Myall Lakes Ramsar site

Ecological character description

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Office of Environment and Heritage NSW
59–61 Goulburn Street, Sydney
PO Box A290, Sydney South 1232

Phone: 131 555 (NSW only – publication and information requests)
(02) 9995 5000 (switchboard)
Fax: (02) 9995 5999 TTY: (02) 9211 4723

Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

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Bottom left: Pelicans and egret, Bombah Point/F Miller, NPWS
Bottom centre: Paperbark forest, Myall lakes/G Woods, NPWS
Bottom right: Royal spoonbills/OEH

Summary

In 1999, the Myall lakes were designated as a Wetland of International Importance under the Ramsar Convention. The Convention requires that the site is managed to maintain or improve its ecological character. The Ramsar site is located on the mid-north coast of New South Wales and is protected by conservation reserves managed by the NSW Government, consisting of Myall Lakes National Park, Little Broughton Island Nature Reserve, Corrie Island Nature Reserve, and part of Gir-um-bit National Park. The estuarine and brackish waters and the beaches and intertidal areas in the site are within Port Stephens – Great Lakes Marine Park.

This ecological character description provides baseline information about the wetlands' values and the components, processes and services that characterise Myall Lakes Ramsar site. It also identifies limits of acceptable change, threats to the Ramsar site's ecological character, knowledge gaps in the site's components and processes, and recommendations for future monitoring.

Myall Lakes Ramsar site was originally listed under the Ramsar Convention's pre-1999 criteria 1a, 1c, 2a and 3b. The Ramsar site is now listed under the following three updated criteria:

- Criterion 1: A representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- Criterion 2: Wetland supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- Criterion 3: Wetland supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The Ramsar site is now not considered to meet the updated Criterion 5 (wetland regularly supports 20,000 or more waterbirds), equivalent to the pre-1999 criterion 3b, as there is no evidence to show that the wetlands regularly support such large numbers of waterbirds.

The Myall lakes consist of a mosaic of near-natural wetlands ranging from fresh to brackish and estuarine waters within a relatively unmodified coastal lake system unique in NSW. The site's wetlands include brackish waters, fringing swamps, freshwater swamps, mangroves, saltmarshes, riverine ecosystems and rocky marine shores and beaches, and are surrounded by a near-natural terrestrial ecosystem. As a consequence of the habitats provided by this range of wetlands and by the surrounding terrestrial vegetation, the site supports a rich biodiversity. The site plays an important role in linking key fauna habitats to the north and west and in providing connectivity between estuarine wetland ecosystems to the north and the south, and is a drought refuge for waterbirds. The site's estuarine and brackish waters provide a food source, spawning ground and nursery for many common fish species.

The Ramsar site's large area of 44,612 ha supports a rich biodiversity, containing a range of undisturbed terrestrial and wetland vegetation communities with a large number of plant and animal species. The site's vegetation is particularly diverse, with 968 species of terrestrial and aquatic plants recorded, and vegetation communities ranging from littoral rainforest to forest, heath, grassland, swamp, mangrove, seagrass, submerged aquatic vegetation and emergent freshwater vegetation. The terrestrial species occur in a wide range of vegetation communities, from rainforest and wet sclerophyll forest to heathland and sand dune vegetation. There is also a high diversity of animal species, with 298 bird, 58 mammal, 44 fish, 37 reptile and 29 amphibian species recorded in the Ramsar site. The number of amphibian species is exceptionally high as the Ramsar site provides a large permanent body of fresh to brackish water and associated swamps, creeks and rivers in a near-natural condition.

There are 22 species of shorebirds listed under migratory bird agreements (JAMBA, CAMBA and ROKAMBA) which use the site as roosting, feeding, nesting and breeding habitat. The lakes in the Ramsar site are part of the coastal lake system in NSW which provides drought refuge for waterbirds.

Myall Lakes Ramsar site provides habitat for 12 nationally or internationally threatened species, including several wetland-dependent species. There are five wetland-dependent threatened species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), or listed in the IUCN Red List of Threatened Species: Australasian bittern (*Botaurus poiciloptilus*), Freycinet's frog (*Litoria freycineti*), green and golden bell frog (*Litoria aurea*), green-thighed frog (*Litoria brevipalmata*) and stuttering frog (*Mixophyes balbus*). The site also supports one threatened ecological community listed under the EPBC Act – littoral rainforest and coastal vine thickets of eastern Australia. The site supports seven other species which are listed as nationally threatened or internationally threatened – Gould’s petrel *(Pterodroma leucoptera leucoptera)*, grey-headed flying-fox (*Pteropus poliocephalus*), spotted-tailed quoll (*Dasyurus maculatus*), swift parrot (*Lathamus discolor*), Guthrie’s grevillea (*Grevillea guthrieana*), magenta lilly pilly (*Syzygium paniculatum*) and black-eyed Susan (*Tetratheca juncea*).

The lakes maintain high water quality (oligotrophic clear waters) by effectively retaining, recycling and removing suspended solids, organic and inorganic nutrients, and other pollutants from water that flows through the lakes via several mechanisms. The lakes act as a sink for nutrients, organic matter and sediments, due to very long flushing times. The long water retention times allow sediments to settle out and allow primary producers (algae and macrophytes) to convert nutrients to plant biomass. The lakes can remove up to 90% of phosphorus deposited from catchment runoff, and the removal rate for nitrogen is considered to be high given the long water residence time in the lakes. The majority of nutrients are stored as plant biomass, detritus or sediment, with a small amount remaining in the lakes’ waters.

The lakes, which cover an area of 100–150 km^2 (depending on water levels) and drain a catchment of 780 km^2, hold a large volume of the catchment’s runoff and groundwater, and slowly release this water into Port Stephens via the constricted entrance channel in the lower Myall River. The water quality in the lakes is dependent on retention of the large area of native vegetation in the site’s catchment (about 78% of total area of catchment), as increased sediment and nutrient loads can result in increased turbidity, decreased abundance of submerged aquatic vegetation, and occurrences of blue–green algae (cyanobacteria) blooms.

The Myall lakes support the only known occurrence in Australia of gyttja – a green–brown organic-rich sediment derived from the decomposition of charophytes, macrophytes and cyanobacterial algae. The gyttja found in the Myall lakes is believed to be important in structuring and maintaining the characteristic submerged aquatic vegetation of the lakes.

Myall Lakes Ramsar site also provides a broad range of opportunities for recreational, educational and scientific activities, and has a high social and cultural value. Its recreational and aesthetic amenity is particularly important, as the lakes’ high quality waters, their naturalness and their attraction for recreation were the primary reasons for the protection of the area as Myall Lakes National Park in 1972. It is a major tourist site for NSW and receives approximately 100,000 visitors per year. The site has been a major focus for research activities since the 1930s, and numerous scientific studies and investigations have been undertaken in the site, particularly relating to biodiversity and to the geomorphology and hydrology of the lakes and the other wetlands.

The Myall lakes are within the traditional lands of the Worimi people. The varied wetlands, environments and abundant resources of the Myall lakes provided an ideal living environment for the Worimi people, and evidence of this traditional occupation exists across the landscape in the form of shell and stone middens, campsites and burials. Evidence of European occupation of the lands around the lakes and use of the lakes themselves remains in the form of historic sites and items such as graves associated with villages and with subsistence farming, former timber mills, Tamboy fishing village, and the roads, camps and waste associated with sandmining.

The site has not been greatly modified by human activity, and is relatively healthy compared to other coastal lakes in NSW. However, periodic excessive phytoplankton growth, including toxic blue–green algae (cyanobacteria) blooms, shows that the system is very sensitive to increases in nutrient levels. Nutrient loads associated with runoff from high rainfall events in the lakes' catchment can contribute significantly to the nutrient levels in the lakes, and pose a threat to the integrity of the system. While the nutrients in existing sediments are recycled through the water column and are absorbed by aquatic plants in the lakes, all new nutrients driving increased water column production and algal blooms come from the catchment. The expansion of urban areas and intensive agriculture within the catchment pose the greatest threat to the lakes' water quality. Other main threats include climate change, fire, introduced species, and overuse or inappropriate recreational activities.

