented and the impacts of some of these changes are likely to be permanent. This means that not all of the reasons for describing ecological character as listed in the national guidelines for Ramsar wetlands can be easily applied. For example, using the ecological character description as an early warning system for ecological change presents difficulties when done retrospectively.

It would not be beneficial to the site to endeavour to maintain a fixed state (i.e. the Marshes in 1986) or return the Marshes to some remembered and inevitably disputed condition at a specific point in time. The current ecological condition of the Macquarie Marshes Nature Reserve is not the same as it was when listed in 1986. Information exists for the period between 1981 and 1991, describing waterbird breeding, vegetation, geomorphology and hydrology from studies carried out in the Marshes, and this has been used to describe baseline condition and for comparison with 2008. Current condition and response to the 2010–11 and 2011–12 floods has not yet been quantified, although improvements in the extent and condition of many species have been observed.

Photograph 6: River red gum woodland with wetland understorey of water couch, cumbungi and common reed along Bora Channel northern section of the Macquarie Marshes Nature Reserve in 1993 (Photo: Bill Johnson, 1993)

9.1 Northern section of the Macquarie Marshes Nature Reserve component of the Macquarie Marshes Ramsar site

The North Marsh supports the most extensive area of river red gum forest and woodlands in the Macquarie Marshes. The results of vegetation mapping in 2008 in the northern section of the nature reserve (Bowen & Simpson 2010) are shown in Table 14. The area of river red gum forest and woodland remained relatively stable from 1991–2008 however the condition of these communities had declined both in overstorey condition (tree health) and understorey composition (species richness and type) (Bowen & Simpson 2010). Bowen and Simpson (2010) found that only 23 per cent of the river red gum communities in the northern section of the Macquarie Marshes Nature Reserve were in good condition (<10 per cent dead canopy) in 2008. These healthy river red gum communities were only found along the Bora channel. The majority (57 per cent) of river red gum communities in the northern section of the reserve were classed as in poor condition (80–100 per cent dead canopy) (Bowen & Simpson 2010).

Photograph 7: River red gum woodland with a grassy understorey along a small flood channel in the northern section of the Macquarie Marshes Nature Reserve in 1998 (Photo: Bill Johnson, 1998)

Nairn (2008) also surveyed tree health and demographics in the Macquarie Marshes and found that 73 per cent of sites surveyed within the northern section of the nature reserve were under extreme water stress and only eight per cent of sites were showing a demographic profile which indicated a 'fair' regenerative potential – none were found to be 'good'. The composition of the understorey of river red gum woodland was dominated by chenopod shrub species (black roly poly and buckbush) more indicative of dryland communities (Bowen & Simpson 2010). The chenopod shrubs replaced the grass and forb species formerly described by Paijmans (1981) as the understorey dominants in this community.

The death of more than 30 per cent of river red gums in the woodlands of the North Marsh has been attributed to lack of flooding (Bacon 2004). River red gums in the Marshes need floods every 1–2 years and Bacon found that trees that received a flood in 2000 but were not flooded in 2003 were under severe stress or dead. Between 2001 and 2010, the Marshes received less than 25 per cent of the environmental water that would be available at 100 per cent general security allocation, which meant less than 5000 ha of the Marshes received a flood every 1–2 years. The mapped area of river red gum forest and woodland in the Marshes was 40,000 ha in 1991 (Wilson et al.1993), a large proportion of this in the North Marsh. It is likely that as much as 75 per cent of these woodlands had not received adequate flooding for their survival as of 2008 (Bowen & Simpson 2010).

Photograph 8: Dead river red gum woodland with a chenopod understorey in the northern section of the Macquarie Marshes Nature Reserve in 2007 (Photo: Bill Johnson, 2007)

Table 14 lists the results of analysis of changes in vegetation community spatial extent and condition between 1991 and 2008 in the northern section of the Macquarie Marshes Nature Reserve. There was a 41 per cent reduction in the area of waterbird habitat provided by semi-permanent wetland vegetation, that is, common reed, cumbungi and water couch marsh (Bowen & Simpson 2010). In 1991 a total of 3314 ha were mapped, while in 2008 only 1946 ha remained intact. Individually, common reed had reduced in area by 17 per cent (2147 ha mapped in 1991 to 1774 ha in 2008), cumbungi by 100 per cent (259 ha in 1991 to 0 ha in 2008) and water couch marsh by 95 per cent (908 ha in 1991 to 49 ha in 2008).

Colonial nesting waterbirds have historically been recorded breeding in five locations in the northern section of the Macquarie Marshes Nature Reserve. In the 2000 flood and breeding event, three locations were used. The two locations not used were Hunt's Woodland, a river red gum breeding site that has not been used since 1993 and Louden's Lagoon, a common reed and marsh club rush site that has not been used since 1998. There was also a small egret colony that nested successfully in river red gum forest in P-block/river paddock in 2008 and in 2010. In the 2010–11 and 2011–12 floods breeding by colonial waterbirds occurred at the P-block and the Bora North colony sites.

Table 14: Results of analysis of changes in vegetation community spatial extent between 1991 and 2008 in the northern section of the Macquarie Marshes Nature Reserve. Condition data is provided for river red gum, based on canopy condition (Bowen & Simpson 2010)

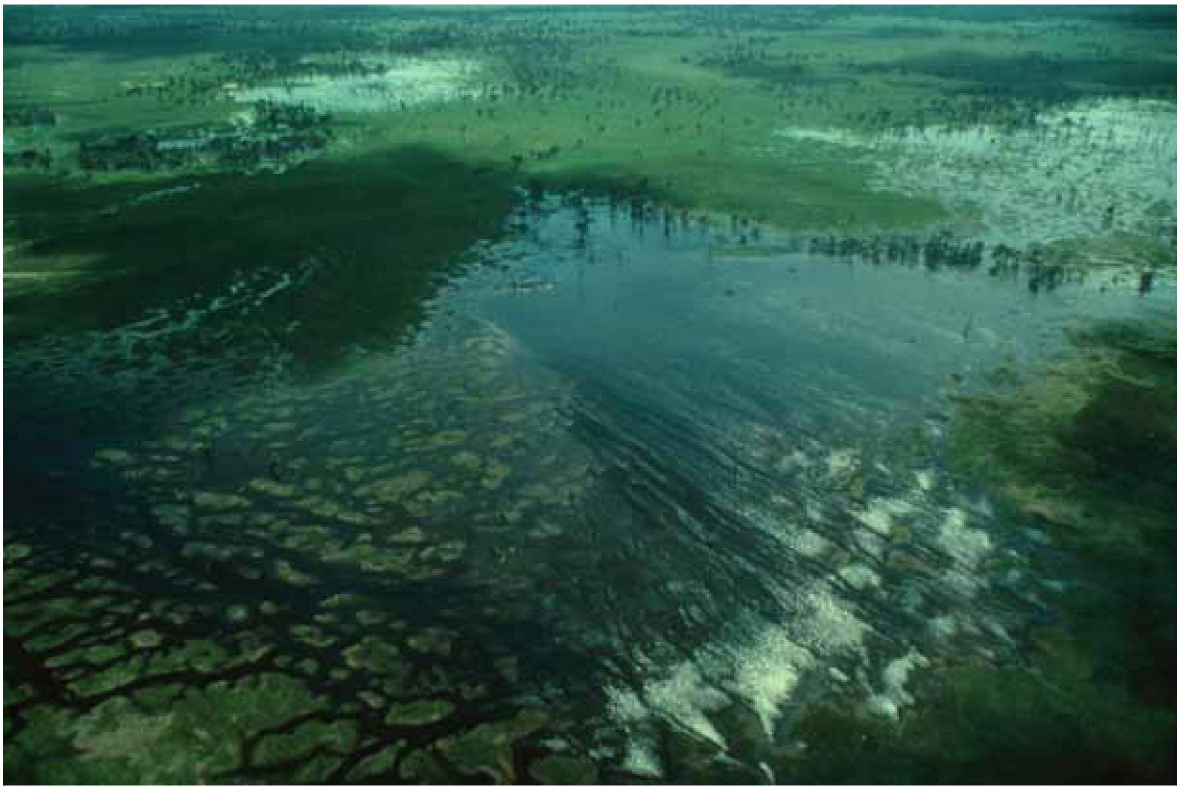
Vegetation type	Vegetation community	1991 area (ha)	2008 area (ha)	Change (ha)	% Change
Semi-permanent wetland vegetation	Common reed	2,147	1,774	-373	-17
	Cumbungi	259	0	-259	-100
	Water couch	908	49	-859	-95
	Mixed marsh	#	123		
	Total	**3,314**	**1,946**	**-1,368**	**-41**
Semi-permanent wetland vegetation colonised by chenopods	Common reed/chenopod shrubland	#	45		
	Water couch/chenopod shrubland	#	25		
	Mixed marsh/chenopod shrubland	#	258		
	Total		**328**		
Floodplain wetland vegetation communities	Lignum	17	10	-7	-41
	River cooba	7	7‡	0	0
	River red gum communities	6,071	1,413 ha – good 1,155 ha – intermediate 73 ha – intermediate /poor 3,489 ha – poor	+59	+1
	Coolibah communities (includes coolibah/black box)	515	515‡	0	0
	Black box	80	80‡	0	0
	Total	**6,690**	**6,742**	**+52**	**+<1**
Dryland vegetation communities	Myall	3	3‡	0	0
	Poplar box	11	11	0	0
	Grassland	1,901	0	-1,901	-100
	Chenopod shrubland/grassland	#	1,863		
	Chenopod shrubland	#	1,061		
Open water lagoons		56	22	-34	-61
Total mapped area		**11,975**	**11,976**		

new community for 2008, not mapped in 1991
‡ chenopods have colonised understorey

9.2 Southern section of the Macquarie Marshes Nature Reserve component of the Macquarie Marshes Ramsar site

The evidence of change includes a significant reduction of common reed. Extensive stands of common reed ('reed beds') are a distinctive part of the character of the Macquarie Marshes. In the Marshes common reed is habitat for many waterbirds and provides nest platforms for large breeding colonies of ibis. In 1981 Paijmans mapped large stands of reed, approximately 2000 ha in the South Marsh, mostly in the southern section of Macquarie Marshes Nature Reserve (Paijmans 1981). In 1991 Wilson mapped an almost identical area of reed (Wilson et al.1993). In 2006 areas of the South Marsh previously mapped with extensive reed beds supported only a few clumps of reed near channels (DNR 2007). Table 15 shows the changes in spatial extent that have occurred to wetland vegetation since 1991 in the southern section of the Macquarie Marshes Nature Reserve. There has been almost a complete loss of the 1207 ha of common reed mapped in 1991. In 2008 common reed only occurred in a narrow band along Monkeygar Creek, interspersed with chenopod shrubs (Bowen & Simpson 2010).

In 1981 Paijmans mapped approximately 500 ha of cumbungi rushland in the South Marsh, most of it outside the southern section of the Macquarie Marshes Nature Reserve (Paijmans 1981). Locations included the Mole Marsh, Monkeygar Swamp, Monkey Swamp and Buckiinguy Swamp, but it was noted that the cumbungi appeared to be dying at the Mole Marsh and Buckiinguy Swamp. In 1991 a small area of cumbungi rushland was mapped in the southern section of the Macquarie Marshes Nature Reserve and the only other areas remained along Monkey Creek and in Buckiinguy Swamp. In 2006 cumbungi was only found in one location in the South Marsh at Buckiinguy Lagoon (DNR 2007). Bowen and Simpson (2010) found no cumbungi remained in the southern section of the Macquarie Marshes Nature Reserve in 2008.



Photograph 9: Open lagoon and water couch marsh in southern section of the Macquarie Marshes Nature Reserve in 1990 (Photo: Bill Johnson, 1990)

Water couch forms extensive grasslands in the Marshes as well as being an important understorey plant in woodland areas. It provides important feeding areas for many waterbird species, in particular magpie geese, which feed on its prolific seeds. Water couch needs to be wet or moist for 75 per cent of the year, although it can tolerate dry periods of up to three years. It does not tolerate grazing when water stressed (that is when dry) or persistent grazing when under water (Middleton 1990). In the Macquarie Marshes most areas of water couch did not receive the flows they needed between 2000 and 2008. Bowen and Simpson (2010) found no water couch remaining in the southern section of the Macquarie Marshes Nature Reserve in 2008, a loss of 220 ha since 1991.

Photograph 10: Chenopod shrubland/grassland in the southern section of the Macquarie Marshes Nature Reserve in 2008 (Photo: Sharon Bowen, 2008)

In the southern section of the Macquarie Marshes Nature Reserve Bowen and Simpson (2010) found ‘catastrophic’ change since 1991, with the loss of almost 100 per cent of semi-permanent wetland vegetation, a decline in the condition of river red gum, coolibah and black box communities, and a 100 per cent loss of grassland communities. Chenopod shrubland covered over 90 per cent of the southern section of the Macquarie Marshes Nature Reserve in 2008. Updated information regarding extent and condition of semi-permanent wetland vegetation for the 2010–11 flood is not yet available, however some improvements in the extent of common reed beds have been observed (D Love, pers. comm., March 2011).There have been two colonial nesting waterbird breeding locations recorded in the southern section of the Macquarie Marshes Nature Reserve, but breeding has not occurred at these sites since the 1960s.

Table 15: Results of analysis of changes in vegetation community spatial extent between 1991 and 2008 in the southern section of the Macquarie Marshes Nature Reserve. Condition data is provided for river red gum, based on canopy condition (from Bowen & Simpson 2010)

Vegetation type	Vegetation community	1991 area (ha)	2008 area (ha)	Change (ha)	% Change
Semi-permanent wetland vegetation	Common reed	1,207	0	-1,207	-100
	Cumbungi	19	0	-19	-100
	Water couch	220	0	-220	-100
	Total	**1,446**	**0**	**-1,446**	**-100**
Semi-permanent wetland vegetation colonised by chenopods	Common reed/chenopod shrubland	#	56		
	Mixed marsh/chenopod shrubland	#	7		
	Total		**63**		
Floodplain wetland vegetation communities	River red gum communities	212	12 ha good 117 ha intermediate 23 ha intermediate /poor 68 ha poor	+8	+4
	Coolibah/black box	55	55‡	0	0
	Black box communities	41	41‡	0	0
	Total	**308**	**316**	**+8**	**+3**
Dryland vegetation communities	Grassland	4,511	0	-4,511	-100
	Chenopod shrubland	#	1,439		
	Chenopod shrubland/grassland	#	4,473		
Open water lagoons		27	0	-27	-100
Total mapped area		**6,292**	**6,291**		

new community for 2008, not mapped in 1991
‡ chenopods have colonised understorey

9.3 U-block component of the Macquarie Marshes Ramsar site

There is some evidence of changes in the area of vegetation communities within U-block. Chenopods have invaded the wetland, particularly the mixed marsh, and in 2008 the area of mixed marsh had decreased to be less than the LAC set for this community. It is also noted that 50 per cent of the river red gums were recorded as being in poor condition in 2008 (Table 16). There is a long-term IMEF monitoring site within U-block; this data was not available but should be used in future to assess changes in species composition and health within U-block. There was a good response observed from water couch and mixed marsh within the U-block site in response to the 2010–11 flooding, however dead river red gum will take a long time to be replaced (A Curtin, pers. comm., March 2011).