Limits of acceptable change have been set for the site's critical components, processes and services, including for measures of water quality in the lakes: chlorophyll-a, external nutrient loads, turbidity, Secchi depth and salinity. Whilst the LAC for chlorophyll-a and turbidity in Bombah Broadwater have been exceeded, none of the other LACs for water quality measures or for other critical components and processes has been exceeded, and it is considered that there has not been a change in the site's ecological character since time of listing. The site's ecological character continues to be maintained as a result of the largely natural catchment of the lakes and the effective management of the site's wetlands and terrestrial ecosystems.

The site is now under greater protection than it was in 1999 due to the adoption in 2002 of the plan of management for Myall Lakes National Park and Little Broughton Island Nature Reserve, and the gazettal in 2005 of Port Stephens – Great Lakes Marine Park.

There is a need to collect more data on many of the site's components and processes, and to continue to monitor the wetlands' water quality and biodiversity, especially nationally and internationally listed threatened species. High priorities for further investigation are water quality in the lakes, extent of aquatic vegetation communities, number and abundance of waterbird species, and groundwater levels.

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1 Introduction

This description of the ecological character of Myall Lakes Ramsar site was prepared by the Office of Environment and Heritage NSW (OEH) (Table 1) following the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008).

1.1 Brief description of the site

The Myall lakes were designated as a wetland of international importance under the Ramsar Convention on Wetlands in 1999 and lies within Myall Lakes National Park, Little Broughton Island Nature Reserve, Gir-um-bit National Park and Corrie Island Nature Reserve.

It is one of the few coastal wetlands systems in NSW that has not been greatly impacted by human activities and is in a relatively healthy condition. It is renowned for its rich biodiversity and complex variety of habitats.

Table 1 Details of the ecological character description of Myall Lakes Ramsar site

Site name	Myall Lakes Ramsar site
Location	In the Hunter (coastal) region of NSW, approximately 75 km north of Newcastle and 30 km south of Forster.
Area	44,612 ha
Geographical Coordinates	Latitude 32° 19′ S to 32° 42′ S Longitude 152° 02′ E to 152° 31′E
Date of listing as a Ramsar site	14 June 1999
Date the description of ecological character applies	1999 (Information gathered since listing has been included where appropriate.)
Management authority	Office of Environment and Heritage Department of Premier and Cabinet NSW
Status of description	This is the first description of the ecological character.
Name of compilers	Dr Peter Scanes, Ms Kirsty Brennan, Mr Brian Leahy, Ms Fiona Miller, Dr Jane Jelbart* and Dr Li Wen Office of Environment and Heritage Department of Premier and Cabinet NSW * now with Umwelt (Australia) Pty Ltd
Date of compilation	July 2011
Reference for Ramsar Information Sheet	Australia 5AU052 www.environment.gov.au/water/wetlands/database/index.html
Reference for management plan	NPWS (2002) DEC (2006)

1.2 Statement of purpose

The description of the ecological character of a Ramsar site forms the baseline for management planning and action, including recommendations for site monitoring to detect negative impacts.

The legal objectives of the ecological character description (ECD) are to:

- assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the Environment Protection and Biodiversity Conservation Regulations 2000 (Cwlth):
- describe and maintain the ecological character of the wetlands in a Ramsar site
- 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.
- assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar list has changed, is changing or is likely to change as a result of technological developments, pollution or other human interference
- supplement the description of the ecological character contained in the Ramsar Information Sheet submitted to the Ramsar Convention for each listed wetland and collectively form an official record of the ecological character of the site
- assist the administration of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)[1], particularly to:
  i) determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act, or
  ii) assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.
- assist other relevant NSW planning or impact assessment legislation such as the *Environmental Planning and Assessment Act 1979*
- assist any person considering taking an action that may impact on a declared Ramsar wetland in deciding whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval
- inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

From the perspective of management planning and action, the ECD forms the reference for:

- development and implementation of a management plan designed to maintain the ecological character of the site
- design and implementation of monitoring programs to detect change in ecological character and to assess the effectiveness of management actions
- regular evaluation of the results of the monitoring program to assist in site management.

[1] www.environment.gov.au/epbc/index.html

1.3 Relevant legislation and treaties

Australia addresses its obligations under the Convention through the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Environment Protection and Biodiversity Conservation Regulations 2000, relevant state legislation, and national, state, territory, and local government wetland policies and natural resource management programs.

1.3.1 NSW legislation and policies

The following NSW legislation and policies are relevant to management of Myall Lakes Ramsar site.

NSW Wetlands Policy 2010

The NSW Wetlands Policy provides a framework for the protection, ecologically sustainable use and management of NSW wetlands. It highlights the importance of protecting and managing wetlands of international importance such as the Myall lakes and other Ramsar sites.

National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act 1974* (NPW Act) provides for the establishment, protection and management of national parks and other conservation reserves in NSW. Under the Act a plan of management for Myall Lakes National Park is required to be prepared and updated on a regular basis.

Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act 1995* provides for the listing and conservation of threatened plants and animals and of endangered ecological communities in NSW. There are 11 plant species, 46 animal species and two ecological communities listed under the Act which have been recorded in the Ramsar site.

Marine Parks Act 1997

The *Marine Parks Act 1997* provides for the establishment and management of marine parks in NSW. The lakes and estuarine waters of the Ramsar site are included in Port Stephens – Great Lakes Marine Park, and are subject to a zoning plan under the Act which determines where activities such as commercial and recreational fishing are permitted.

Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) regulates commercial and recreational fishing in NSW. Commercial fishing in the Ramsar site includes prawning in the lower Myall River, with eel trapping and mesh netting for fish in those parts of the lakes outside the marine park's sanctuary zones.

Protection of the Environment Operations Act 2000

The *Protection of the Environment Operations Act 2000* aims to minimise the impacts of air, water and noise pollution and wastes on the environment of NSW. The Act regulates activities such as the discharge of untreated sewage effluent and of wastes from intensive agricultural production, and runoff from timber harvesting and road construction on lands and in waters within the catchment of the Myall lakes.

Water Management Act 2000

The *Water Management Act 2000* provides for the preparation of water sharing plans to ensure the equitable sharing of water resources for urban, industrial and agricultural purposes and for the benefit of the community and the environment. The Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources, which includes the streams and rivers and the groundwater in the catchment of the Ramsar site and the Myall lakes, was adopted in 2009.

1.3.2 International agreements and conventions

Migratory shorebirds use the East Asian – Australasian Flyway, which stretches from New Zealand and Australia, through south-east Asia, China and Japan, and north to Siberia and Alaska. International agreements and conventions that protect bird species known to use the flyway include:

- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (JAMBA)[2]
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA)[3]
- Agreement between the Government of Australia and the Government of the Republic of Korea for the Protection of Migratory Birds and their Environment (ROKAMBA)[4]
- Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention)[5]
- Convention on Biological Diversity[6]
- Asia–Pacific Migratory Waterbird Conservation Strategy 2001–2005.[7]

1.4 Approach taken in this ecological character description

This report has been complied to meet the requirements of the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008), which requires presentation of:

- a general description of the site
- a baseline description of the components, processes and services of the site around the time of Ramsar listing (1999)
- definition of the critical components, processes and services of the site
- setting of limits of acceptable change for the critical components, processes and services, and nomination of indicators to measure change
- identification of changes in ecological character within the site since 1999
- a summary of knowledge gaps and recommendations for monitoring
- key communication messages for the site.

Myall Lakes Ramsar site was gazetted in 1999 to correspond with the then boundaries of Myall Lakes National Park, Little Broughton Island Nature Reserve and Corrie Island Nature Reserve. Myall Lakes Ramsar site is centred around the large open-water fresh to brackish lakes system, with other wetland types either directly connected (such as fringing wetlands around lakes, riverine wetlands upstream of lakes, tidal wetlands downstream of lakes) or located nearby (perched dune wetlands). These linked wetlands, with the supporting terrestrial habitat, will be referred to as the Myall lakes throughout the ECD. The marine coast of Myall Lakes National Park is part of the Ramsar site, and has also been addressed in this ECD.

Since 1999 the Fame Cove section of Myall Lakes National Park has been gazetted as part of Gir-um-bit National Park, and there have been a number of additions to Myall Lakes National Park (Figure 3). While the new additions to the national park do not form part of the Ramsar site, some are inextricably linked to the site and its values and are relevant to this ECD.

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[2] www.austlii.edu.au/au/other/dfat/treaties/1981/6.html
[3] www.austlii.edu.au/au/other/dfat/treaties/1988/22.html
[4] www.aph.gov.au/HOUSE/committee/jsct/27february2007/treaties/korea_nia.pdf
[5] www.cms.int/
[6] www.cbd.int/
[7] www.environment.gov.au/biodiversity/migratory/publications/asia-pacific/index.html

Areas that have been referred to in this ECD, even though they are not part of the Ramsar site, are listed below. It is anticipated that an application may be made to include all or some of these areas into the Ramsar site in the future.

1 In 2001 Myall Lakes National Park was extended to low tide, whereas the previous gazettal was to high tide, and it now includes all the sandy and rocky marine shores of Myall Lakes National Park and the estuarine areas of Fame Cove and Myall River.

2 In 2005 additional lands on Myall River were gazetted as part of the national park; this includes estuarine tidal flats and habitats such as mangroves, saltmarshes and associated fringing forest.

3 The upper and lower Myall River, where it traverses the national park, is not part of the Ramsar site (this includes estuarine waters and macrophyte beds).

4 Corrie Island Nature Reserve and Little Broughton Island Nature Reserve are gazetted to high tide; the region between mean low tide and mean high tide is Crown land. These areas include sand spits, sand shores, rocky shores and intertidal flats.

In summary, Myall Lakes Ramsar site consisted of 44,612 ha of conservation reserves at the time of listing in 1999.

2 General description

2.1 Site characteristics

The Myall lakes are four interlinked water bodies that originally (prior to European settlement) probably had ecologies that were fundamentally similar, but differed in detail due to the effects of salinity. The water bodies are, in order of increasing salinity, Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater. Myall River upstream of Bombah Broadwater is brackish below the township of Bulahdelah and becomes freshwater just upstream of Bulahdelah.

The Myall lakes have been recognised as having natural values of high conservation significance, including a largely unmodified catchment. A review of coastal lakes in NSW in 2002 concluded that the Myall lakes require significant protection in order to restore and preserve their critical natural ecosystem processes (Healthy Rivers Commission 2002). The dominant feature of the site is the large interconnected lakes system which covers an area of 10,000–15,000 ha (the range is due to varying water levels). The two large lakes – Myall Lake in the north, and Bombah Broadwater in the south – are connected by two smaller lakes – Two Mile Lake and Boolambayte Lake. The lower Myall River links the lakes to the Tasman Sea via Port Stephens (Figure 1).

The lakes system is bounded by high sand dunes on the coast and older, flatter dunes to the west which support a range of wetlands interconnected with the lakes and river systems. There are fringing wetlands around the margins of the lakes and tidal wetlands from the lower Myall River to the Tasman Sea. The perched freshwater wetlands are located between the eastern shores of Myall Lake and the coastal dunes, and over 40 km of ocean beaches and headlands are part of the Ramsar site.

In addition to the four main lakes, Nerong Creek, sections of the upper and lower Myall River, Boolambayte Creek, the estuarine environments of Fame Cove inlet and Corrie Island in Port Stephens, and Broughton Island and Little Broughton Island offshore are part of the Ramsar site. The site includes approximately 30% of the catchment surrounding the lakes, which includes significant terrestrial habitats and extends through hills to the west to approximately 30 km inland from the coastline.

Figure 1 Corrie Island and confluence of Myall River with Port Stephens

Because of the extensive waterways, dune systems and beaches, Myall Lakes Ramsar site is one of the most frequently visited national parks in NSW. It is within a comparatively short distance of a number of population centres and offers a range of recreational opportunities.

The ecology of the Myall lakes is complex and poorly understood. The limits of our understanding consist of observations and inferences from correlated patterns of distribution. However, the physiochemical water characteristics and the distributions of macrophytes and algae have been described in some detail (Dasey et al. 2004).

Prior to European settlement the lakes would probably have all been mostly clear water, with low nutrient and chlorophyll concentrations and dominated by benthic macrophytes. The types of macrophytes would have differed among the lakes due to exposure to salinity (Dasey et al. 2004; DECC 2007a).

It is assumed that, prior to European disturbance of the system, macrophytes in Myall Lake and Boolambayte Lake would have been similar, with seasonally fluctuating dominance between annual macrophytes such as charophytes (algae from the Characeae family, mainly *Chara fibrosa* and *Nitella hyalina*) and *Najas*; Two Mile Lake and Bombah Broadwater would have had fewer *Najas* and tended to be dominated by charophytes and the perennial seagrass *Ruppia* (Sainty and Jacobs 1981, 2003).

The macrophyte beds form an important resource for macroinvertebrate, avian and fish fauna in the lakes. The annual macrophytes which dominate the Myall lakes vegetation are also thought to be the major source of material for gyttja, which is a key feature and is believed to have a considerable influence on the presence and distribution of many other biota.

The associated fringing wetlands are much more strongly associated with terrestrial flora, and consist largely of low-lying lands which are inundated when lake levels rise due to tidal forcing during spring tides, high flows from the catchment or increased groundwater levels. The perched dune wetlands of The Moors and other unnamed systems form in the interdune swales along the eastern margin of the Ramsar site, and are influenced by groundwater and partly by sea levels (Peter Myerscough 2010, pers. comm.). They are also dominated by terrestrial vegetation and would be used by a range of avian and amphibian fauna.

Intertidal wetlands consist of unconsolidated tidal flats composed of sands and muds, usually backed by mangroves and saltmarsh. These areas provide important foraging for resident and migratory shorebirds. The open ocean beaches and dunes also provide extensive inter- and supratidal habitat for resident and migratory shorebirds. The terrestrial forests in the hills and dunes surrounding the wetlands provide habitat for a wide range of biota, including many threatened species, and are a natural buffer around the lakes.

The marine coast has some rocky headlands and extensive dunes and open beaches, which are used by many migratory birds and other shorebirds, including threatened species such as the little tern. The offshore islands have some beach and rocky intertidal habitat, as well as the supratidal regions of the islands. They are influenced primarily by prevailing weather, the existing vegetation on the islands and the surrounding marine waters.

2.2 Location and regional context

The centre of Myall Lakes Ramsar site is approximately 75 km north-east of Newcastle and 30 km south of Forster on the lower north coast of NSW, between the coastal sand barrier and the hills around the township of Bulahdelah. The site is largely contained within the catchment of Myall River, whose tributaries are the Crawford River, Boolambayte Creek and Nerong Creek, with a small area of the site in the estuarine part of the Karuah River catchment (Figure 12). The Ramsar site is located in the South East Coast Drainage Division, and the lakes and estuarine parts of the site are in the Manning Shelf Bioregion under the Interim Marine and Coastal Regionalisation of Australia (Environment Australia 1998).

The prevailing climate is warm and temperate with a maritime influence. Summers are warm to hot and humid, winters are cool to mild. Rainfall is typical of a temperate coastal region.

The site covers 44,612 ha and is in terrestrial and marine conservation reserves. It contains the only remaining example of a large coastal brackish lake system on the NSW coast that has not been greatly modified by human activity. Figure 2 shows the boundaries of Myall Lakes Ramsar site.

Although the site is protected in national parks, nature reserves and a marine park, 70% of the surrounding catchment is freehold land and state forest (Figure 3). Land use in the catchment greatly influences water quality in the lakes system and potentially threatens the ecological character of the site.

The catchment plays a critical role in maintaining the water quality of the Ramsar site, in particular the lakes system. The Myall lakes catchment has a total area of 780 km^2, with approximately 30% protected in Myall Lakes National Park, 18% managed for timber production in state forests and 52% freehold land (comprising a variety of agricultural and urban land use). The dominant land use in the catchment is summarised in Table 2 (Figure 4).