Table 16. Results of analysis of changes in vegetation community spatial extent between 1991 and 2008 in U-block (from Bowen & Simpson 2010)

<table>
<tr><th>Vegetation group</th><th colspan="2">Vegetation community</th><th>1991[a]</th><th>2008[b]</th></tr>
<tr><td>Amphibious wetland vegetation (good condition)</td><td colspan="2">Mixed marsh / grassland</td><td>51</td><td>0</td></tr>
<tr><td>Amphibious wetland with invasive chenopods (intermediate condition)</td><td colspan="2">Mixed marsh / chenopod shrubland</td><td>Community not mapped in 1991</td><td>30</td></tr>
<tr><td rowspan="6">Flood dependant vegetation</td><td rowspan="5">River red gum</td><td>Good condition</td><td rowspan="4">River red gum condition not mapped in 1991</td><td>0</td></tr>
<tr><td>Intermediate condition</td><td>41</td></tr>
<tr><td>Intermediate/poor condition</td><td>1</td></tr>
<tr><td>Poor condition</td><td>43</td></tr>
<tr><td>Total</td><td>85</td><td>85</td></tr>
<tr><td colspan="2">Coolibah</td><td>21</td><td>21</td></tr>
<tr><td rowspan="2">Floodplain communities</td><td colspan="2">Grassland / cleared land</td><td>33</td><td>0</td></tr>
<tr><td colspan="2">Chenopod shrubland / grassland / cleared land</td><td>Community not mapped in 1991</td><td>54</td></tr>
<tr><td colspan="3">Total</td><td>190</td><td>190</td></tr>
</table>

[a] Wilson (1991)
[b] Bowen & Simpson (2010)

9.4 Fish

Data on fish populations are only available for the greater Macquarie Marshes and no data on fish abundance are available for 1986. However, examination of historical records, using 1975 as a benchmark, indicates that native fish may have declined in the Macquarie Marshes over the past 30 years. In 1975, eight species of native fish were recorded in the lower Macquarie system and Marshes, compared to three species in 1989, five species in 1995, and three species in 2004 (Table 17; Jenkins et al*.* 2004). Furthermore, all native species captured in 2003 were *Hypseleotris* sp, small native fish. Records from long-term residents of the region support findings of declining native fish species, as fewer native fish are captured currently, compared to the past (Kim Jenkins, pers. comm. of anecdotal interviews with landholders, 2009). There are however, episodic increases in native fish numbers associated with sporadic rising river levels (Macquarie Marshes Management Committee anecdotal records).

A survey of fish communities in creeks and river channels within the Macquarie Marshes was undertaken in winter and spring of 2003 (Jenkins et al*.* 2004). All sites surveyed were in channels with reduced flow variability (Macquarie River, Bulgeraga Creek, Monkeygar Creek and Bora Creek). A total of six species of fish were captured, comprising 1018 individuals. These included three native species (western carp gudgeon, Midgley's carp gudgeon *Hypseleotris* sp. and flathead gudgeon) and three introduced species (European carp, gambusia and goldfish). Numbers of fish captured in spring (954 individuals) were higher than winter (64 individuals). Larval fish were not captured in light traps in either the winter or spring sampling. Length data for carp indicate a spawning event occurred within the Macquarie River system approximately 43 days earlier, coinciding with the timing of increased water levels in the river.

Table 17: Fish captured at the Macquarie Marshes 1975–2003

Common name	1975[a]	1989[b]	1995[c]	2003[d]
Silver perch	✓	✓	×	×
Western carp gudgeon	×	×	✓	✓
Gudgeon	✓	×	×	✓
Spangled perch	✓	×	×	×
Murray cod	✓	×	×	×
Golden perch	✓	✓	✓	×
Rainbow fish	×	×	✓	×
Bony herring	✓	✓	✓	×
Flathead gudgeon	×	×	×	✓
Australian smelt	✓	×	✓	×
Freshwater catfish	✓	×	×	×
Goldfish	✓	✓	×	✓
European carp	✓	✓	✓	✓
Gambusia	✓	✓	✓	✓
Redfin perch	✓	×	×	×

[a]NSW Fisheries database; [b]Harris & Edwards (1990); [c]the most widely distributed species, captured at all sites, except carp which were absent at one site; Swales & Curran (1995); [d]Jenkins et al*.* (2004)

9.5 Aquatic invertebrates

The diversity and abundance of microinvertebrates has been investigated in relation to flooding patterns. In 2004–05 floodplain sediments were collected within the nature reserve and the greater Marshes and then inundated in the laboratory to study the emergence of microinvertebrates (>35µm), release of nutrients, bacterial activity and algal production (Jenkins 2006). Sediments were taken from patches that had been dry for one, four and 14 years. Within the nature reserve, these data show the number of microinvertebrate taxa that hatch from eggs when dry sediments are inundated significantly declines as the duration of drying extends from one year to four and 14 years (Jenkins 2006).

Presence/absence data indicate that the three major groups of microinvertebrates in the nature reserve (ostracods, cladocerans and rotifers) declined in occurrence and became increasingly patchy the longer sediments remained dry. These shifts were associated with declines in soil organic matter and a shift from heterotrophic to autotrophic production (Jenkins 2006). It is currently not possible to assess whether these trends exceed the acceptable limits but there is clear evidence for loss of productivity with increasing length between flood events.

In 2006 the first Australian recorded occurrence of the rotifer *Lecane shieli,* which was previously thought to be endemic to Thailand, took place in the Bora channel (Kobayashi et al. 2007).

9.6 Hydrological change – flow regime

Several studies using both measured and modelled flow data have shown changes to flow frequency and duration, particularly since the construction of Burrendong dam. They include:

- an estimated more than 50 per cent reduction in natural flows reaching the Oxley flow gauge; 51 per cent of flows reached the Oxley flow gauge before river regulation compared to only 21 per cent after regulation (Kingsford & Thomas 1995)
- a significant reduction in moderate to high flows in the Macquarie River and end-of-system flows (CSIRO 2008)
- a 114 per cent increase in the average period between large flows, which are important inundation events for the Marshes, and a reduction in the average volume of these events (CSIRO 2008)
- a reduction in the number of smaller flows likely to cause flooding (greater than 1000 ML/day) passing the Oxley gauge following the construction of Burrendong Dam (Jenkins et al. 2007)
- a reduction in flood frequency, particularly of smaller size floods (Brereton et al. 2000)
- the imposition of permanent low flows in previously intermittent streams (Grimes 2001)
- a significant reduction in area inundated and frequency of floods to the Marshes (Thomas et al*.* 2011).

Thomas et al. (2011) mapped the inundation frequency over the past three decades in the Macquarie Marshes. Figure 18 shows the number of times different parts of the Marshes have been inundated between 1979 and 2006, and is a useful indicator of the location of different vegetation types. Areas of higher inundation frequency are coloured blue, purple and pink and represent areas that sustain or have sustained semi-permanent wetland vegetation. This includes river red gum forest and woodland, water couch, common reed, cumbungi and lignum. Lower inundation frequency areas (yellow) represent high magnitude floods that support ephemeral wetland vegetation. Coolibah, black box and Myall woodland are more likely to occur in these areas. Aquatic and semi-aquatic species occur throughout the Marshes when conditions are suitable.

Figure 18 shows maps for each of three decades: 1979 to 1987, 1988 to 1996, and 1997 to 2006. They show that the area of the Marshes experiencing high inundation frequency has declined. This decline is closely related to water availability and flow size as it is also seen in general security water allocations since 1979. Average allocations for the years identified in Figure 18 are:

- 1979–80 to 1987–88 91.1 per cent
- 1988–89 to 1997–98 81.1 per cent
- 1998–09 to 2006–07 51.3 per cent

The years from 1998 to 2007 (with average allocation close to the modelled long-term average for the valley) began with three very wet years. From 2000 to 2007 conditions were much drier, and the average allocation between 2000–01 and 2007–08 was 34 per cent. This period was also one of very low river flows to the Marshes (DECCW 2010a).

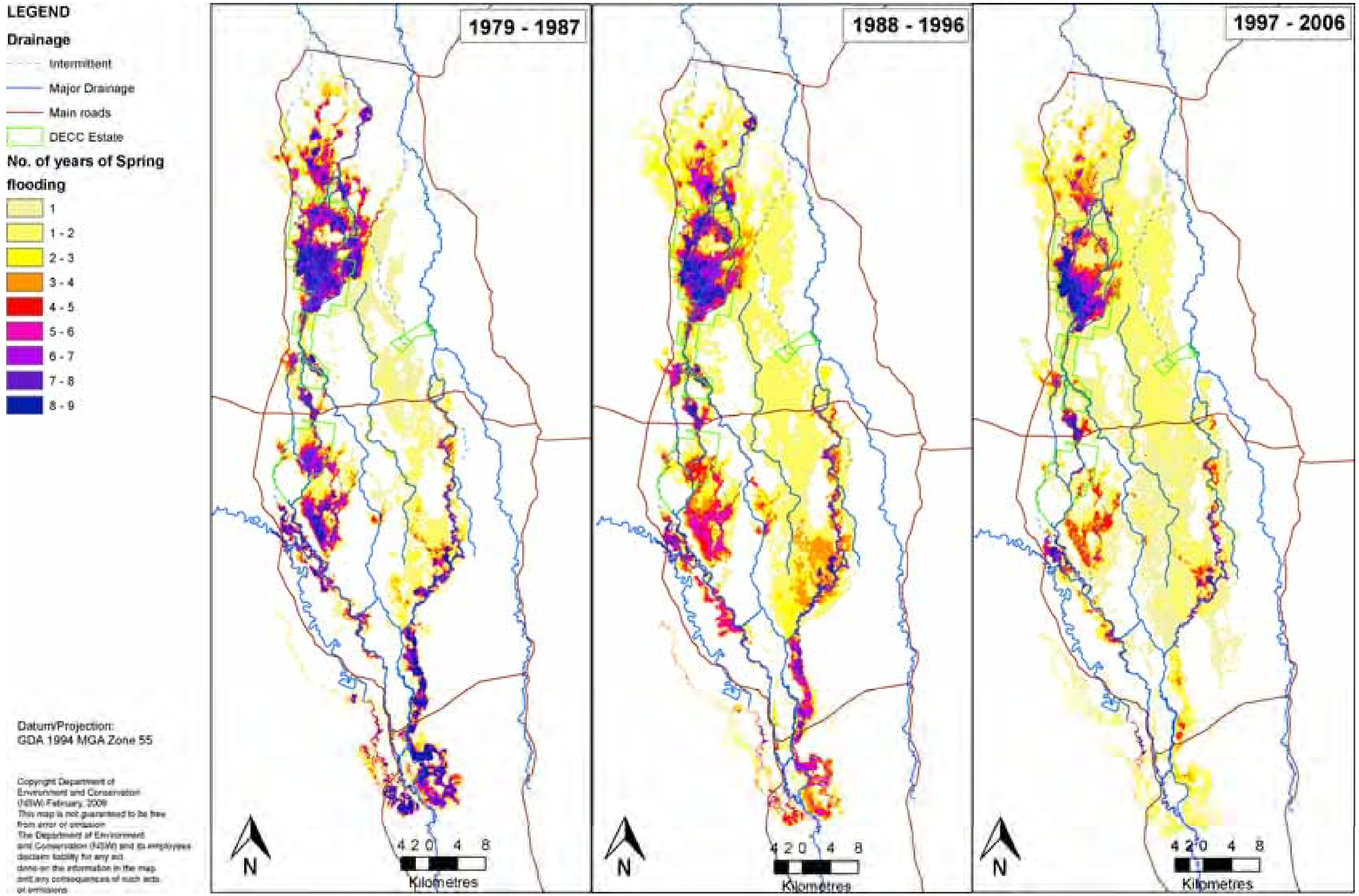


Figure 18: Changes in frequency and extent of inundation in the Macquarie Marshes for each decade: 1979–1987, 1988–1996 and 1997–2006

9.7 Geomorphological change

Work in the Southern Marsh by Ralph (2001, 2008) found short-term rates of sediment accumulation are an order of magnitude greater than long-term rates. Since European settlement of the Marshes and the Macquarie River catchment, significant landscape change has been associated with urban and agricultural development. The construction of dams, weirs, off-river storages, by-pass channels and levee banks has changed the landscape and affected river and floodplain flows (Steinfeld & Kingsford 2008). Channel surveys carried out in the Southern Marshes since 1968 have shown that flow down Monkeygar Creek has caused the channel to increase in both width and depth (Rankine & Hill 1979; Brander 1987; Brereton 1993), probably due to regulation and more constant base-flows. In 1968 it was estimated that a flow of 300 ML/day in the Monkeygar would cause flooding but by 1992 1000 ML/day was required due to the increased channel size (Brereton 1993). In 2006, a survey of ecological responses to an environmental flow found a flow rate of greater than 1600 ML/day was required to flood the South Marsh. This survey also found that the South Marsh had few remaining wetland areas and was ‘mostly a windswept treeless plain’ (DNR 2007).

9.8 Waterbird breeding

In 1986, the time of Ramsar listing, 4590 colonial waterbird nests were counted within the Macquarie Marshes Nature Reserve (Table 18, overleaf). Since then, number of nests, frequency of breeding and location of active breeding colonies has declined throughout the Macquarie Marshes and the nature reserve component of the Ramsar site.

Within the Macquarie Marshes Nature Reserve numbers in the colony in Hunt’s Woodland declined between 1985 and 1993 after which no breeding has taken place. In the southern section of the Macquarie Marshes Nature Reserve no breeding has taken place since the 1960s in the two recorded colony sites. These areas were once dominated by reeds and lignum and were often flooded however dry land grasses and chenopods now dominate the landscape.

The frequency of breeding events has also altered. From the time of Ramsar listing, 1986 to 2001, waterbirds bred in the Marshes every two years. Since 2001 there have been three small breeding colonies of egrets at the P-block/river paddock site, two colonies in the Bora channel sites and one large breeding event in 2010–11 in the greater Macquarie Marshes area. Note that Table 18 only shows results for P-block from 2008 onwards, earlier information was not available.

9.9 Meeting Ramsar criteria in 2010

The Ramsar criteria – 1, 2, 3, 4, 5 and 8 – were met by the Macquarie Marshes Nature Reserve component of the Ramsar site at the time of Ramsar listing in 1986 (see Section 2.2). Changes to critical components, processes and benefits/services since Ramsar listing are documented above. These changes raise concerns with regard to how well the site meets Ramsar criteria in 2012. Based on the evidence summarised in this ECD, it is concluded that the Macquarie Marshes Nature Reserve and U-block components of the Ramsar site still meet all criteria for which the site was originally listed. The impacts of changes since listing on justification against the various criteria are discussed below.

Criterion 1. The Macquarie Marshes Nature Reserve component of the Ramsar site contains a representative, rare, or unique example of a natural or near natural wetland type found within the appropriate biogeographic region.

Within the MDB the Macquarie Marshes Nature Reserve component of the Ramsar site remains a representative example of an inland floodplain wetland relying on water from a higher rainfall upper catchment and having extensive and changeable wetlands in the semi-arid lowland reaches. The northern section of the nature reserve still contains rare or unique examples of near natural wetland types including river red gum forests and woodlands, common reed reed beds and water couch marsh. The area and health of these wetland types has diminished since Ramsar listing (Bowen & Simpson 2010; Nairn 2008).

The southern section of the nature reserve contains almost no semi-permanent wetland, with all wetland types having undergone substantial change since 1986 (Bowen & Simpson 2010; DECCW 2010a). Arguably this area remains wetland, however it has changed from a semi-permanent system to an ephemeral system which is only inundated in large floods. U-block remains in similar condition to when listed in 1986 (Garry Hall, pers. comm., 2010).

Table 18: Number of nests of colonial nesting waterbirds in the Macquarie Marshes Nature Reserve between 1986 and 2012 (unpublished data, sources: R Kingsford 2008; R Jones 2010; D Love 2011; T Hosking 2012)

Year	Louden's Lagoon	Bora Channel colonies	Hunt's Woodland colony	J-block reed colony	P-block/ river paddock	Total for nature reserve	Total for Macquarie Marshes
1986	1,500	0	3,190	0		4,690	4,940
1987	200	0	260	0		460	2,830
1988	0	1,780	1,550	1,000		3,330	8,255
1989	0	2,565	765	0		3,330	12,630
1990	61	2,895	1,100	2,000		4,056	70,626
1991	0	150	0	0		150	150
1992	0	0	0	0		0	0
1993	0	3,000	0	0		3,000	17,582
1994	0	0	0	0		0	0
1995	0	1,545	0	0		1,545	2,818
1996	200	2,271	0	0		2,471	14,746
1997	0	0	0	0		0	0
1998	5,400	3,325	0	282		8,725	77,857
1999	0	150	0	0		150	8,426
2000	0	3,550	0	280		3,550	60,305
2001	0	0	0	0		0	0
2002	0	0	0	0		0	0
2003	0	0	0	0		0	0
2004	0	0	0	0		0	0
2005	0	0	0	0		0	0
2006	0	0	0	0		0	0
2007	0	0	0	0		0	0
2008	0	0	0	0	2,100	0	0
2009	0	0	0	0	0	0	0
2010	0	0	0	0	200	0	2,000[2]
2011	0	25,000	0	0	25,000	50,000	150,000[3]
2012	0	1,500	0	0	1,500	3,000	3,050

[2] Small event at P-block in March 2010 (Source: R Jones, pers. comm., 2010)

[3] Large breeding event in 2010–11 – two similar-sized mixed colonies on the Bora channel (P-block and Bora North)

Criterion 2. The Macquarie Marshes Nature Reserve component of the Ramsar site supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Although some species have not been recorded in recent years this is probably due to the nature of rare species, a lack of survey, and the ongoing dry conditions affecting many wetland species. The Macquarie Marshes Nature Reserve component of the Ramsar site is still likely to support four internationally endangered and vulnerable species (IUCN Red List 2011), three nationally endangered or vulnerable species (EPBC Act) and 34 species regarded as endangered or vulnerable in NSW (TSC Act, *Fisheries Management Act 1994*), as listed in Table 3.

Criterion 3. The Macquarie Marshes Nature Reserve component of the Ramsar site supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Within the MDB, the northern section of the Macquarie Marshes Nature Reserve component of the Ramsar Site still supports one of the few extensive river red gum woodlands, providing important habitat for both waterbirds and woodland birds, and one of the two most extensive common reed reed beds, providing important habitat for many waterbirds and waders. The extensive areas of semi-permanent wetland vegetation including water couch marsh, cumbungi swamp and mixed marsh almost disappeared throughout the Macquarie Marshes Nature Reserve between 2000 and 2010 but research into the presence and viability of seed banks suggest it is possible that these wetland types can be restored if they receive the water required for their regeneration (Bowen & Simpson 2010; DECCW 2010a).

Criterion 4. The Macquarie Marshes Nature Reserve component of the Ramsar site supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

The Macquarie Marshes Nature Reserve component of the Ramsar site still supports plant and/or animal species at a critical stage in their life cycles and provides refuge during adverse conditions.

Since 1986 colonial nesting waterbirds have been recorded breeding in five locations in the northern section of the nature reserve and no locations in the southern section of the nature reserve. In 2000, when the area of the greater Macquarie Marshes inundated was more than 200,000 ha, two locations in the northern section of the nature reserve were not used: Hunt’s Woodland, a river red gum breeding site, and Louden’s Lagoon, a common reed and open water lagoon (Kingsford & Auld 2003). Between 2001 and 2009 very dry conditions were experienced in the Marshes with only 12 per cent of average water flow (DECCW 2010a). In 2008, a relatively small flood supported a successful nesting of approximately 2000 egrets and cormorants in river red gum forest in the P-block/river paddock colony in the northern section of the nature reserve. This was unpredicted with such low flows and the first record of colonial nesting waterbirds breeding at only one location in the Marshes, indicating the importance of the site as a refuge during adverse conditions. P-block was also used for a small breeding event in 2010. In 2010–11 a large breeding event occurred and two sites within the northern section of the nature reserve were used by colonial nesting waterbirds and one site on ‘Wilgara’.

Criterion 5. The Macquarie Marshes Nature Reserve component of the Ramsar site regularly supports 20,000 or more waterbirds.

The Macquarie Marshes are temporally highly variable. Waterbird numbers correspond to river flows and inundation which is driven by climatic conditions. Up to the year 2000, the Macquarie Marshes supported more than 20,000 waterbirds in at least two-thirds of the seasons when adequate habitat was available (i.e. flows of >200 GL at Oxley gauge) (see Section 2.2).

From 2001–2009 adequate habitat was not available in the Marshes to support large numbers of waterbirds. In spring–summer 2010–11, following rainfall and flows to the Macquarie Marshes, a large waterbird breeding colony established in the South Marsh in the Monkeygar swamp, outside the Ramsar site. This colony bred twice and consisted of approximately 30,000 and 70,000 straw-necked ibis nests. At the same time two mixed colonies of egrets, cormorants and herons successfully bred within the Ramsar site (approximately 25,000 nests at each site), in the northern section of the nature reserve. There was also a colony of sacred ibis breeding on 'Wilgara' and approximately 10–12 other small colonies throughout the marshes. Waterfowl numbers were also reported to be high (D Love, pers. comm., March 2011).

These events show that where climatic conditions allow and with appropriate and timely floodplain inundation, the Macquarie Marshes Ramsar site will still meet criterion 5 and can regularly support 20,000 or more waterbirds.

Criterion 8. Is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

This criterion has only recently been added and has been justified in Section 2.2 of this document.

9.10 Changes to the Ramsar site boundary and area

In 2006, the northern section of the Macquarie Marshes Nature Reserve was extended by 688.17 ha to include the property 'Creswell'. In 2012 'Creswell' was added to the Ramsar site, increasing the total area of the site to 19,850 ha, made up of 19,078 ha[4] of the Macquarie Marshes Nature Reserve, 189 ha being U-block and 583 ha of 'Wilgara'.

'Creswell' is contiguous with the northern boundary of the nature reserve and includes Lot 1 – DP403974, Lot 4 – DP751575, Lot 2 – DP751622 and Lot 1 – DP751622 (as shown in Figure 3). The additional area has the same wetland values as the northern section of the nature reserve and includes an extensive area of river red gum woodland, coolibah and black box communities, grasslands/chenopod shrublands and a small area of myall woodland. In 2008 most of the river red gum in 'Creswell' was mapped as poor condition (Bowen & Simpson 2010).

'Creswell' is also of importance for scientific research as it provides accommodation for researchers within the Macquarie Marshes.

[4] The area of the nature reserve has been updated to the most accurate gazetted area data available from OEH in 2012. The area given includes 'Creswell' but excludes 'Ninia'.

10 Knowledge gaps

The amount of information that exists differs substantially among the various components and processes associated with the Macquarie Marshes Ramsar site. The *Water Information System for the Environment (WISE),* an online database that provides extensive information on catchments in Australia, including the Macquarie River Catchment, was used to quantify the amount of published information (www.wise.unsw.edu.au). A comparison of the number of publications showed that hydrology was most heavily researched, followed by birds, vegetation and inundation (Table 19). However, for many of the components of the Macquarie Marshes ecosystem, relatively little information is available (Table 20).

Long-term data (>20 years) exist for inundation, and the abundance and breeding events of waterbirds. While some spatial data on vegetation are available, changes in vegetation over time are poorly documented. Some long-term data on fire incidents and climate exist. For most other potential biological indicators, such as the diversity and abundance of mammals and insects, virtually no temporal or spatial data are available. Information that increases our confidence in defining LACs and measuring change for the critical components, processes and services of the Macquarie Marshes Ramsar site should be a priority.

Table 19: List of ecological components and processes for the Macquarie Marshes and current knowledge as defined by the number of publications (extracted from the *Water Information System for the Environment* – information current at 2010)

Ecological components and processes	Type	Number of publications
birds (e.g. waterbirds, passerines)	biological	47
invertebrates (e.g. butterflies, dragonflies, macroinvertebrates)	biological	12
fish	biological	18
reptiles (snakes, turtles)	biological	15
amphibians (frogs)	biological	14
mammals	biological	13
vegetation	biological	45
water quality	chemical	20
nutrient cycles	chemical	3
soil characteristics	chemical	10
hydrology	physical	104
fire	physical	13
inundation (flooding)	physical	24
climate (rainfall)	physical	3
geomorphology	physical	19

Table 20: Knowledge gaps for components and processes in the Macquarie Marshes

Ecological components & processes	Identified knowledge gaps		
	Ecosystem structure	**Ecosystem function**	**Temporal data**
Waterbirds	Little information exists for many parts of the Macquarie Marshes. Information is poor for cryptic and threatened species. It is not known whether the waterbirds that breed in the Macquarie Marshes also breed at other sites.	Apart from colonial nesting species, little is known of breeding of other species. Use of habitat is poorly known for all species and their requirement for food resources. Food web links are also not known.	Relatively little information exists outside the annual October aerial survey and some breeding season data for colonial waterbirds.
Other birds	Only species lists exist. There is no abundance data.	Little is known about how terrestrial species use the habitat, in particular woodland birds.	There are no temporal data.
Invertebrates	Some species are known and there is some knowledge for parts of the Macquarie Marshes about macroinvertebrates.	There is an understanding of how abundance of microinvertebrates varies with inundation patterns. Little understanding exists in terms of interactions with food webs.	There are few temporal data.
Mammals	Only species lists exist. There is no abundance data.	Little is known about how mammal species use the habitat.	There are no temporal data.
Reptiles	Only species lists exist. There is no abundance data.	Little is known about how reptile species use the habitat.	There are no temporal data.
Frogs	Only species lists exist. There is no abundance data.	Little is known about how frog species use the habitat. Specific information about timing of breeding and movements is also not known.	There are no temporal data.
Fish	Species lists exist and some analysis has been done to compare surveys.	Little is known about how fish species use the habitat or interact with other organisms. Specific information about timing of breeding, recruitment and movements is also poorly known.	There are no temporal data.
Wetland vegetation	Vegetation data exist for plant communities, mapped data and point data.	Little is known of how different vegetation communities interact with other organisms or respond to flow regime, or how to maintain vegetation structural diversity.	There are few temporal data and only some analyses.

Table 20 continued

Ecological components & processes	Identified knowledge gaps		
	Ecosystem structure	**Ecosystem function**	**Temporal data**
Hydrology – flow regime	There is some long-term data but little analysis of the flow regime of the Macquarie River and its relationship with the Marshes.	Little is known of the 'natural' flow regime of the Marshes and its relationship with the river. Long-term average flows are misleading when applied to wetland ecosystems such as the Marshes, which need relatively frequent small and medium flows in addition to large floods.	Some temporal data exist but with limited analysis. Need for spell analysis for better understanding of natural flow regime.
Hydrology – inundation	Good data and understanding of changes but little analysis of long-term changes to inundation patterns.	Little analysis of long-term changes to inundation patterns with and without river regulation. Need also to know durations of flooding for different events and relationships with biological processes.	Good temporal data exists for different flow gauges and inundation data is currently being collated.
Geomorphology	Some studies on the geomorphology of the Marshes but limited in extent.	The requirements for maintaining natural geomorphological processes are not well known. Need to understand the difference between change that is part of the normal functioning of the system and acute change caused by recent human actions.	There are few temporal data and only some analyses.
Energy and nutrient cycles	Data are available with some limited analysis.	Given the importance of organic matter and microinvertebrates as the basis of wetland food webs in the Macquarie Marshes Nature Reserve, it is important to gain a better understanding of the relationship between flow regime and energy and nutrient cycling.	Some temporal data exist but with limited analysis.
Water quality	Data are available with some limited analysis.	Little is known about how water quality varies or responds to changes.	Some temporal data exist but with limited analysis.
Soil	Some spatial data exist but there appear to be areas within the nature reserve that have not been mapped.	Little is known about how soil characteristics vary or respond to changes in flow regimes.	There are no temporal data.
Fire	Some extent data exist particularly since the gazetting of the nature reserve.	There is little understanding of the relationships between fire and other components and processes within the Macquarie Marshes.	Temporal data exist.

11 Identifying Macquarie Marshes Nature Reserve monitoring needs

As a signatory to the Ramsar Convention, Australia has made a commitment to promote the conservation of the ecological character of its Ramsar sites. Whilst there is no explicit requirement for monitoring the site, a monitoring program would provide data to assist in assessing changes to the site, and thereby to determine if the site's ecological character is being maintained. The ECD identifies the monitoring recommendations for critical components and processes and for assessing against the LACs.

The purpose of the monitoring recommended in this ECD is to:

- identify objectives for monitoring critical components, processes, services or threats
- recommend indicators or measures to be used and the frequency of monitoring
- provide priorities for monitoring, and
- address key knowledge gaps identified for the site.

The recommended monitoring is presented in Table 21.

Table 21: Recommended ecological components and processes for monitoring in Macquarie Marshes Nature Reserve and U-block

Overarching component or process	Specific component or processes	Objective of monitoring	Indicator / measure	Frequency	Priority
Hydrology	Flow regime – size, frequency, duration, timing and rate of change of flows	Establish variability of flow and impact of extraction	Gauges at Bathurst, Dubbo, Marebone, Oxley, Pillicawarrina	Continuous	High
	Inundation	Establish relationship between flow regime and area inundated	Total area inundated and frequency of inundation	All flood events	High
Wetland vegetation and types	River red gum woodland and forests	Detect changes in area and condition Establish relationship between flow regime and wetland vegetation area, diversity and health Establish extent of lippia infestation	Mapped area, tree health, understorey condition, recruitment	Every 2 years for condition & every 5 years for extent	High
	Coolibah woodland				Medium
	Black box woodland				
	Common reed reed beds		Mapped area, condition, recruitment	Every 2 years for condition & every 5 years for extent	High
	Cumbungi rushland				
	Water couch marsh				
	Mixed marsh vegetation				
	Mixed grassland			Every 3 years for condition & every 5 years for extent	High
	Lagoons		Mapped area, inundation frequency	Every 2 years for condition & every 5 years for extent	High

Table 21 continued

Overarching component or process	Specific component or processes	Objective of monitoring	Indicator / measure	Frequency	Priority
Birds	Waterbird numbers and species	Detect changes in waterbird numbers and species	Total numbers of waterbirds and number of waterbird species recorded during annual aerial surveys in the northern third of the Macquarie Marshes	All flood events, at least every year	Medium
	Waterbird breeding	Detect changes in number, frequency and location of waterbird breeding events	Number and frequency of breeding of colonial waterbirds and number of breeding sites	All flood events	High
Aquatic ecological community	Macroinvertebrates Microinvertebrates (rotifers and crustaceans including cladocerans, copepods and ostracods)	Detect changes in numbers and species of invertebrates Establish macro and microinvertebrate food webs in relation to flow regimes	Presence/ absence of families Total number of families Diversity and densities after flood and dry periods	All flood events	Medium
	Native fish	Detect changes in distribution and abundance of endemic and feral fish fauna	Species diversity Species abundance Recruitment	Every 2 years and all flood events	Medium
Other vertebrates	Reptiles, in particular red-bellied black snakes	Establish baseline abundance information Establish ecological requirements Establish sustainable grazing levels	Diversity and density of species at different locations Condition after flood/dry Health of understorey in grazed and un-grazed areas	On going	Low
	Frogs				Medium
	Mammals, in particular water rats				Low
	Cattle				Medium

12 Communication, education, participation and awareness (CEPA)

Communication, education, participation and awareness (CEPA) activities can play an important role in wetland conservation, wise use and management. Under the Ramsar Convention, a CEPA program has been established to help raise awareness of wetland values and functions.