The largest subcatchment, which comprises 47% of the total catchment area, drains via the Myall and Crawford rivers and flows into Bombah Broadwater (Figure 12). While much of this subcatchment is forested, it has large areas of mostly extensive agriculture, urban areas at Bulahdelah and Nerong and, at the time of listing, had some intensive agricultural practices (dairy and poultry) (Figure 4).

The next largest subcatchment drains into Boolambayte Lake via Boolambayte Creek, and is also predominantly forested with significant areas of agricultural land (beef grazing) in the low lying areas of the subcatchment. The smaller subcatchments around the periphery of Myall Lake are forested with the exception of the Shinglers Creek catchment and the urban area at Bungwahl. Other inputs of water into the lakes are from direct rainfall and groundwater drainage from the sand mass on the eastern shore.

Table 2 Land use in the Myall lakes catchment

Land use[1]	Area (ha)	Catchment area (%)
Conservation	49,203	31.5
Forestry	29,912	19.2
Grazing	18,246	11.7
Residential – rural residential, rural living	2,321	1.5
Transport (i.e. roads)[2]	876	0.6
Marsh/wetland (on private land)	591	0.4
Residential – urban	396	0.2
Plantation[2]	144	<0.1
Intensive animal production[2]	30	<0.1
Cropping[2]	8	<0.1
Other minimal use[3]	54,299	34.8
Total	**156,026**	**100**

Adapted from Bureau of Rural Sciences (2006)

1 Land use is classified according to the Australian Land Use and Management (ALUM) classification (Bureau of Rural Sciences 2006).

2 Areas of catchment occupied by land use such as roads, intensive animal production (e.g. poultry) and cropping are too small or too dispersed to be shown in Figure 4.

3 This includes large areas of private land covered by native vegetation, and areas classified as 'rehabilitation' (approximately 1712 ha).