In response to this, Australia established the Wetland Communication, Education and Public Awareness (CEPA) National Action Plan 2001–2005. This plan provided an umbrella for coordinated activities across Australia; however, it is no longer current. A revised national approach to CEPA will be articulated in the National Wetlands Policy Statement currently being drafted through the Natural Resource Management Ministerial Council. Whilst the 2001–2005 national action plan is no longer current it continues to provide guidance towards the collaboration of effectively delivered CEPA activities. It also provides a number of guiding principles relevant to the development of a CEPA action plan for the Macquarie Marshes Ramsar site. The principles are:

- The CEPA plan will recognise education in its broadest sense. This includes involving people in wetland research; conducting debates on topical wetland issues; experiential activities; theatre productions and other artistic activities.
- Motivating and empowering people are implicit in all CEPA initiatives. All people (managers, policy-makers, researchers, etc.) have a responsibility to educate.
- It is acknowledged that wetland CEPA is a shared responsibility, and decision-making and actions are to be undertaken in an atmosphere of inclusiveness and through partnerships.
- Wetland CEPA must involve major participation from the group, sector or organisation where the impact of the CEPA activity or process is most felt.
- Actions will be appropriate to community needs and situations.
- The dissemination of research and the involvement of wetland managers in wetland research are important to the conservation and ecologically sustainable use of wetlands.
- Indigenous people's knowledge and practices in relation to wetlands are supported and respected.
- The existing structures of agencies, organisations, educational institutions and community groups and their expertise will form the basis for building an effective network.
- Systems of communication, negotiation and coordinated decision-making, which can be sustained for the long term, are crucial to the promotion of practical, efficient and effective actions.
- Social justice, equity and democratic processes and principles are fundamental to the development of, and the process of developing, actions.
- The CEPA action plan will evolve in response to monitoring, evaluation and emerging issues.
- The basis of all actions must be in terms of environmental benefits.

A management plan or a CEPA action plan for the Macquarie Marshes Ramsar site needs to acknowledge not only the ecological significance of the Macquarie Marshes, but also the social significance. The following are some examples of management responsibilities that have been identified during preparation of this ECD:

- The Macquarie Marshes are renowned as one of the most significant colonial waterbird breeding sites in Australia. Nesting occurs both within the nature reserve and in the surrounding private lands. Advise relevant stakeholders of proposed studies, position papers, consultation and reviews to be undertaken to secure a greater understanding and ecological future for waterbird breeding sites. This includes any emerging information associated with the impacts of climate change.
- The Macquarie Marshes exist because of the unique interplay of geomorphic features and hydrologic regime. Advise relevant Macquarie Marshes landholders of ecological and water requirements for wetland vegetation including river red gum forest and woodland, common reed reed beds, cumbungi and water couch marsh.
- Advise government agencies and stakeholders of ecological and water requirements for wetland vegetation including river red gum forest and woodland, common reed reed beds, cumbungi and water couch marsh.
- Inform relevant landholders who are likely to be impacted by any proposed change to environmental water allocations to the Marshes.
- Consult Aboriginal people to ascertain their requirements to research, support, maintain and manage sites of significance and access to Macquarie Marshes Nature Reserve.
- Develop processes with Aboriginal people to improve their involvement in the management and interpretation of cultural values associated with the Macquarie Marshes Nature Reserve.
- Raise awareness of management actions that impact on the Macquarie Marshes Ramsar site through national media organisations.
- Develop and promote educational material in relation to wetlands, ecological communities, cultural heritage sites and current research findings to local, state and national media organisations, if information is ethically approved and in the interests of the preservation and conservation of specific sites, values and interests.

Abbreviations

CAMBA	China–Australia Migratory Bird Agreement
CMS	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
DSE	Department of Sustainability and Environment (Victoria)
DPI	Department of Primary Industries (NSW)
EAAF	East Asian–Australasian Flyway
EAASRN	East Asian–Australasian Shorebird (or wading bird) Reserve Network (now falls under the Asia–Pacific Migratory Waterbird Conservation Strategy)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
IUCN	International Union for Conservation of Nature and Natural Resources
JAMBA	Japan–Australia Migratory Bird Agreement
NPWS	National Parks and Wildlife Service (NSW)
NSW	New South Wales
NWI	National Water Initiative
OEH	Office of Environment and Heritage (NSW)
RIS	Ramsar Information Sheet
ROTAP	Rare or Threatened Australian Plants
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth)
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
WISE	Water Information System for the Environment

Glossary

Administrative authority The agency within each contracting party charged by the national government with oversight of implementation of the Ramsar Convention within its territory (Ramsar Convention 2012).

Adverse conditions Ecological conditions unusually hostile to the survival of plant or animal species, such as those that occur during severe weather like prolonged drought, flooding, cold, etc. (Ramsar Convention 2008).

Assessment The identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (as defined by Ramsar Convention 2002, Resolution VIII.6).

Baseline condition at a starting point For Ramsar wetlands, it will usually be the time of listing of a Ramsar site (Lambert & Elix 2006).

Benchmark A standard or point of reference (ANZECC and ARMCANZ 2000). A predetermined state (based on the values that are sought to be protected) to be achieved or maintained (Lambert & Elix 2006).

Benefits Benefits here refer to the economic, social and cultural benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). These benefits often rely on the underlying ecological components and processes in the wetland. See also 'Ecosystem services'.

Biogeographic region A scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc. (Ramsar Convention 2008; Wolfgang 1998).

Biological diversity The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes. This definition is based largely on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2008).

Catchment The total area draining into a river, reservoir, or other body of water (ANZECC and ARMCANZ 2000).

Change in ecological character Human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005, Resolution IX.1 Annex A).

Community An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).

Community composition All the types of taxa present in a community (ANZECC and ARMCANZ 2000).

Community structure All the types of taxa present in a community and their relative abundances (ANZECC and ARMCANZ 2000).

Conceptual model Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Manley et al. 2000; Gross 2003).

Contracting Parties Countries that are Member States to the Ramsar Convention on Wetlands; 161 as at May 2012. Membership of the convention is open to all states that are members of the United Nations (UN), one of the UN specialised agencies, or the International Atomic Energy Agency, or are a Party to the Statute of the International Court of Justice. www.ramsar.org/cda/en/ramsar-about-parties/main/ramsar/1-36-123_4000_0__

Critical stage	Stage of the life cycle of wetland-dependent species (e.g. breeding, migration stopovers, moulting) that, if interrupted or prevented from occurring, may threaten long-term conservation of the species (Ramsar Convention 2008).
Ecological character	The combination of the ecosystem components, processes, benefits and services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the variety of benefits to people (ecosystem services). The phrase ‘at a given point in time’ refers to Resolution VI.1 paragraph 2.1, which states that ‘It is essential that the ecological character of a site be described by the Contracting Party concerned at the time of designation for the Ramsar List, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7) (Ramsar Convention 1996).
Ecological community	Any naturally occurring group of species inhabiting a common environment that interact with each other, especially through food relationships, and that are relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2008).
Ecosystem	Within the Millennium Ecosystem Assessment, an ecosystem is described as the complex of living communities (including human communities) and nonliving environment (ecosystem components) interacting (through ecological processes) as a functional unit, which provides, inter alia, a variety of benefits to people (ecosystem services) (Ramsar Convention 2005, Resolution IX.1 Annex A).
Ecosystem components	Include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Ramsar Convention 2005, Resolution IX.1 Annex A).
Ecosystem processes	Dynamic forces within an ecosystem. They include all those processes that occur between organisms and within and between populations and communities, including interactions with the nonliving environment that result in existing ecosystems and that bring about changes in ecosystems over time (Australian Heritage Commission 2002). They may be physical, chemical or biological.
Ecosystem services	Benefits that people receive or obtain from an ecosystem (Ramsar Convention 2005, Resolution IX.1 Annex A). The components of ecosystem services include (Millennium Ecosystem Assessment 2005a): · provisioning services — such as food, fuel and freshwater· regulating services — the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation · cultural services — the benefits people obtain through spiritual enrichment, recreation, education and aesthetics · supporting services — the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota (Quinn et al. 2000). These services will generally have an indirect benefit to humans or a direct benefit in the long term. See also ‘Benefits’.
Ecologically sustainable development	Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ANZECC and ARMCANZ 2000).
Fluvial geomorphology	Study of water-shaped landforms (Gordon et al. 1999)
Indicator species	Species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2008).

Indigenous species	Species that originates and occurs naturally in a particular country (Ramsar Convention 2008).
Introduced (non native) species	Species that does not originate or occur naturally in a particular country (Ramsar Convention 2008).
IUCN Red List	The IUCN Red List of Threatened Species™ is a list of species identified as being at risk of extinction, maintained by the International Union for Conservation of Nature and Natural Resources. The aim of the list is to provide information about the status, trends and threats to such species, to inform and facilitate action for biodiversity conservation. www.iucnredlist.org/
Limits of acceptable change (LACs)	Degree of variation considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character that could lead to a reduction or loss of the criteria for which the site was Ramsar listed (modified from definition adopted by Phillips 2006).
List of wetlands of international importance ('the Ramsar List')	Wetlands that have been designated by the Ramsar Contracting Party in which they reside as internationally important, according to one or more of the criteria adopted by the Conference of the Parties (Ramsar Convention 2012).
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 (Ramsar Convention 2002, Resolution VIII.6).
Ramsar	City in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title, 'Ramsar Convention on Wetlands' (Ramsar Convention 2012).
Ramsar criteria	Criteria for identifying wetlands of international importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values (Ramsar Convention 2012).
Ramsar Convention	*Convention on Wetlands of International Importance especially as Waterfowl Habitat*. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names 'Convention on Wetlands (Ramsar, Iran, 1971)' or 'Ramsar Convention' are used more commonly. www.ramsar.org/cda/en/ramsar-documents-texts/main/ramsar/1-31-38_4000_0__
Ramsar Information Sheet (RIS)	Form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and conservation measures taken and needed (Ramsar Convention 2012).
Ramsar List	List of Wetlands of International Importance. Wetlands are designated by their Contracting Party for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria (Ramsar Convention 2012).
Ramsar Sites Database	Repository of ecological, biological, socio-economic, and political data and maps with boundaries on all Ramsar sites, maintained by Wetlands International in Wageningen, the Netherlands, under contract to the Convention (Ramsar Convention 2012).

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 (Ramsar Convention 1987).
Wetland assessment	Identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Finlayson et al. 2001; Ramsar Convention 2002).
Wetland ecological risk assessment	Quantitative or qualitative evaluation of the actual or potential adverse effects of stressors on a wetland ecosystem.
Wetland types	Categories of wetland as defined by the Ramsar Convention's wetland classification system. www.ramsar.org/cda/en/ramsar-documents-info-information-sheet-on/main/ramsar/1-31-59%5E21253_4000_0__#type
Wise use of wetlands	Maintenance of the ecological character of wetlands, 'achieved through the implementation of ecosystem approaches, within the context of sustainable development' (Ramsar Convention 2005 Resolution IX.1 Annex A).

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Appendix 1: Plant species recorded in the Macquarie Marshes Nature Reserve

(Sources: Atlas of NSW Wildlife 2008; Harden 1990–1993; Shelly 2005; Wilson et al. 1993)

Species	**Common name**	**Family**	**Origin**	**Bioregion abundance**
Abutilon fraseri		Malvaceae	Native	Occasionally recorded
Abutilon malvifolium		Malvaceae	Native	Occasionally recorded
Abutilon oxycarpum	Flannel weed	Malvaceae	Native	Abundant
Abutilon theophrasti		Malvaceae	Exotic	Rarely recorded
Acacia excelsa	Ironwood	Fabaceae (Mimosoideae)	Native	Commonly recorded
Acacia oswaldii	Miljee	Fabaceae (Mimosoideae)	Native	Abundant
Acacia paradoxa		Fabaceae (Mimosoideae)	Native	Rarely recorded
Acacia pendula	Boree	Fabaceae (Mimosoideae)	Native	Abundant
Acacia salicina	Cooba	Fabaceae (Mimosoideae)	Native	Abundant
Acacia stenophylla	River cooba	Fabaceae (Mimosoideae)	Native	Abundant
Aeschynomene indica	Budda pea	Fabaceae (Faboideae)	Native	Commonly recorded
Alectryon oleifolius	Western rosewood	Sapindaceae	Native	Abundant
Allocasuarina luehmannii	Bulloak	Casuarinaceae	Native	Abundant
Alstonia constricta	Quinine bush	Apocynaceae	Native	Abundant
Alternanthera denticulata	Lesser joyweed	Amaranthaceae	Native	Abundant
Alternanthera nana	Hairy joyweed	Amaranthaceae	Native	Commonly recorded
Alternanthera pungens	Khaki weed	Amaranthaceae	Exotic	Occasionally recorded
Amaranthus macrocarpus	Dwarf amaranth	Amaranthaceae	Native	Abundant
Ammi visnaga		Apiaceae	Native	Rarely recorded
Amyema gaudichaudii		Loranthaceae	Native	Rarely recorded
Amyema lucasii		Loranthaceae	Native	Occasionally recorded
Amyema miquelii		Loranthaceae	Native	Abundant
Amyema miraculosum subsp. *boormanii*		Loranthaceae	Native	Abundant
Amyema quandang var. *quandang*		Loranthaceae	Native	Occasionally recorded
Anacampseros australiana		Portulacaceae	Native	Rarely recorded

Species	Common name	Family	Origin	Bioregion abundance
Anagallis arvensis	Scarlet/blue pimpernel	Primulaceae	Exotic	Commonly recorded
Apophyllum anomalum	Warrior bush	Capparaceae	Native	Abundant
Aristida muricata		Poaceae	Native	Occasionally recorded
Aster subulatus	Wild aster	Asteraceae	Exotic	Abundant
Astrebla pectinata	Barley mitchell grass	Poaceae	Native	Abundant
Atalaya hemiglauca	Whitewood	Sapindaceae	Native	Abundant
Atriplex conduplicata		Chenopodiaceae	Native	Occasionally recorded
Atriplex eardleyae		Chenopodiaceae	Native	Commonly recorded
Atriplex leptocarpa	Slender-fruit saltbush	Chenopodiaceae	Native	Abundant
Atriplex lindleyi		Chenopodiaceae	Native	Abundant
Atriplex nummularia	Old man saltbush	Chenopodiaceae	Native	Abundant
Atriplex pseudocampanulata		Chenopodiaceae	Native	Abundant
Atriplex semibaccata	Creeping saltbush	Chenopodiaceae	Native	Abundant
Atriplex suberecta		Chenopodiaceae	Native	Commonly recorded
Atriplex vesicaria	Bladder saltbush	Chenopodiaceae	Native	Abundant
Austrodanthonia caespitosa	Ringed wallaby grass	Poaceae	Native	Commonly recorded
Austrostipa scabra	Speargrass	Poaceae	Native	Abundant
Avena fatua	Wild oats	Poaceae	Exotic	Commonly recorded
Azolla filiculoides		Azollaceae	Native	Commonly recorded
Azolla pinnata		Azollaceae	Native	Rarely recorded
Boerhavia dominii	Tarvine	Nyctaginaceae	Native	Abundant
Brachychiton populneus	Kurrajong	Sterculiaceae	Native	Occasionally recorded
Brachyscome basaltica var. *gracilis*	Swamp daisy	Asteraceae	Native	Occasionally recorded
Brachyscome debilis		Asteraceae	Native	Occasionally recorded
Brachyscome heterodonta		Asteraceae	Native	Abundant
Brachyscome leptocarpa		Asteraceae	Native	Rarely recorded
Brachyscome lineariloba	Hard-headed daisy	Asteraceae	Native	Commonly recorded
Brachyscome whitei	Spreading daisy	Asteraceae	Native	Occasionally recorded
Brassica tournefortii	Mediterranean turnip	Brassicaceae	Exotic	Commonly recorded
Callitris glaucophylla	White cypress pine	Cupressaceae	Native	Abundant
Calotis hispidula	Bogan flea	Asteraceae	Native	Commonly recorded

Species	Common name	Family	Origin	Bioregion abundance
Calotis scabiosifolia var. *scabiosifolia*		Asteraceae	Native	Abundant
Calotis scapigera	Tufted burr-daisy	Asteraceae	Native	Abundant
Canthium oleifolium	Wild lemon	Rubiaceae	Native	Commonly recorded
Capparis lasiantha	Nepine	Capparaceae	Native	Abundant
Capparis mitchellii	Native orange	Capparaceae	Native	Abundant
Capsella bursa-pastoris	Shepherd's purse	Brassicaceae	Exotic	Occasionally recorded
Carex inversa	Knob sedge	Cyperaceae	Native	Abundant
Carthamus lanatus	Saffron thistle	Asteraceae	Exotic	Commonly recorded
Casuarina cristata	Belah	Casuarinaceae	Native	Abundant
Centaurea melitensis	Maltese cockspur	Asteraceae	Exotic	Abundant
Centipeda minima	Spreading sneezeweed	Asteraceae	Native	Abundant
Chamaesyce drummondii	Caustic weed	Euphorbiaceae	Native	Abundant
Cheilanthes austrotenuifolia	Rock fern	Adiantaceae	Native	Commonly recorded
Chenopodium curvispicatum		Chenopodiaceae	Native	Abundant
Chenopodium melanocarpum	Black crumbweed	Chenopodiaceae	Native	Commonly recorded
Chenopodium murale	Nettle-leaf goosefoot	Chenopodiaceae	Exotic	Occasionally recorded
Chenopodium pumilio	Small crumbweed	Chenopodiaceae	Native	Abundant
Chloris divaricata var. *divaricata*	Slender chloris	Poaceae	Native	Abundant
Chloris truncata	Windmill grass	Poaceae	Native	Abundant
Cirsium vulgare	Spear thistle	Asteraceae	Exotic	Abundant
Citrullus colocynthis		Cucurbitaceae	Exotic	Occasionally recorded
Convolvulus erubescens		Convolvulaceae	Native	Abundant
Conyza bonariensis	Flaxleaf fleabane	Asteraceae	Exotic	Abundant
Conyza sumatrensis		Asteraceae	Exotic	Rarely recorded
Cotula australis	Common cotula	Asteraceae	Native	Occasionally recorded
Cotula coronopifolia	Water buttons	Asteraceae	Exotic	Rarely recorded
Crinum flaccidum	Darling lily	Amaryllidaceae	Native	Abundant
Cucumis myriocarpus subsp. *leptodermis*	Paddy melon	Cucurbitaceae	Native	Abundant
Cullen cinereum	Annual verbine	Fabaceae (Faboideae)	Native	Occasionally recorded
Cullen tenax	Emu-foot	Fabaceae (Faboideae)	Native	Abundant
Cuscuta victoriana		Convolvulaceae	Native	Occasionally recorded

Species	Common name	Family	Origin	Bioregion abundance
Cynodon dactylon	Common couch	Poaceae	Native	Abundant
Cynodon incompletus		Poaceae	Exotic	Occasionally recorded
Cynoglossum australe		Boraginaceae	Native	Commonly recorded
Cyperus bifax		Cyperaceae	Native	Abundant
Cyperus concinnus		Cyperaceae	Native	Abundant
Cyperus dactylotes		Cyperaceae	Native	Rarely recorded
Cyperus difformis	Dirty dora	Cyperaceae	Native	Commonly recorded
Cyperus exaltatus		Cyperaceae	Native	Commonly recorded
Cyperus involucratus		Cyperaceae	Native	Rarely recorded
Cyperus pygmaeus		Cyperaceae	Native	Occasionally recorded
Cyperus victoriensis		Cyperaceae	Native	Rarely recorded
Dactyloctenium radulans	Button grass	Poaceae	Native	Abundant
Damasonium minus	Starfruit	Alismataceae	Native	Occasionally recorded
Daucus glochidiatus	Native carrot	Apiaceae	Native	Abundant
Dianella revoluta		Phormiaceae	Native	Occasionally recorded
Dichondra repens	Kidney weed	Convolvulaceae	Native	Abundant
Diplachne fusca		Poaceae	Native	Occasionally recorded
Dodonaea viscosa		Sapindaceae	Native	Abundant
Echinochloa colona	Awnless barnyard grass	Poaceae	Native	Commonly recorded
Echium plantagineum	Patterson's curse	Boraginaceae	Exotic	Abundant
Eclipta platyglossa		Asteraceae	Native	Abundant
Einadia nutans	Climbing saltbush	Chenopodiaceae	Native	Abundant
Eleocharis pallens		Cyperaceae	Native	Abundant
Eleocharis plana		Cyperaceae	Native	Abundant
Eleocharis pusilla		Cyperaceae	Native	Commonly recorded
Eleocharis sphacelata	Tall spike rush	Cyperaceae	Native	Abundant
Enchylaena tomentosa	Ruby saltbush	Chenopodiaceae	Native	Abundant
Enchylaena tomentosa var. *tomentosa*		Chenopodiaceae	Native	Rarely recorded
Enneapogon nigricans	Niggerheads	Poaceae	Native	Occasionally recorded
Epilobium hirtigerum		Onagraceae	Native	Occasionally recorded
Eragrostis cilianensis	Stinkgrass	Poaceae	Exotic	Abundant

Species	Common name	Family	Origin	Bioregion abundance
Eragrostis elongata	Clustered lovegrass	Poaceae	Native	Occasionally recorded
Eragrostis falcata	Sickle lovegrass	Poaceae	Native	Occasionally recorded
Eragrostis kennedyae	Small-flowered lovegrass	Poaceae	Native	Occasionally recorded
Eragrostis lacunaria	Purple lovegrass	Poaceae	Native	Abundant
Eragrostis parviflora	Weeping lovegrass	Poaceae	Native	Commonly recorded
Eragrostis pilosa		Poaceae	Exotic	Rarely recorded
Eragrostis setifolia	Neverfail	Poaceae	Native	Abundant
Eremophila debilis	Amulla	Myoporaceae	Native	Commonly recorded
Eremophila deserti	Turkeybush	Myoporaceae	Native	Commonly recorded
Eremophila longifolia	Emubush	Myoporaceae	Native	Abundant
Eremophila mitchellii	Budda	Myoporaceae	Native	Abundant
Eriochloa crebra	Cup grass	Poaceae	Native	Abundant
Erodium crinitum	Blue storksbill	Geraniaceae	Native	Abundant
Erodium malacoides		Geraniaceae	Exotic	Occasionally recorded
Eucalyptus camaldulensis	River red gum	Myrtaceae	Native	Abundant
Eucalyptus chloroclada	Dirty gum	Myrtaceae	Native	Commonly recorded
Eucalyptus coolabah	Coolibah	Myrtaceae	Native	Abundant
Eucalyptus largiflorens	Black box	Myrtaceae	Native	Abundant
Eucalyptus populnea subsp. *bimbil*	Bimble box	Myrtaceae	Native	Abundant
Euphorbia drummondii		Euphorbiaceae	Native	Abundant
Euphorbia planiticola		Euphorbiaceae	Native	Occasionally recorded
Evolvulus alsinoides var. *decumbens*		Convolvulaceae	Native	Occasionally recorded
Flindersia maculosa	Leopardwood	Rutaceae	Native	Abundant
Geijera parviflora	Wilga	Rutaceae	Native	Abundant
Glinus lotoides		Aizoaceae	Native	Occasionally recorded
Glossogyne tannensis	Cobbler's tack	Asteraceae	Native	Occasionally recorded
Glycine clandestina		Fabaceae (Faboideae)	Native	Commonly recorded
Gnephosis tenuissima		Asteraceae	Native	Rarely recorded
Goodenia cycloptera		Goodeniaceae	Native	Commonly recorded
Goodenia fascicularis		Goodeniaceae	Native	Abundant
Goodenia glauca		Goodeniaceae	Native	Abundant

Species	**Common name**	**Family**	**Origin**	**Bioregion abundance**
Goodenia hederacea		Goodeniaceae	Native	Occasionally recorded
Goodenia lunata		Goodeniaceae	Native	Rarely recorded
Haloragis aspera		Haloragaceae	Native	Occasionally recorded
Haloragis glauca forma *glauca*		Haloragaceae	Native	Abundant
Haloragis heterophylla		Haloragaceae	Native	Occasionally recorded
Heliotropium supinum	Prostrate heliotrope	Boraginaceae	Exotic	Commonly recorded
Hibiscus trionum	Bladder ketmia	Malvaceae	Native	Commonly recorded
Hordeum leporinum	Barley grass	Poaceae	Exotic	Abundant
Hypochaeris glabra	Smooth catsear	Asteraceae	Exotic	Commonly recorded
Hypochaeris radicata	Catsear	Asteraceae	Exotic	Abundant
Hypoxis glabella var. *glabella*		Hypoxidaceae	Native	Rarely recorded
Indigofera australis		Fabaceae (Faboideae)	Native	Occasionally recorded
Isoetes muelleri		Isoetaceae	Native	Occasionally recorded
Isoetopsis graminifolia	Grass cushion	Asteraceae	Native	Occasionally recorded
Jasminum lineare	Desert jasmine	Oleaceae	Native	Abundant
Juncus amabilis		Juncaceae	Native	Occasionally recorded
Juncus aridicola		Juncaceae	Native	Abundant
Juncus radula		Juncaceae	Native	Rarely recorded
Juncus subsecundus		Juncaceae	Native	Occasionally recorded
Lactuca saligna	Willow-leaved lettuce	Asteraceae	Exotic	Occasionally recorded
Lactuca serriola	Prickly lettuce	Asteraceae	Exotic	Commonly recorded
Lamium amplexicaule	Dead nettle	Lamiaceae	Exotic	Occasionally recorded
Lemna disperma		Lemnaceae	Native	Occasionally recorded
Leontodon taraxacoides subsp. *taraxacoides*	Lesser hawkbit	Asteraceae	Exotic	Rarely recorded
Lepidium fasciculatum		Brassicaceae	Native	Commonly recorded
Lepidium hyssopifolium		Brassicaceae	Native	Rarely recorded (threatened NSW)
Leptochloa digitata	Umbrella canegrass	Poaceae	Native	Abundant

Species	Common name	Family	Origin	Bioregion abundance
Ludwigia peploides subsp. *montevidensis*	Water primrose	Onagraceae	Native	Abundant
Lycium ferocissimum	African boxthorn	Solanaceae	Exotic	Abundant
Lysiana subfalcata		Loranthaceae	Native	Occasionally recorded
Lythrum hyssopifolia	Hyssop loosestrife	Lythraceae	Exotic	Occasionally recorded
Maireana aphylla	Cotton bush	Chenopodiaceae	Native	Abundant
Maireana brevifolia		Chenopodiaceae	Native	Occasionally recorded
Maireana ciliata		Chenopodiaceae	Native	Occasionally recorded
Maireana coronata		Chenopodiaceae	Native	Commonly recorded
Maireana decalvans	Black cotton bush	Chenopodiaceae	Native	Abundant
Maireana enchylaenoides		Chenopodiaceae	Native	Occasionally recorded
Maireana pentagona	Hairy bluebush	Chenopodiaceae	Native	Occasionally recorded
Malacocera tricornis	Soft horns	Chenopodiaceae	Native	Occasionally recorded
Malva parviflora	Small-flowered mallow	Malvaceae	Exotic	Abundant
Malva sylvestris		Malvaceae	Native	Rarely recorded
Malvastrum americanum	Spiked malvastrum	Malvaceae	Exotic	Abundant
Marrubium vulgare	Horehound	Lamiaceae	Exotic	Abundant
Marsdenia australis	Doubah	Asclepiadaceae	Native	Occasionally recorded
Marsilea costulifera		Marsileaceae	Native	Occasionally recorded
Marsilea drummondii	Common nardoo	Marsileaceae	Native	Abundant
Medicago laciniata	Cut-leaved medic	Fabaceae (Faboideae)	Exotic	Abundant
Medicago minima	Woolly burr medic	Fabaceae (Faboideae)	Exotic	Abundant
Medicago polymorpha	Burr medic	Fabaceae (Faboideae)	Exotic	Abundant
Melilotus indicus	Hexham scent	Fabaceae (Faboideae)	Native	Commonly recorded
Mentha australis	River mint	Lamiaceae	Native	Occasionally recorded
Mimulus gracilis	Slender monkey-flower	Scrophulariaceae	Native	Abundant
Minuria cunninghamii		Asteraceae	Native	Occasionally recorded

Species	Common name	Family	Origin	Bioregion abundance
Minuria denticulata		Asteraceae	Native	Occasionally recorded
Minuria integerrima		Asteraceae	Native	Abundant
Minuria leptophylla		Asteraceae	Native	Occasionally recorded
Muehlenbeckia florulenta	Lignum	Polygonaceae	Native	Abundant
Muehlenbeckia horrida		Polygonaceae	Native	Commonly recorded
Myoporum montanum	Western boobialla	Myoporaceae	Native	Abundant
Myoporum platycarpum	Sugarwood	Myoporaceae	Native	Commonly recorded
Myriophyllum propinquum		Haloragaceae	Native	Occasionally recorded
Neptunia gracilis forma *gracilis*	Sensitive plant	Fabaceae (Mimosoideae)	Native	Abundant
Nicotiana glauca	Tree tobacco	Solanaceae	Exotic	Occasionally recorded
Nicotiana simulans		Solanaceae	Native	Occasionally recorded
Nicotiana velutina		Solanaceae	Native	Abundant
Nymphoides crenata		Menyanthaceae	Native	Rarely recorded
Oenothera indecora subsp. *bonariensis*		Onagraceae	Exotic	Rarely recorded
Onopordum acanthium subsp*. acanthium*	Scotch thistle	Asteraceae	Exotic	Commonly recorded
Osteocarpum acropterum		Chenopodiaceae	Native	Abundant
Osteocarpum acropterum var*. deminuta*		Chenopodiaceae	Native	Commonly recorded
Oxalis corniculata	Creeping oxalis	Oxalidaceae	Exotic	Abundant
Oxalis perennans		Oxalidaceae	Native	Abundant
Pandorea pandorana	Wonga wonga vine	Bignoniaceae	Native	Occasionally recorded
Panicum decompositum	Native millet	Poaceae	Native	Abundant
Panicum effusum	Poison or hairy panic	Poaceae	Native	Commonly recorded
Panicum laevifolium		Poaceae	Native	Rarely recorded
Panicum laevinode	Pepper grass	Poaceae	Native	Commonly recorded
Panicum miliaceum		Poaceae	Exotic	Rarely recorded
Parietaria debilis		Urticaceae	Native	Rarely recorded
Paspalidium constrictum	Knottybutt grass	Poaceae	Native	Abundant
Paspalidium gracile	Slender panic	Poaceae	Native	Abundant
Paspalidium jubiflorum	Warrego grass	Poaceae	Native	Abundant
Paspalum dilatatum	Paspalum	Poaceae	Exotic	Occasionally recorded