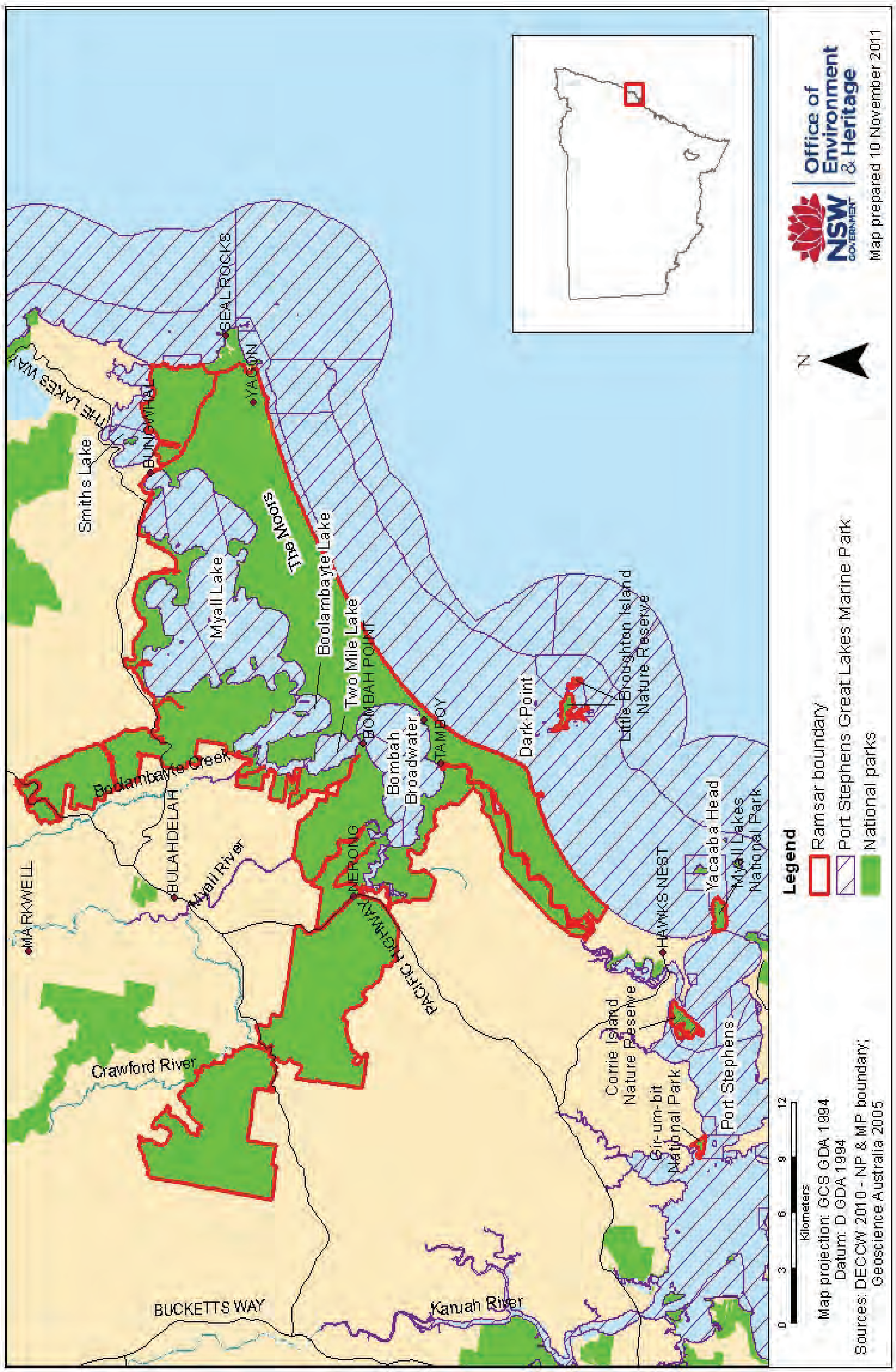


Figure 2 Myall Lakes Ramsar site boundary

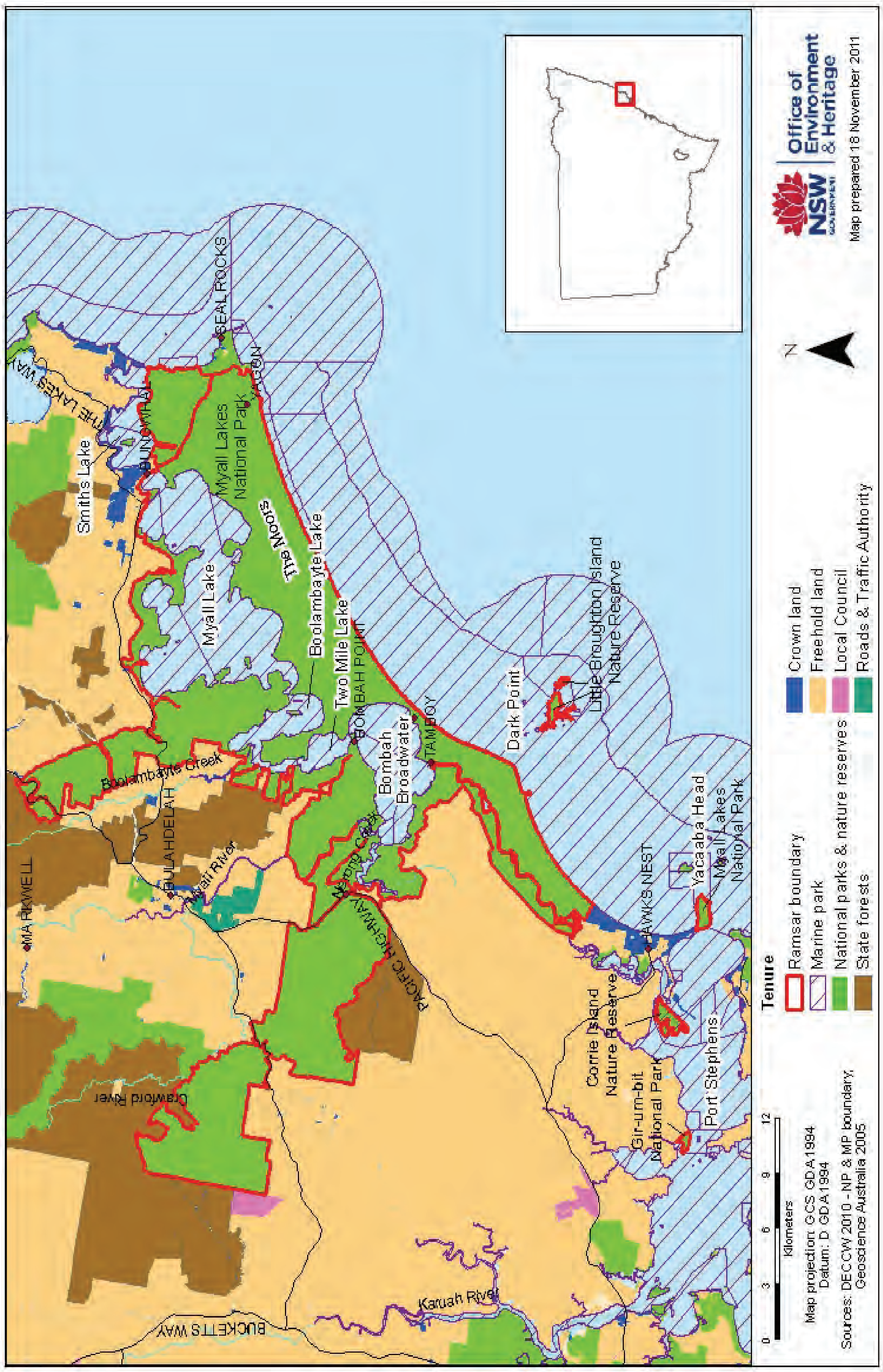


Figure 3 **Tenure of Myall Lakes Ramsar site**

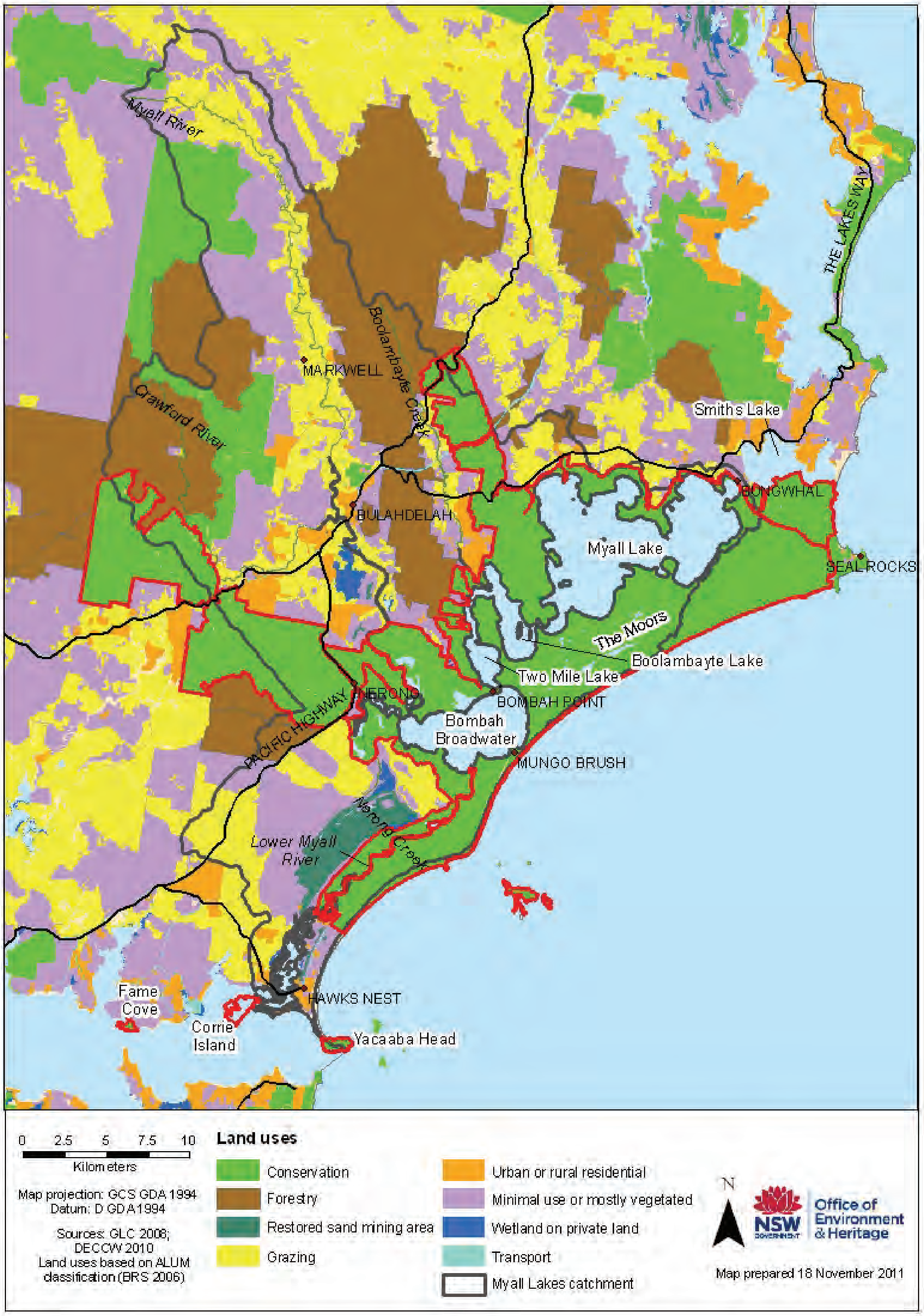


Figure 4 Major land use in the Myall lakes catchment

2.3 Land tenure

Myall Lakes Ramsar site is comprised of national park (Myall Lakes National Park and part of Gir-um-bit National Park) and nature reserve (Little Broughton Island Nature Reserve and Corrie Island Nature Reserve), which are protected under the NPW Act and managed by OEH. The waterways of the Ramsar site are included within the Port Stephens – Great Lakes Marine Park, protected under the Marine Parks Act.

2.4 Ramsar criteria

Myall Lakes Ramsar site was listed as meeting the pre-1999 Ramsar criteria 1a, 1c, 2a and 3b (equating to the current Ramsar criteria 1, 2 and 3):

- Criteria 1a and 1c: criteria for representative, natural or near-natural wetlands, and for a wetland which plays a substantial hydrological, biological or ecological role in ecosystem functioning
- Criterion 2a: general criterion based on plants or animals, including rare and threatened species
- Criterion 3b: specific criterion for a wetland supporting substantial numbers of waterfowl from particular groups.

The current criteria met by the Ramsar site are described below.

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The Myall lakes are a relatively unmodified large coastal brackish lake system. The main streams flowing into the lakes (Myall River and Boolambayte Creek) are free of dams and mostly free of weirs. Consequently the water level changes in the lakes are considered to be close to natural and represent a rare example of near-natural flow regimes in the South East Coast Drainage Division. The coastal wetland types in the Ramsar site are representative of near-natural wetlands in the Manning Shelf Bioregion, and include marine subtidal aquatic beds, intertidal marshes, and intertidal forested wetlands (mangroves). The range of wetlands, combined with the adjoining near-natural terrestrial ecosystem, provides a complex variety of habitats and a rich biodiversity.

The Myall lakes are significant because they:

- represent a unique association of at least 18 Ramsar wetland types, ranging from fresh to marine waters, with the entire association covering an extensive area with minimal structural and hydrological disturbance, and supporting ecosystems and processes in near-natural condition
- are one of the two largest brackish–freshwater barrier estuaries in the South East Coast Drainage Division, and are an excellent, near-natural representative example of this wetland type in the bioregion
- contain a unique co-existence of deep and shallow water macrophytes and gyttja.

The site met Criterion 1 at the time of listing and continues to do so.

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Myall Lakes Ramsar site supports five wetland-dependent species which are listed as nationally threatened under the EPBC Act, or listed as internationally threatened in the IUCN Red List of Threatened Species (IUCN 2010). They are:

- Australasian bittern (*Botaurus poiciloptilus*): endangered, EPBC Act; IUCN Red List
- Freycinet's frog (*Litoria freycineti*): vulnerable, IUCN Red List
- green and golden bell frog (*Litoria aurea*): vulnerable, EPBC Act; IUCN Red List
- green-thighed frog (*Litoria brevipalmata*): endangered, IUCN Red List
- stuttering frog (*Mixophyes balbus*): vulnerable, EPBC Act.