Species	Common name	Family	Origin	Bioregion abundance
Paspalum distichum	Water couch	Poaceae	Exotic	Abundant
Persicaria decipiens	Slender knotweed	Polygonaceae	Native	Abundant
Persicaria orientalis	Princes feathers	Polygonaceae	Exotic	Occasionally recorded
Persicaria prostrata	Creeping knotweed	Polygonaceae	Native	Occasionally recorded
Phragmites australis	Common reed	Poaceae	Native	Commonly recorded
Phyla nodiflora var. *nodiflora*	Lippia	Verbenaceae	Exotic	Abundant
Phyllanthus virgatus		Euphorbiaceae	Native	Commonly recorded
Physalis ixocarpa	Ground cherry	Solanaceae	Exotic	Occasionally recorded
Picris hieracioides		Asteraceae	Exotic	Rarely recorded
Pimelea microcephala subsp. *microcephala*		Thymelaeaceae	Native	Abundant
Plagiobothrys plurisepaleus		Boraginaceae	Native	Occasionally recorded
Plantago cunninghamii		Plantaginaceae	Native	Abundant
Plantago turrifera		Plantaginaceae	Native	Commonly recorded
Poa annua	Winter grass	Poaceae	Exotic	Occasionally recorded
Polygonum aviculare	Wireweed	Polygonaceae	Exotic	Commonly recorded
Portulaca oleracea	Pigweed	Portulacaceae	Native	Abundant
Pratia concolor	Poison pratia	Lobeliaceae	Native	Abundant
Ptilotus semilanatus		Amaranthaceae	Native	Commonly recorded
Ranunculus pumilio		Ranunculaceae	Native	Commonly recorded
Ranunculus sceleratus	Celery buttercup	Ranunculaceae	Native	Rarely recorded
Ranunculus undosus		Ranunculaceae	Native	Abundant
Rapistrum rugosum	Turnip weed	Brassicaceae	Exotic	Abundant
Rhagodia spinescens		Chenopodiaceae	Native	Abundant
Rhynchosia minima	Ryncho	Fabaceae (Faboideae)	Native	Occasionally recorded
Rorippa eustylis		Brassicaceae	Native	Abundant
Rorippa palustris	Yellow cress	Brassicaceae	Exotic	Occasionally recorded
Rumex bidens		Polygonaceae	Native	Rarely recorded
Rumex brownii	Swamp dock	Polygonaceae	Native	Abundant
Rumex crystallinus	Shiny dock	Polygonaceae	Native	Abundant
Salsola tragus		Chenopodiaceae	Native	Abundant
Salvia verbenaca	Wild sage	Lamiaceae	Exotic	Occasionally recorded
Schoenoplectus validus		Cyperaceae	Native	Rarely recorded

Species	Common name	Family	Origin	Bioregion abundance
Scleranthus biflorus		Caryophyllaceae	Native	Occasionally recorded
Scleranthus pungens		Caryophyllaceae	Native	Rarely recorded
Scleroblitum atriplicinum	Purple goosefoot	Chenopodiaceae	Native	Commonly recorded
Sclerolaena anisacanthoides	Yellow burr	Chenopodiaceae	Native	Occasionally recorded
Sclerolaena bicornis	Goathead burr	Chenopodiaceae	Native	Abundant
Sclerolaena birchii	Galvinized burr	Chenopodiaceae	Native	Abundant
Sclerolaena brachyptera		Chenopodiaceae	Native	Abundant
Sclerolaena calcarata	Redburr	Chenopodiaceae	Native	Abundant
Sclerolaena limbata		Chenopodiaceae	Native	Occasionally recorded
Sclerolaena muricata	Black rolypoly	Chenopodiaceae	Native	Abundant
Sclerolaena stelligera		Chenopodiaceae	Native	Abundant
Sclerolaena tricuspis	Giant redburr	Chenopodiaceae	Native	Abundant
Senecio cunninghamii		Asteraceae	Native	Occasionally recorded
Senecio lautus subsp. *dissectifolius*		Asteraceae	Native	Occasionally recorded
Senecio quadridentatus	Cotton fireweed	Asteraceae	Native	Abundant
Senecio runcinifolius	Tall groundsel	Asteraceae	Native	Abundant
Sesbania cannabina var. *cannabina*	Sesbania pea	Fabaceae (Faboideae)	Native	Commonly recorded
Sida corrugata		Malvaceae	Native	Abundant
Sida cunninghamii		Malvaceae	Native	Abundant
Sida fibulifera		Malvaceae	Native	Abundant
Sida rhombifolia	Paddy's lucerne	Malvaceae	Exotic	Commonly recorded
Sida trichopoda		Malvaceae	Native	Abundant
Silybum marianum	Variegated thistle	Asteraceae	Exotic	Abundant
Sisymbrium irio	London rocket	Brassicaceae	Native	Commonly recorded
Solanum esuriale	Quena	Solanaceae	Native	Abundant
Solanum nigrum	Black-berry nightshade	Solanaceae	Exotic	Abundant
Sonchus oleraceus	Common sowthistle	Asteraceae	Exotic	Abundant
Spergularia rubra	Sandspurry	Caryophyllaceae	Exotic	Occasionally recorded
Sporobolus caroli	Fairy grass	Poaceae	Native	Abundant
Sporobolus contiguus		Poaceae	Native	Rarely recorded
Sporobolus mitchellii	Rat's tail couch	Poaceae	Native	Abundant

Species	Common name	Family	Origin	Bioregion abundance
Stachys arvensis	Stagger weed	Lamiaceae	Exotic	Occasionally recorded
Stellaria angustifolia	Swamp starwort	Caryophyllaceae	Native	Abundant
Stellaria media	Common chickweed	Caryophyllaceae	Exotic	Occasionally recorded
Swainsona swainsonioides		Fabaceae (Faboideae)	Native	Occasionally recorded
Tetragonia tetragonioides	New Zealand spinach	Aizoaceae	Native	Abundant
Teucrium racemosum	Grey germander	Lamiaceae	Native	Abundant
Themeda australis	Kangaroo grass	Poaceae	Native	Occasionally recorded
Tragus australianus	Small burrgrass	Poaceae	Native	Commonly recorded
Trianthema triquetra		Aizoaceae	Native	Abundant
Tribulus terrestris	Catshead	Zygophyllaceae	Native	Abundant
Triglochin procerum	Water ribbons	Juncaginaceae	Native	Rarely recorded
Tripogon loliiformis	Fiveminute grass	Poaceae	Native	Commonly recorded
Typha domingensis	Narrow-leaved cumbungi	Typhaceae	Native	Abundant
Urtica urens	Small nettle	Urticaceae	Exotic	Occasionally recorded
Vaccaria hispanica	Cow soapwort	Caryophyllaceae	Exotic	Rarely recorded
Velleia paradoxa		Goodeniaceae	Native	Rarely recorded
Ventilago viminalis	Supple jack	Rhamnaceae	Native	Commonly recorded
Verbascum virgatum	Twiggy mullein	Scrophulariaceae	Exotic	Occasionally recorded
Verbena bonariensis	Purpletop	Verbenaceae	Exotic	Occasionally recorded
Verbena officinalis	Common verbena	Verbenaceae	Exotic	Abundant
Verbesina encelioides subsp. *encelioides*	Crownbeard	Asteraceae	Exotic	Commonly recorded
Vittadinia cuneata	Fuzzweed	Asteraceae	Native	Abundant
Vittadinia pterochaeta	Rough fuzzweed	Asteraceae	Native	Abundant
Wahlenbergia communis	Tufted bluebell	Campanulaceae	Native	Commonly recorded
Xanthium occidentale	Noogoora burr, cockle burr	Asteraceae	Exotic	Abundant
Xanthium orientale	Californian burr	Asteraceae	Native	Occasionally recorded
Xanthium spinosum	Bathurst burr	Asteraceae	Exotic	Abundant
Zaleya galericulata subsp. *australis*		Aizoaceae	Native	Commonly recorded
Zygophyllum glaucum		Zygophyllaceae	Native	Commonly recorded

Appendix 2: Animal species recorded in the Macquarie Marshes Nature Reserve

(Sources: Atlas of NSW Wildlife 2008; Shelly 2005; Reid 1999; Kingsford & Auld 2003)

Legend

Legal status: P Protected V Vulnerable E Endangered
M Protected Migratory Bird U Unprotected

Conservation status: D Declining Woodland Bird B Waterbird Breeding Record

Common name	Scientific name	NSW legal status	National legal status	Declining Woodland Bird	JAMBA CAMBA ROKAMBA	Waterbird Breeding	Atlas of NSW wildlife records	Shelly records (2005)
MAMMALS								
Monotremes	**Monotremata**							
Short-beaked echidna	*Tachyglossus aculeatus*	P					X	X
Marsupials	**Marsupialia**							
Stripe-faced dunnart	*Sminthopsis macroura*	V					X	X
Narrow-nosed planigale	*Planigale tenuirostris*	P					X	X
Fat-tailed dunnart	*Sminthopsis crassicaudata*	P					X	X
Western grey kangaroo	*Macropus fuliginosus*	P					X	
Eastern grey kangaroo	*Macropus giganteus*	P					X	X
Wallaroo	*Macropus robustus*	P						X
Red kangaroo	*Macropus rufus*	P					X	X
Swamp wallaby	*Wallabia bicolor*	P					X	X
Squirrel glider	*Petaurus norfolcensis*	V					X	X
Sugar glider	*Petaurus breviceps*	P					X	X
Common brushtail possum	*Trichosurus vulpecula*	P					X	X
Placental mammals (native)	**Eutheria**							
Yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	V					X	X
Eastern freetail bat	*Mormopterus norfolkensis*	V					X	
Little mastiff bat	*Mormopterus planiceps*	P					X	
Mastiff bat	*Mormopterus sp. (big penis)*	P					X	X
Mastiff bat	*Mormopterus sp. (little penis)*	P					X	X
White-striped freetail bat	*Nyctinomus australis*	P					X	X
Water rat	*Hydromys chrysogaster*	P					X	X
Pale field rat	*Rattus tunneyi*	P					X	
Grey-headed flying fox	*Pteropus poliocephalus*	V	V					X
Little red flying-fox	*Pteropus scapulatus*	P					X	X
Little pied bat	*Chalinolobus picatus*	V					X	X

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Gould's wattled bat	*Chalinolobus gouldii*	P					X	X
Chocolate wattled bat	*Chalinolobus morio*	P						X
Lesser long-eared bat	*Nyctophilus geoffroyi*	P					X	X
Gould's long-eared bat	*Nyctophilus gouldi*	P					X	X
Inland broad-nosed bat	*Scotorepens balstoni*	P					X	X
Little broad-nosed bat	*Scotorepens greyii*	P					X	X
Eastern broad-nosed bat	*Scotorepens orion*	P					X	
Inland forest bat	*Vespadelus baverstocki*	P						X
Southern forest bat	*Vespadelus regulus*	P					X	
Little forest bat	*Vespadelus vulturnus*	P					X	X
Introduced mammals								
European cattle	*Bos taurus*	U					X	
Goat	*Capra hircus*	U					X	X
Fox	*Vulpes vulpes*	U					X	X
Cat	*Felis catus*	U					X	X
Brown hare	*Lepus capensis*	U					X	X
Rabbit	*Oryctolagus cuniculus*	U					X	X
House mouse	*Mus musculus*	U					X	X
Black rat	*Rattus rattus*	U					X	
Pig	*Sus scrofa*	U					X	X
BIRDS								
Birds of prey								
Osprey	*Pandion haliaetus*	V					X	
Black-shouldered kite	*Elanus axillaris*	P					X	X
Letter-winged kite	*Elanus scriptus*	P					X	
Whistling kite	*Haliastur sphenurus*	P					X	X
Black-breasted buzzard	*Hamirostra melanosternon*	V					X	
Square-tailed kite	*Lophoictinia isura*	V					X	
Black kite	*Milvus migrans*	P					X	X
White-bellied sea-eagle	*Haliaeetus leucogaster*	P			M		X	X
Swamp harrier	*Circus approximans*	P					X	X
Spotted harrier	*Circus assimilis*	P					X	
Collared sparrowhawk	*Accipiter cirrocephalus*	P					X	X
Brown goshawk	*Accipiter fasciatus*	P					X	X
Wedge-tailed eagle	*Aquila audax*	P					X	X
Little eagle	*Hieraaetus morphnoides*	P					X	
Brown falcon	*Falco berigora*	P					X	X

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Nankeen kestrel	*Falco cenchroides*	P					X	X
Australian hobby	*Falco longipennis*	P					X	X
Peregrine falcon	*Falco peregrinus*	P					X	X
Black falcon	*Falco subniger*	P					X	X
Waterbirds								
Great crested grebe	*Podiceps cristatus*	P				B	X	
Hoary-headed grebe	*Poliocephalus poliocephalus*	P				B	X	
Australasian grebe	*Tachybaptus novaehollandiae*	P				B	X	X
Australian pelican	*Pelecanus conspicillatus*	P					X	X
Great cormorant	*Phalacrocorax carbo*	P				B	X	X
Little pied cormorant	*Phalacrocorax melanoleucos*	P				B	X	X
Little black cormorant	*Phalacrocorax sulcirostris*	P				B	X	X
Pied cormorant	*Phalacrocorax varius*	P					X	X
Darter	*Anhinga melanogaster*	P				B	X	X
Great egret	*Ardea alba*	P			M	B	X	X
Cattle egret	*Ardea ibis*	P			M	B	X	X
Intermediate egret	*Ardea intermedia*	P				B	X	X
White-necked (Pacific) heron	*Ardea pacifica*	P				B	X	X
Pied heron	*Ardea picata*	P				B	X	
Little egret	*Egretta garzetta*	P				B	X	X
White-faced heron	*Egretta novaehollandiae*	P				B	X	X
Little bittern	*Ixobrychus minutus*	P				B	X	
Nankeen (Rufous) night heron	*Nycticorax caledonicus*	P				B	X	X
Australasian bittern	*Botaurus poiciloptilus*	V	E				X	X
Black-necked stork	*Ephippiorhynchus asiaticus*	E1					X	
Australian white ibis	*Threskiornis molucca*	P				B	X	X
Straw-necked ibis	*Threskiornis spinicollis*	P				B	X	X
Glossy ibis	*Plegadis falcinellus*	P			M	B	X	X
Yellow-billed spoonbill	*Platalea flavipes*	P				B	X	X
Royal spoonbill	*Platalea regia*	P				B	X	X
Magpie goose	*Anseranas semipalmata*	V				B	X	X
Wandering whistling-duck	*Dendrocygna arcuata*	P					X	
Plumed whistling-duck	*Dendrocygna eytoni*	P				B	X	X
Black swan	*Cygnus atratus*	P				B	X	X
Freckled duck	*Stictonetta naevosa*	V				B	X	
Australian shelduck	*Tadorna tadornoides*	P					X	X
Pacific black duck	*Anas superciliosa*	P				B	X	X

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Chestnut teal	*Anas castanea*	P					X	X
Grey teal	*Anas gracilis*	P				B	X	X
Garganey	*Anas querquedula*	P					X	
Australasian shoveler	*Anas rhynchotis*	P				B	X	
Pink-eared duck	*Malacorhynchus membranaceus*	P				B	X	X
Hardhead	*Aythya australis*	P				B	X	
Australian wood duck	*Chenonetta jubata*	P				B	X	X
Cotton pygmy-goose	*Nettapus coromandelianus*	E1					X	
Green pygmy-goose	*Nettapus pulchellus*	P					X	
Blue-billed duck	*Oxyura australis*	V				B	X	X
Musk duck	*Biziura lobata*	P				B	X	
Brolga	*Grus rubicundus*	V				B	X	X
Buff-banded rail	*Gallirallus philippensis*	P					X	
Lewin's rail	*Rallus pectoralis*	P					X	
Australian spotted crake	*Porzana fluminea*	P					X	
Baillon's crake	*Porzana pusilla*	P					X	
Spotless crake	*Porzana tabuensis*	P				B	X	
Eurasian coot	*Fulica atra*	P				B	X	X
Dusky moorhen	*Gallinula tenebrosa*	P				B	X	X
Black-tailed native-hen	*Gallinula ventralis*	P					X	X
Purple swamphen	*Porphyrio porphyrio*	P				B	X	X
Waders								
Bush stone-curlew	*Burhinus grallarius*	E1					X	
Australian painted snipe	*Rostratula australis*	V	V				X	X
Masked lapwing	*Vanellus miles*	P				B	X	X
Banded lapwing	*Vanellus tricolor*	P					X	X
Red-capped plover	*Charadrius ruficapillus*	P					X	
Black-fronted dotterel	*Elseyornis melanops*	P				B	X	X
Red-kneed dotterel	*Erythrogonys cinctus*	P				B	X	X
Black-winged stilt	*Himantopus himantopus*	P				B	X	X
Red-necked avocet	*Recurvirostra novaehollandiae*	P					X	
Common sandpiper	*Actitis hypoleucos*	P			M		X	
Sharp-tailed sandpiper	*Calidris acuminata*	P			M		X	
Curlew sandpiper	*Calidris ferruginea*	P			M		X	
Red-necked stint	*Calidris ruficollis*	P			M		X	
Latham's snipe	*Gallinago hardwickii*	P			M		X	X
Bar-tailed godwit	*Limosa lapponica*	P			M		X	

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Black-tailed godwit	*Limosa limosa*	V			M		X	X
Wood sandpiper	*Tringa glareola*	P			M		X	
Common greenshank	*Tringa nebularia*	P			M		X	X
Marsh sandpiper	*Tringa stagnatilis*	P			M		X	
Australian pratincole	*Stiltia isabella*	P					X	
Silver gull	*Larus novaehollandiae*	P					X	
Whiskered tern	*Chlidonias hybridus*	P				B	X	X
Caspian tern	*Sterna caspia*	P			M		X	
Gull-billed tern	*Sterna nilotica*	P					X	
Ground birds								
Stubble quail	*Coturnix pectoralis*	P					X	X
Brown quail	*Coturnix ypsilophora*	P					X	X
Red-backed button-quail	*Turnix maculosa*	V					X	
Red-chested qutton-quail	*Turnix pyrrhothorax*	P					X	X
Little button-quail	*Turnix velox*	P					X	X
Australian bustard	*Ardeotis australis*	E1					X	
Emu	*Dromaius novaehollandiae*	P		D			X	X
Pigeons & doves								
Diamond dove	*Geopelia cuneata*	P					X	X
Bar-shouldered dove	*Geopelia humeralis*	P					X	X
Peaceful dove	*Geopelia placida*	P					X	X
Crested pigeon	*Ocyphaps lophotes*	P					X	X
Common bronzewing	*Phaps chalcoptera*	P					X	X
Parrots								
Sulphur-crested cockatoo	*Cacatua galerita*	P					X	X
Major Mitchell's cockatoo	*Cacatua leadbeateri*	V					X	X
Little corella	*Cacatua sanguinea*	P					X	
Red-tailed black-cockatoo	*Calyptorhynchus banksii*	V					X	X
Glossy black-cockatoo	*Calyptorhynchus lathami*	V					X	X
Galah	*Eolophus roseicapillus*	P					X	X
Cockatiel	*Nymphicus hollandicus*	P					X	X
Red-winged parrot	*Aprosmictus erythropterus*	P					X	X
Mallee ringneck	*Barnardius zonarius barnardi*	P					X	X
Budgerigar	*Melopsittacus undulatus*	P					X	X
Blue-winged parrot	*Neophema chrysostoma*	P					X	
Turquoise parrot	*Neophema pulchella*	V					X	X
Blue bonnet	*Northiella haematogaster*	P					X	

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Pale-headed (white cheeked) rosella	*Platycercus adscitus*	P					X	
Eastern rosella	*Platycercus adscitus eximius*	P					X	X
Superb parrot	*Polytelis swainsonii*	V	V				X	X
Red-rumped parrot	*Psephotus haematonotus*	P					X	X
Mulga parrot	*Psephotus varius*	P					X	X
Cuckoos								
Fan-tailed cuckoo	*Cacomantis flabelliformis*	P					X	
Horsfield's bronze-cuckoo	*Chalcites basalis*	P					X	X
Shining bronze-cuckoo	*Chalcites lucidus*	P					X	
Black-eared cuckoo	*Chalcites osculans*	P					X	X
Pallid cuckoo	*Cuculus pallidus*	P					X	X
Kingfishers, rollers & bee-eaters								
Laughing kookaburra	*Dacelo novaeguineae*	P					X	X
Red-backed kingfisher	*Todiramphus pyrrhopygia*	P					X	X
Sacred kingfisher	*Todiramphus sanctus*	P					X	X
Dollarbird	*Eurystomus orientalis*	P					X	X
Rainbow bee-eater	*Merops ornatus*	P					X	X
Night birds								
Australian owlet-nightjar	*Aegotheles cristatus*	P					X	X
Spotted nightjar	*Eurostopodus argus*	P					X	X
Tawny frogmouth	*Podargus strigoides*	P					X	X
Barking owl	*Ninox connivens*	V					X	X
Southern boobook	*Ninox boobook*	P					X	X
Barn owl	*Tyto alba*	P					X	X
Swifts, swallows & martins								
Fork-tailed swift	*Apus pacificus*	P			M		X	
White-throated needletail	*Hirundapus caudacutus*	P			M		X	X
White-backed swallow	*Cheramoeca leucosternus*	P					X	
Welcome swallow	*Hirundo neoxena*	P					X	X
Fairy martin	*Petrochelidon ariel*	P					X	X
Tree martin	*Petrochelidon nigricans*	P					X	X
Larks, robins & flycatchers								
Brown songlark	*Cincloramphus cruralis*	P					X	X
Rufous songlark	*Cincloramphus mathewsi*	P					X	X
Singing bushlark	*Mirafra javanica*	P					X	X

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Australian pipit	*Anthus australis*	P					X	X
Ground cuckoo-shrike	*Coracina maxima*	P					X	X
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	P					X	X
White-bellied cuckoo-shrike	*Coracina papuensis*	P					X	X
White-winged triller	*Lalage tricolor*	P					X	X
Hooded robin	*Melanodryas cucullata*	V		D			X	X
Eastern yellow robin	*Eopsaltria australis*	P		D			X	X
Jacky winter	*Microeca fascinans*	P		D			X	X
Red-capped robin	*Petroica goodenovii*	P		D			X	X
Flame robin	*Petroica phoenicea*	P					X	
Eastern shrike-tit	*Falcunculus frontatus*	P		D			X	X
Crested bellbird	*Oreoica gutturalis*	P		D			X	X
Golden whistler	*Pachycephala pectoralis*	P					X	
Rufous whistler	*Pachycephala rufiventris*	P		D			X	X
Grey shrike-thrush	*Colluricincla harmonica*	P					X	X
Restless flycatcher	*Myiagra inquieta*	P		D			X	X
Grey fantail	*Rhipidura albiscapa*	P					X	X
Willie wagtail	*Rhipidura leucophrys*	P					X	X
Spotted quail-thrush	*Cinclosoma punctatum*	P					X	
Grey-crowned babbler	*Pomatostomus temporalis temporalis*	V		D			X	X
Chestnut-crowned babbler	*Pomatostomus ruficeps*	P					X	X
White-browed babbler	*Pomatostomus superciliosus*	P		D			X	X
Warblers & wrens								
Clamorous (Australian) reed warbler	*Acrocephalus australis*	P					X	
Golden-headed cisticola	*Cisticola exilis*	P					X	X
Little grassbird	*Megalurus gramineus*	P					X	X
Tawny grassbird	*Megalurus timoriensis*	P					X	
Superb fairy-wren	*Malurus cyaneus*	P					X	X
Variegated fairy-wren	*Malurus lamberti*	P					X	X
White-winged fairy-wren	*Malurus leucopterus*	P					X	X
Splendid fairy-wren	*Malurus splendens*	P					X	X
Inland thornbill	*Acanthiza apicalis*	P					X	X
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*	P					X	X
Yellow thornbill	*Acanthiza nana*	P					X	X
Buff-rumped thornbill	*Acanthiza reguloides*	P					X	

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Chestnut-rumped thornbill	*Acanthiza uropygialis*	P		D			X	X
Southern whiteface	*Aphelocephala leucopsis*	P		D			X	X
Western gerygone	*Gerygone fusca*	P					X	X
Weebill	*Smicrornis brevirostris*	P					X	X
Honeyeaters & their allies								
Varied sittella	*Daphoenositta chrysoptera*	P		D			X	X
Brown treecreeper	*Climacteris picumnus*	V		D			X	X
White-browed treecreeper	*Climacteris affinis*	P					X	
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*	P					X	X
Black honeyeater	*Certhionyx niger*	P					X	X
Blue-faced honeyeater	*Entomyzon cyanotis*	P					X	X
Painted honeyeater	*Grantiella picta*	V					X	X
Yellow-plumed honeyeater	*Lichenostomus ornatus*							X
White-plumed honeyeater	*Lichenostomus penicillatus*	P					X	X
Singing honeyeater	*Lichenostomus virescens*	P					X	X
Yellow-throated miner	*Manorina flavigula*	P					X	X
Noisy miner	*Manorina melanocephala*	P					X	X
Brown-headed honeyeater	*Melithreptus brevirostris*	P					X	X
Black-chinned honeyeater	*Melithreptus gularis gularis*	V					X	X
Little friarbird	*Philemon citreogularis*	P					X	X
Noisy friarbird	*Philemon corniculatus*	P					X	X
Striped honeyeater	*Plectorhyncha lanceolata*	P					X	X
Silvereye	*Zosterops lateralis*	P					X	X
Mistletoebird	*Dicaeum hirundinaceum*	P					X	X
White-fronted chat	*Epthianura albifrons*	P					X	X
Orange chat	*Epthianura aurifrons*	P					X	
Crimson chat	*Epthianura tricolor*	P					X	X
Spotted pardalote	*Pardalotus punctatus*	P					X	X
Red-browed pardalote	*Pardalotus rubricatus*	P					X	
Striated pardalote	*Pardalotus striatus*	P					X	X
Finches								
Diamond firetail	*Stagonopleura guttata*	V		D			X	X
Plum-headed finch	*Neochmia modesta*	P					X	X
Crimson finch	*Neochmia phaeton*	P					X	X
Double-barred finch	*Taeniopygia bichenovii*	P					X	X
Zebra finch	*Taeniopygia guttata*	P					X	X

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Other passerines								
Olive-backed oriole	*Oriolus sagittatus*	P					X	X
Magpie-lark	*Grallina cyanoleuca*	P					X	X
White-winged chough	*Corcorax melanorhamphos*	P					X	X
Apostlebird	*Struthidea cinerea*	P					X	X
Black-faced woodswallow	*Artamus cinereus*	P					X	X
Dusky woodswallow	*Artamus cyanopterus*	P		D			X	X
White-breasted woodswallow	*Artamus leucorynchus*	P					X	X
Little woodswallow	*Artamus minor*	P					X	
Masked woodswallow	*Artamus personatus*	P					X	X
White-browed woodswallow	*Artamus superciliosus*	P		D			X	X
Pied butcherbird	*Cracticus nigrogularis*	P					X	X
Grey butcherbird	*Cracticus torquatus*	P					X	X
Australian magpie	*Gymnorhina tibicen*	P					X	X
Pied currawong	*Strepera graculina*	P					X	X
Spotted bowerbird	*Chlamydera maculata*	P					X	X
Little crow	*Corvus bennetti*	P					X	X
Australian raven	*Corvus coronoides*	P					X	X
Little raven	*Corvus mellori*	P					X	
Introduced birds								
Rock dove	*Columba livia*	U					X	
Eurasian blackbird	*Turdus merula*	U					X	
House sparrow	*Passer domesticus*	U					X	X
Common starling	*Sturnus vulgaris*	U					X	X
Mallard	*Anas platyrhynchos*	U						X
REPTILES								
Turtles	**Chelidae**							
Broad-shelled snake-necked turtle	*Chelodina expansa*	P					X	X
Eastern snake-necked turtle	*Chelodina longicollis*	P					X	X
Murray short-necked turtle	*Emydura macquarii*	P					X	X
Dragons	**Agamidae**							
Jacky lizard	*Amphibolurus muricatus*	P					X	X
Nobbi	*Amphibolurus nobbi* ssp. *nobbi*	P					X	X
Nobbi	*Amphibolurus nobbi* ssp. *coggeri*	P					X	
Burns' dragon	*Lophognathus burnsi*	P					X	
Gilbert's dragon	*Lophognathus gilberti*	P					X	X