Australasian bittern (*Botaurus poiciloptilus*)

The Australasian bittern prefers wetlands with dense vegetation, including sedges, rushes and reeds. This species generally prefers freshwater wetlands, although it also uses dense saltmarsh vegetation in estuaries and flooded grasslands (DECC 2006).

This species was originally recorded in the Ramsar site between 1977 and 1980 (Atlas of NSW Wildlife). It is now occasionally seen in the Ramsar site and is listed as endangered under the EPBC Act and in the IUCN Red List.

Freycinet's frog (*Litoria freycineti*)

Freycinet's frog is found in heaths, paperbark swamps and forest habitats in coastal areas from central NSW to south-eastern Queensland (Cogger 2000).

There are 23 records of Freycinet’s frog in the Ramsar site between 1974 and 2008 (Atlas of NSW Wildlife). It is listed as vulnerable in the IUCN Red List.

Green and golden bell frog (*Litoria aurea*)

The green and golden bell frog lives in large, permanent, open-water swamps or ponds that have a variable water level and dense vegetation, bulrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.) (DECC 2006).

There are several populations of the green and golden bell frog in the Ramsar site: at Mungo Brush, on The Moors, on Broughton Island, and at Neranie Bay in Myall Lake (Susanne Callaghan 2010, pers. comm.). The population on Broughton Island is believed to be free of chytrid fungus affecting populations of the species on the mainland (Susanne Callaghan 2010, pers. comm.). It is listed as vulnerable under both the EPBC Act and in the IUCN Red List.

Green-thighed frog (*Litoria brevipalmata*)

The green-thighed frog occurs in a range of habitats from rainforest and moist eucalypt forest to dry eucalypt forest and heath, typically in areas where surface water gathers after rain (DECC 2006). It is found in isolated localities along the coast and ranges from just north of Wollongong to south-east Queensland (DECC 2006; Cogger 2000).

There are eight records of the green-thighed frog from the Ramsar site between 1995 and 1996 (Atlas of NSW Wildlife). It is listed as endangered in the IUCN Red List.

Stuttering frog (*Mixophyes balbus*)

The stuttering frog is found in rainforest and wet, tall open forest in the foothills and escarpment on the eastern side of the Great Dividing Range from southern Queensland to north-eastern Victoria. It breeds in streams during summer after heavy rain, and lays its eggs on rock shelves or shallow riffles in small, flowing streams (DECC 2006).

Between 1993 and 2001 there were nine recorded sightings of the stuttering frog in the Ramsar site; however, there is no data to estimate the population size and habitat extent (Atlas of NSW Wildlife). It is listed as vulnerable under the EPBC Act.

The site met Criterion 2 at the time of listing and continues to do so.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The Ramsar site’s large area (44,612 ha) supports a rich biodiversity and contains a range of undisturbed terrestrial vegetation communities and wetland types. As a consequence it supports a diversity of terrestrial plants and animals in the South East Coast Drainage Division and aquatic plants and animals in the Manning Shelf Bioregion.

Many groups of bird species are represented in the Ramsar site, such as pelicans (Pelicanidae), cormorants (Phalacrocoracidae), grebes (Podicipedidae), swans and ducks (Anatidae), herons, egrets, bitterns, ibises and spoonbills (Ciconiiformes), plovers and lapwings (Charadriidae), and wetlands-related raptors (Accipitridae and Falconidae).

The site provides a wide range of intertidal habitats for shorebirds, including coastal mudflats, sandy beaches, saltmarshes, brackish marshes, mangroves and swamp forests, as roosting, nesting, breeding, and feeding sites (Lane 1987). The site is important as habitat for migratory birds, with 22 species listed in international agreements (JAMBA, CAMBA and ROKAMBA) recorded in the site (Table 13); these species include the little tern (*Sterna albifrons*), sooty shearwater (*Puffinus griseus*), short-tailed shearwater (*P. tenuirostris*) and wedge-tailed shearwater (*P. pacificus*).

The site's vegetation is particularly diverse, with 946 species of terrestrial flora, two mangrove species and 10 species of submerged aquatic flora, and 10 saltmarsh species expected to occur in the site (Williams et al. 2006; Kelleway et al. 2007; R. Williams 2008, pers. comm.). The terrestrial species occur in a wide range of vegetation communities, from rainforest and wet sclerophyll vegetation to heathland and sand dune vegetation.

There is also a diversity of animal species, with 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species recorded in the Ramsar site (Atlas of NSW Wildlife) (Appendices 1–4). Many of the site's animals are found in a wide range of wetland types, including estuarine waters, intertidal forested wetlands, coastal freshwater lagoons, permanent rivers, streams or creeks, freshwater tree dominated wetlands, and shrub-dominated wetlands.

The site met Criterion 3 at the time of listing and continues to do so.

2.5 Wetland types

Myall Lakes Ramsar site has 18 different wetland types as defined by the Ramsar Convention classification system. These wetlands are a mosaic of fresh to brackish and saline habitats interconnected across time (driven by hydrology) and space (determined by geomorphology).

Because of the large number of wetland types in Myall Lakes Ramsar site, the wetlands have been grouped (on the basis of similar functions) in this ECD (Table 3). The locations of the wetland groups are shown in Figure 5.

Table 3 Wetland types and groups

Ramsar wetland type*	Ramsar code	Wetland group
Permanent shallow marine waters	A	Group 1: Marine coast
Marine subtidal aquatic beds	B	
Rocky marine shores	D	
Sand, shingle or pebble shores	E	
Estuarine waters	F	Group 2: Mangroves and intertidal flats
Intertidal mud or sand flats	G	
Intertidal marshes	H	
Intertidal forested wetlands	I	
Coastal brackish/saline lagoons	J	Group 3: Brackish waters
Coastal freshwater lagoons	K	
Permanent rivers/streams/creeks	M	Group 4: Rivers, creeks and streams
Seasonal/Intermittent rivers/streams/creeks	N	
Permanent freshwater marshes/pools	T_p	Group 5: Freshwater and fringing wetlands
Seasonal/Intermittent freshwater marshes/pools	T_s	
Shrub dominated wetlands	W	
Freshwater tree dominated wetlands	X_f	

* Ramsar wetland classification system (DEWHA 2010)