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Eastern water dragon	*Physignathus lesueurii*	P					X	X
Eastern bearded dragon	*Pogona barbata*	P					X	X
Lined earless dragon	*Tympanocryptis lineata*	P					X	X
Long-tailed earless dragon	*Tympanocryptis tetraporophora*	P					X	X
Legless lizards	**Pygopodidae**							
Patternless delma	*Delma inornata*	P					X	X
Leaden delma	*Delma plebia*	P						X
Burton's snake-lizard	*Lialis burtonis*	P					X	
Western scaly-foot	*Pygopus nigriceps*	P					X	X
Skinks	**Scincidae**							
Shiny-palmed shinning-skink	*Cryptoblepharus carnabyi*	P					X	X
Callose-palmed shinning-skink	*Cryptoblepharus plagiocephalus*	P					X	
Brown-blazed wedgesnout ctenotus	*Ctenotus allotropis*	P					X	X
Unspotted yellow-sided ctenotus	*Ctenotus ingrami*	P					X	X
Pale-rumped ctenotus	*Ctenotus regius*	P					X	X
Robust ctenotus	*Ctenotus robustus*	P					X	X
Eastern barred wedge-snout ctenotus	*Ctenotus strauchii*	P					X	
Tree-crevice skink	*Egernia striolata*	P					X	X
Eastern water-skink	*Eulamprus quoyii*	P					X	
Bar-sided forest-skink	*Eulamprus tenuis*	P					X	X
Dark-flecked garden sunskink	*Lampropholis delicata*	P					X	
Wood mulch-slider	*Lerista muelleri*	P					X	X
Eastern robust slider	*Lerista punctatovittata*	P					X	X
Common dwarf skink	*Menetia greyii*	P					X	X
South-eastern morethia skink	*Morethia boulengeri*	P					X	X
Shrubland morethia skink	*Morethia obscura*	P						
Common bluetongue	*Tiliqua scincoides*	P					X	X
Shingleback lizard	*Trachydosaurus rugosus*	P					X	X
Blind snakes	**Typhlopidae**							
Prong-snouted blind snake	*Ramphotyphlops bituberculatus*	P					X	
Proximus blind snake	*Ramphotyphlops proximus*	P						X
Goannas	**Varanidae**							
Sand monitor	*Varanus gouldii*	P					X	X
Black-tailed monitor	*Varanus tristis*	P					X	X
Lace monitor	*Varanus varius*	P					X	X

Common name	Scientific name	NSW legal status	National legal status	Declining Woodland Bird	JAMBA CAMBA ROKAMBA	Waterbird Breeding	Atlas of NSW wildlife records	Shelly records (2005)
Geckoes	**Gekkonidae**							
Marbled southern gecko	*Christinus marmoratus*	P					X	X
Southern spiny-tailed gecko	*Diplodactylus intermedius*	P					X	X
Tesselated gecko	*Diplodactylus tessellatus*	P					X	X
Dubious dtella	*Gehyra dubia*	P					X	X
Varied dtella	*Gehyra variegata*	P					X	X
Prickly gecko	*Heteronotia binoei*	P					X	X
Beaded gecko	*Lucasium damaeum*	P						X
Marbled velvet gecko	*Oedura marmorata*	P					X	X
Pythons	**Boidae**							
Carpet / diamond python	*Morelia spilota*	P					X	X
Snakes	**Elapidae**							
Southern death adder	*Acanthophis antarcticus*	P					X	
Highlands copperhead	*Austrelaps ramsayi*	P					X	
Yellow-faced whipsnake	*Demansia psammophis*	P					X	X
De Vis's banded snake	*Denisonia devisi*	P					X	X
Red-naped snake	*Furina diadema*	P					X	X
Orange-naped snake	*Furina ornata*	P					X	
Grey snake	*Hemiaspis damelii*	P					X	X
Mulga snake	*Pseudechis australis*	P					X	X
Spotted black snake	*Pseudechis guttatus*	P					X	
Red-bellied black snake	*Pseudechis porphyriacus*	P					X	X
Western brown snake	*Pseudonaja nuchalis*	P						X
Eastern brown snake	*Pseudonaja textilis*	P					X	X
Eastern shovel-nosed (coral) snake	*Simoselaps australis*	P					X	
Spectacled hooded snake	*Suta spectabilis*	P					X	X
Variable black-naped snake	*Suta spectabilis dwyeri*	P					X	
Curl snake	*Suta suta*	P					X	X
Eastern bandy-bandy	*Vermicella annulata*	P					X	
FROGS								
Tree frogs	**Hylidae**							
Water-holding frog	*Cyclorana platycephala*	P					X	X
Rough frog	*Cyclorana verrucosa*	P					X	X
Striped burrowing frog	*Litoria alboguttata*	P					X	X
Green tree frog	*Litoria caerulea*	P					X	X
Broad-palmed frog	*Litoria latopalmata*	P					X	X

Common name	Scientific name	NSW legal status	National legal status	Declining Woodland Bird	JAMBA CAMBA ROKAMBA	Waterbird Breeding	Atlas of NSW wildlife records	Shelly records (2005)
Peron's tree frog	*Litoria peronii*	P					X	X
Desert tree frog	*Litoria rubella*	P					X	X
Southern frogs	**Myobatrachidae**							
Long-thumbed frog	*Limnodynastes fletcheri*	P					X	X
Salmon-striped frog	*Limnodynastes salmini*	P					X	X
Spotted marsh frog	*Limnodynastes tasmaniensis*	P					X	X
Painted burrowing frog	*Neobatrachus sudelli*	P					X	X
Holy cross toad	*Notaden bennettii*	P					X	X
Eastern sign-bearing froglet	*Crinia parinsignifera*	P					X	X
Common eastern froglet	*Crinia signifera*	P					X	X
Sloanes froglet	*Crinia sloanei*	P						X
Wrinkled toadlet	*Uperoleia rugosa*	P					X	X
Small-headed toadlet	*Uperoleia capitulata*	P						X
FISH								
Silver perch	*Bidyanus bidyanus*,	V						
Flyspecked hardyhead	*Craterocephalus stercusmuscarum*							
Carp gudgeon	*Hypseleotris* sp.							
Spangled perch	*Leiopotherapon unicolour*							
Murray cod	*Maccullochella peelii*		V					
Golden perch	*Macquarie ambigua*							
Crimson-spotted rainbowfish	*Melanotaenia fluviatilis*							
Bony herring	*Nematolosa erebi*							
Flathead gudgeon	*Philypnodon grandiceps*							
Australian smelt	*Retropinna semoni*							
Freshwater catfish	*Tandanus tandanus*							
Introduced fish								
Goldfish	*Carassius auratus*							
European carp	*Cyprinus carpio*							
Gambusia	*Gambusia holbrooki*							
Redfin perch	*Perca fluviatilis*							

Aquatic invertebrate fauna of the Macquarie Marshes

(Sources: Gray & Hosking 2003; Turak et al. 2002; Sustainable River Audit)

The classifications follow Hawking, Smith, and Le Busque (2006 onwards) [www.mdfrc.org.au/bugguide/index.htm]; Hawking (2000), Hawking & Smith (1997); and Williams (1980). Aquatic macroinvertebrate families were found in the Macquarie River (Bells Bridge: NSWMACQ01; Gangarry: NSWMACQ03; Oxley Station: NSWMACQ04; 2.7 km downstream from this (MacZ1-X7); upstream from Marebone Weir: NSWMACQ506 in Marthaguy Creek at Wammerawa (NSWMACQ02) and Muerri (MacZ1-X9); in Bulgaraga Creek at Willow Bend (MacZ1-X2); in Bulgergara Creek 5 km downstream from the NR (MacZ1-X6) and in Marra Creek at Buttabone (MacZ1-X4). These aquatic macroinvertebrate families were sampled using NSW AusRivAS protocols (Turak & Waddell 2002; Turak et al. 2004) between Spring 1994 and Spring 1999.

Phylum	**Common name**
Nematoda	nematode worms
Annelida	
Class Oligochaeta	segmented aquatic worms
Mollusca	
Class Gastropoda	
Order Basommatophora	
Family Ancylidae	freshwater limpets
Arthropoda	
Class Arachnida	
Order Acariformes	
Suborder Trombidiformes	freshwater mites
Class Crustacea	
Subclass Ostracoda	seed shrimps
Subclass Copepoda	copepods
Subclass Branchiopoda	
Order Diplostraca	
Sub-order Cladocera	water fleas
Subclass Malacostraca	
Order Isopoda	
Family Cirolanidae	Isopods
Order Decapoda	
Family Atyidae	freshwater shrimps
Family Palaemonidae	freshwater prawns
Family Parastacidae	freshwater crayfish and yabbies
Class Collembola	springtails

Phylum	Common name
Class Insecta	
Order Ephemeroptera	
Family Leptophlebiidae	mayflies
Family Caenidae	mayflies
Family Baetidae	mayflies
Order Odonata	
Family Coenagrionidae	damsel flies
Isostictidae	damsel flies
Aeshnidae	dragonflies
Family Gomphidae	dragonflies
Family Corduliidae	dragonflies
Order Hemiptera	
Family Gerridae	water striders
Family Hebridae	velvet water bugs
Family Corixidae	waterboatmen
Family Naucoridae	creeping waterbugs
Family Nepidae	water scorpions
Family Notonectidae	backswimmers
Family Veliidae	small water striders
Order Coleoptera	
Family Dytiscidae	predacious diving water beetles
Family Carabidae	ground beetles
Family Chrysomelidae	leaf beetles
Family Curculionidae	weevils
Family Hydraenidae	minute rove beetles
Family Staphylinidae	rove beetles
Family Hydrophilidae	scavenger water beetles
Order Diptera	
Family Culicidae	mosquitoes
Family Tabanidae	march/horse flies
Family Ceratopogonidae	biting midges
Family Simuliidae	blackflies
Family Chironomidae	
Sub-family Chironominae	blood worms
Sub-family Orthocladiinae	non-biting midges
Sub-family Tanypodinae	non-biting midges
Order Trichoptera	
Ecnomidae	caddisflies
Family Leptoceridae	longhorned caddisflies
Hydroptilidae	micro caddisflies

Appendix 3: Curricula vitae of authors

Jo Smith

- Ecological Consultant (1999 – current)
- Project Officer Biodiversity Survey and Research, Broken Hill and Dubbo, Western Region, NSW National Parks and Wildlife Service (1996–1998)
- Senior Ranger, Bourke, Western Region, NSW National Parks and Wildlife Service (1988–1996)
- Ranger, Coonabarabran, Western Region, NSW National Parks and Wildlife Service (1986–1988)
- Technical Officer, CSIRO Division of Wildlife Research (1983–1986)

Bachelor of Science, Natural Resource Management, 1982, Canberra University

Jo has been working on the flora and fauna of western NSW since 1983. Her work has included research on the impacts of grazing on semi-arid native vegetation, aerial surveys of kangaroo populations in NSW and Queensland, surveys and management of waterbird breeding events in Macquarie Marshes, Narran Lakes and Nocoleche nature reserves, biodiversity surveys in the Darling riverine floodplains and the western mallee. Her recent projects have focused on providing environmental and rural industry managers with scientific, ecological and social research findings that form the basis of their management plans for the Macquarie Marshes, Gwydir wetlands and organics industry. She also edits and reviews manuscripts, essays and theses on a wide range of topics.

Professor Richard Kingsford

Director of the Australian Wetlands and Rivers Centre, School of Biological, Earth and Environmental Sciences, University of NSW.

Richard has focused his research over about the last 20 years on the waterbirds, wetlands and rivers of arid Australia, which cover about 70 per cent of the continent. He has identified the significant impacts of water resource development on the rivers and wetlands of the MDB and contributed to policy development and environmental flow management. He is a member of the Australian Government's Environmental Flows Scientific Committee. Aerial surveys of waterbirds, mapping of wetlands and development of software for delivering knowledge about catchments are other areas of his work. His research has demonstrated the ecological values of many rivers and impacts of water resource in arid Australia, for which he received a Eureka Award in 2001. He has more than 100 publications including three books, including one on the desert rivers of the world. In 2007 he received the Hoffman medal for contribution to global wetland science and in 2008, the Eureka Award for Promoting Understanding of Science.

Dr Silke Nebel

Silke has substantial scientific expertise in shorebirds, and has published a number of papers including:

Nebel, S, Porter, JL and Kingsford, RT 2008, 'Long-term trends of shorebird populations in eastern Australia and impacts of freshwater extraction'. *Biological Conservation* 141: 871–980. (among top 100 science stories of 2008 according to *Discover Magazine*)

Nebel, S 2007, 'Shorebird migration in the East-Asian Australasian Flyway'. *Emu* 107: 14–18.

Wilson, JR, Nebel, S and Minton, CDT 2007, 'Migration ecology and morphometrics of two bar-tailed godwit populations in Australia'. *Emu* 107: 262–274.

Kate Brandis

- Senior researcher, The Australian Wetlands and Rivers Centre (2005 – current)
- Project officer, Biodiversity Research and Management Division, NSW National Parks and Wildlife Service (1998–2005)
- BSc (Hons) Resource Management and Biology – Macquarie University 1998
- MSc Environmental Science – Macquarie University 2002

Kate has been working in wetland and river systems in the Murray–Darling Basin since 2000, on projects including flow modelling in the Warrego and Paroo rivers, wetland mapping and investigating the relationship between flows and waterbirds in the Macquarie Marshes and Narran Lakes. She has postgraduate qualifications that include studies on wetland ecology and waterbird ecology of the Paroo and Warrego rivers, Macquarie Marshes and Narran Lakes. Kate is currently completing her PhD thesis looking at colonial waterbird breeding, for which a substantial component of the research has been conducted at Narran Lakes. Kate has led a number of projects for The Centre investigating the water requirements for colonial waterbird breeding.

Dr Kerrylee Rogers

Kerrylee Rogers (PhD) has over 12 years research experience in wetlands, including floodplain wetlands, coastal wetlands (fresh and saline) and alpine wetlands. This work has largely been in the fields of geomorphology and ecology and focuses on establishing processes that influence the distribution and health of biota within wetlands.

Kerrylee is currently employed as a research scientist within OEH, is an honorary fellow at the University of Wollongong and was previously employed as a lecturer and research associate at the University of Wollongong and ACU National. She has extensive research experience having published numerous peer-reviewed papers, research reports and presented at conferences. Kerrylee has been a co-author of three ecological character descriptions.

Bill Johnson

Wetland and environmental flow manager and planner on the Macquarie and Gwydir rivers in NSW from 1989 to 2009.

Ramsar coordinator for NSW from 1994 to 1996, and was involved in the nomination of several sites, including private wetlands in the Macquarie Marshes and Gwydir wetlands.

Negotiated the establishment and delivery of environmental flows in regulated rivers. Worked in NSW Water Reforms and Water Sharing Plans, and managed the development of the Macquarie Marshes Water Management Plan and the Macquarie Marshes and Gwydir Wetlands Adaptive Environmental Management Plans.

Currently working with the Murray–Darling Basin Authority on the preparation of the Murray–Darling Basin Plan.

Dr Timothy J Ralph

Academic research and environmental management experience in the fields of geomorphology, soil science and ecology. The focus of much of this work has been to identify and understand key processes that drive floodplain development and change; in particular, linkages and feedbacks between water, sediment, landforms and biota in lowland rivers and wetlands of the MDB.

As a former Senior Environmental Scientist at the NSW Department of Environment, Climate Change and Water, Tim has participated in several key projects including the

Aquatic Ecosystems Climate Change Adaptation Research Project (2007–2009), Macquarie Marshes Joint Agency Strategic Compliance Project (2008–2009), NSW Inland Acid Sulfate Soils Rapid Assessment Project (2008–2010), Pillicawarrina Environmental Water Management and Floodplain Restoration Project (2009–2010), and new projects with landholders in the Macquarie Marshes including the Buckiinguy Wetland Hydrogeomorphic Study (2009–2010) and the Wilgara Wetland Erosion Control Trial (2009–2010).

Tim is currently a lecturer at Macquarie University within the Department of Environment and Geography – Environmental Science.

Alison Curtin

Ramsar coordinator for NSW from 2003 to 2011, and was involved in the nomination of the Paroo River wetlands and in 1998 several sites, including private wetlands in the Macquarie Marshes and Gwydir wetlands.

NSW member of the Wetland and Waterbirds Taskforce that developed the ecological character framework. Involved in coordinating and critiquing ECDs for all NSW Ramsar sites.

Background includes wetlands policy and science, waterbirds, fish and water quality surveys and threatened species listing.

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