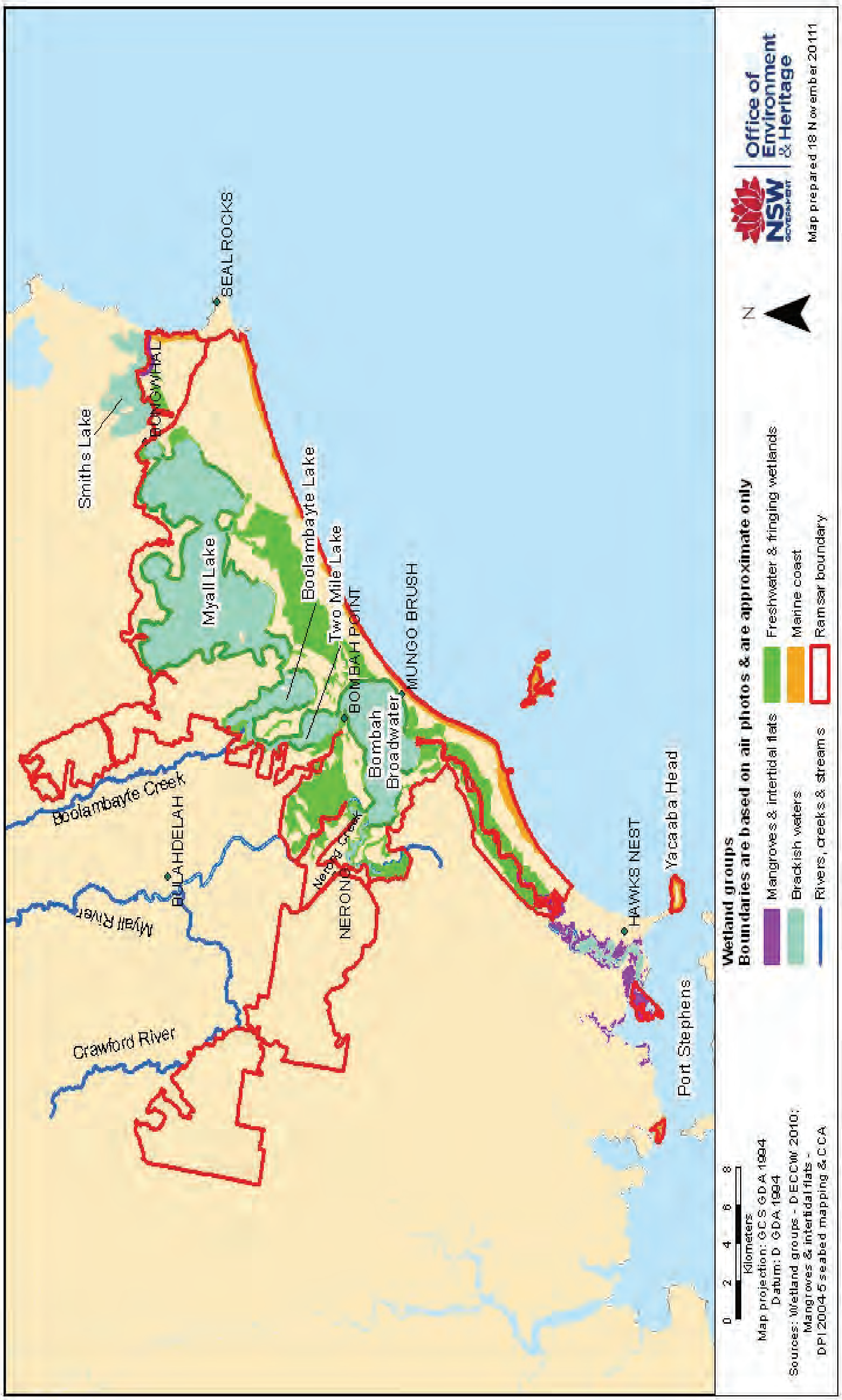


Figure 5 Wetland groups

A brief description of each wetland group is provided below, along with their respective estimated areas and locations in the Ramsar site. A short summary of the ecosystem components, processes and services associated with each wetland group is also provided. Further information on the components and processes can be found in section 3. Ecosystem services are discussed in section 4. Threats to each wetland group are also listed and discussed in section 8.

- **Group 1: Marine coast**

Ramsar wetland types: A, B, D, E

Where found: Port Stephens, Fame Cove, Corrie Island, Little Broughton Island, Yacaaba Head, Broughton Island, Myall coastline and beaches (Figure 6)

Estimated area: 730 ha

Description: Permanent shallow waters associated with Fame Cove and Corrie Island; seagrass beds of the Myall River and Bombah Broadwater; rocky shores associated with the Myall coastline, Yacaaba Head and Broughton and Little Broughton islands; sandy shores including beaches, dunes and Corrie Island

Ecological components and processes: Rocky and sandy shores; nationally threatened species; shorebirds

Services supported: Physical habitat and biodiversity; nationally threatened species; shoreline stabilisation and protection; fisheries production; recreation and tourism; cultural heritage

G Mason

Figure 6 Wetland type group 1: marine coast – Yagon Gibber Headland and Treachery Beach

Threats: Loss of habitat and changed vegetation types due to clearing, disturbance by human intrusion, predation and competition by introduced species

- **Group 2: Mangroves and intertidal flats**

Ramsar wetland types: F, G, H, I, B

Where found: Corrie Island, Smiths Lake shoreline, lower Myall River, Fame Cove (Figure 7)

Estimated area: 200 ha

Description: Intertidal sand and mudflats at Corrie Island and Smiths Lake; mangroves and saltmarsh in the lower Myall River and Fame Cove

Ecological components and processes: Intertidal mudflats and sandflats, saltmarsh, forested swamp (mangroves) and seagrass beds; migratory shorebirds; tidal flushing; salinity regime

P Scanes

Figure 7 Wetland type group 2: mangroves and intertidal flats

Services supported: Physical habitat and biodiversity; nationally threatened species; priority wetland species; ecological connectivity; shoreline stabilisation and protection; fisheries production; maintenance of fishery productivity

Threats: Loss of habitat; changed vegetation types due to clearing, disturbance by human intrusion, predation and competition by introduced species

- **Group 3: Brackish waters**

Ramsar wetland types: J, K

Where found: Bombah Broadwater, Two Mile Lake, Boolambayte Lake and Myall Lake (Figure 8)

Estimated area: 10,300 ha

Description: Large relatively undisturbed brackish to freshwater lake system connected to the sea by the lower Myall River via Port Stephens. Includes Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater. Located in embayment between hills to the west and coastal dune system to the east.

Ecological components and processes: Submerged and emergent aquatic vegetation; waterbird habitat and drought refuge; oligotrophic clear water; maintenance of hydrological processes and nutrient cycling; habitat for fish, macroinvertebrates, plankton and gyttja.

G Mason

Figure 8 Wetland type group 3: brackish waters – Neranie Headland and Myall Lake

Services supported: Hydrological processes; physical habitat and biodiversity; primary production and food webs; nationally threatened species; ecological connectivity; natural or near-natural wetland ecosystems; maintenance of hydrological regimes; fisheries production; recreation and tourism.

Threats: Loss of habitat and changed vegetation types due to increased loads of nutrients and sediments from catchment clearing, algal blooms, disturbance by human intrusion, predation and competition by introduced species, changed lake levels from changed rainfall patterns, climate change and sea level rise.

- **Group 4: Rivers, creeks and streams**

Ramsar wetland types: M, N

Where found: Myall River, Boolambayte Creek, upper catchment (Figure 9)

Estimated area: 500 ha

Description: Myall River, Boolambayte Creek, Nerong Creek and their tributaries (permanent and ephemeral creeks and streams).

Ecological components and processes: Wet sclerophyll, she-oak and paperbark forests; habitat for amphibians and freshwater fish (freshwater parts of upper Myall River and Boolambayte Creek); seagrasses; habitat for euryhaline and estuarine fish species (brackish parts of lower Myall River).

Services supported: Hydrological processes; physical habitat and biodiversity; habitat for nationally threatened wetland species; ecological connectivity; maintenance of hydrological regimes.

S Thompson

Figure 9 Wetland type group 4: rivers, creeks and streams – Myall River (top right) and wetland type group 5: freshwater and fringing wetlands (centre)

Threats: Loss of riparian vegetation and changed in-stream vegetation types due to clearing, algal blooms, disturbance by human intrusion, predation and competition by introduced species, changed flow patterns from changed rainfall patterns, climate change and sea level rise.

- **Group 5: Freshwater and fringing wetlands**

Ramsar wetland types: K, W, X_f, T_p, T_s, 7, 9

Where found: The Moors; extensive wetlands adjoining lakes system; between upper Myall River and northern shore of Bombah Broadwater; along both sides of the lower Myall River downstream of Bombah Broadwater (Figures 9, 10, 11)

Estimated area: 6000 ha

Description: The Moors – coastal heath swamps occupying low-lying areas in the Eurunderee sand mass; coastal swamp forests dominated by paperbarks and swamp mahogany and by casuarinas along the lake margins.

Ecological components and processes: Emergent vegetation; *Melaleuca-Casuarina* fringe forest, wet heath forest, swamp forest and coastal heath swamps.

Services supported: Hydrological processes; habitat and biodiversity; gyttja; nationally threatened wetland species; ecological connectivity; natural or near-natural wetland ecosystems; maintenance of hydrological regimes; recreation and tourism.

Threats: Loss of habitat and changed vegetation types due to clearing, disturbance by human intrusion, predation and competition by introduced species, changed water levels from changed rainfall patterns, climate change and sea level rise.

F Miller

Figure 10 Wetland type group 5: freshwater and fringing wetlands – The Moors

F Miller

Figure 11 Wetland type group 5: freshwater and fringing wetlands – Bombah Broadwater

2.6 Terrestrial ecosystems

Myall Lakes Ramsar site also contains a wide variety of terrestrial habitats which comprise over 60% of the site's area and contribute to its ecological value.

Keith (2004) identified 11 terrestrial vegetation formations that are expected to occur in Myall Lakes Ramsar site. The exact locations of these formations have not yet been mapped. Each vegetation formation will have an associated faunal community.

The vegetation formations indicated by Keith (2004) are three classes of dry sclerophyll forest, coastal valley grassy woodlands, maritime grasslands, two classes of heath, two classes of rainforest and two classes of wet sclerophyll forest.

The terrestrial ecosystems provide an important buffer around the wetlands and a vegetation corridor that connects to Smiths Lake and Wallis Lake to the north of the Ramsar site.

3 Ecosystem components and processes

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

This section is a review of information available for the components and processes of the Myall lakes ecosystem. This review will identify the components and processes that determined the ecological character of the Ramsar site at the time of listing. The critical components and processes are summarised in section 5.

3.1 Climate

The prevailing climate is warm and temperate with a maritime influence. Summers are warm to hot and humid, winters are cool to mild. Rainfall is typical of a temperate coastal region. The mean annual rainfall is 1328 mm at Bulahdelah, and slightly higher towards the ocean (1346 mm at Nelson Bay) (BoM 2007). The wettest months are in late summer and early autumn, when the mean monthly rainfall exceeds 100 mm, and the driest months are in late winter and early spring, with mean monthly rainfall about 60 mm (BoM 2007).

Temperatures vary across the catchment depending on sea breezes and elevation. At Bulahdelah the mean monthly maximum temperatures range from 27°C in summer to 17°C in winter, with minima of 15°C and 3°C, respectively. At Nelson Bay, the temperatures are generally mild to warm with a mean summer maximum of 28°C (winter 17°C) and a mean summer minimum of 15°C (winter 7°C).

Wind direction is predominantly from the south or south-east in summer and from the north-west in winter (Thom et al. 1992; MHL 1999). Wind movement over the water surface induces directional surface currents (Thom et al. 1992). Thus, the water at the surface of the Myall lakes can be expected to move in a northerly direction during summer. A flow of water in the opposite direction commonly accompanies the surface waves, especially in shallow water, and this is normally near the bottom of the water column (Pritchard and Vieira 1984; Thom et al. 1992). The circulation pattern may also be three-layered, so that the return flow of water is in the middle of the water column (Schubel and Carter 1984).

Solar radiation and evaporation are typical of temperate climates, with high values in summer and lower values in winter. Average daily solar radiation on clear days ranges from 24.3 MJ/m^2 in January to 8.9 MJ/m^2 in June.

3.2 Geology

3.2.1 Geology and soils

The underlying geology of Myall Lakes Ramsar site is metasediments and interbedded volcanics such as rhyolite and basalt (Skilbeck and Cawood 1994). Structural features include prominent folds, such as the Myall syncline (which delineates the western edge of Myall Lake), and strike ridges which outcrop sporadically and have become anchors for the characteristic sand deposits of the Eurunderee sand mass and coastal dunes.

Soils in the catchment come from sedimentary and volcanic parent material, and are generally of low fertility (Great Lakes Council 2009). The major soil types in the Ramsar site are:

- colluvial soils – formed from unconsolidated soil and rock, and largely mobilised by gravitational forces; found across approximately 41% of the lakes' catchment
- erosional soils – formed by the erosive action of water, and typically on undulating slopes and surrounding catchment drainage lines; found across 14% of the catchment

- alluvial soils – formed by deposition along rivers and streams, and are found around the confluence of the Myall River and Crawford River, as well as along the lower reaches of the Myall River and Boolambayte Creek; they occupy about 9% of the catchment
- aeolian soil landscapes – formed by the deposition of wind-driven sand particles, creating dunes and sand sheets; they occupy about 7% of the catchment
- swamp and estuarine soil landscapes – commonly associated with the aeolian dune complex in the eastern parts of the catchment; together occupy about 4% of the catchment.

3.2.2 Geomorphological features

The Myall lakes are drowned river basins and the remnants of former hind-dune drainage systems, and their configuration is largely determined by the irregular bedrock topography of the western shoreline. The eastern shores are mainly formed by the two distinct beach ridge systems of an inner and outer barrier, and represent two separate periods of deposition. The inner barrier, which extends parallel to the coast, was laid down before the last glacial period, about 60,000 years ago, and is composed of highly podzolised Pleistocene sands overlying a sandrock hardpan (Thom et al. 1992). The outer barrier was formed after the sea stabilised at its present level about 6,000 years ago, and is composed of only moderately podzolised Holocene sands (Thom et al. 1992).

The main rock types of the Myall syncline (downfold) on the western side of the lakes are sedimentary rocks (sandstones, siltstones and mudstones) with some underlying volcanic rocks. Erosion of bedrock at times of lower sea levels has left a complex of rocky hills and ridges. With the rise in sea level during the Holocene, some rock outcrops became isolated from the mainland, producing a series of offshore islands, including Broughton Island and Little Broughton Island (NPWS 2002).

There are three main geomorphological features of the Ramsar site: the Myall River catchment, the lakes system and the coastal sand deposits.

Myall River catchment

The river catchment originates in the hills to the north-west of Bulahdelah and runs south and east to Bombah Broadwater. It is composed of two major subcatchments – the Myall and the Crawford. Gradients are steep in the headwaters but become much more moderate in the lowlands near Bulahdelah.

Lakes system

Bombah Broadwater is a shallow, low-relief lagoon. The current lake floor morphology is the result of several processes including exposure to waves, wind-generated currents, fluvial currents, aquatic plants and relict processes. Sandy sediments are associated with elongated sand bars, which are normally found adjacent to the barriers and in water depths less than 1.5 metres. Muddy sediments dominate water depths of 3–4.5 metres; however, sheltered locations have mud at depths of less than two metres. Two Mile Lake is very similar in morphology to Bombah Broadwater (Thom et al. 1992).

Active sedimentation of sand and mud is occurring in two primary locations. The first is near the mouth of the upper Myall River, and the second is the flood–tidal delta where the lower Myall River enters Bombah Broadwater. Anecdotal information suggests there may also be sediment accumulation on the western shore of Bombah Broadwater. The general form of the deepest section of Bombah Broadwater suggests a remnant, meandering channel, which may mark the course of the Last Glacial upper Myall valley (Thom et al. 1992).

Boolambayte Lake and Myall Lake have a flat and relatively featureless lake floor, except for sand bars or bedrock projections. The lake depths vary according to fetch distance and directions. In areas exposed to dominant southerly and westerly wind directions, a depth of 4–4.5 metres is common. Depths are normally less than two metres in sheltered bays and near the western and northern margins of the lake (Thom et al. 1992). Although lake depths appear to be generally related to the degree of exposure to wave-induced bottom currents, wind-induced currents cause local scouring adjacent to exposed headlands, while flood currents have resulted in a channel up to 14 metres deep at the entrance to the lake between Violet Hill and Johnsons Hill (Thom et al. 1992).

The beds of Myall Lake, Boolambayte Lake and Two Mile Lake are largely covered by gyttja, a highly organic and mobile mud which has a gelatinous appearance. When the distribution of gyttja was recorded in the Myall lakes in 2004, about 20% of the bed of Myall Lake was covered with concentrated gyttja, with about 80% covered by less concentrated gyttja; about 10% of the bed of Boolambayte Lake (including Two Mile Lake) was covered with concentrated gyttja, with about 90% covered with less concentrated gyttja (Dasey et al. 2004). Gyttja was not recorded in Bombah Broadwater (Figure 18).

Acid sulphate soils are present throughout the low-lying estuarine and creek flat areas, and are typically found at or near the surface in areas with a high water table. There are 14,092 ha classified as potential acid sulfate soils within Myall Lakes Ramsar site.The extent of acid sulphate soils affecting the Ramsar site is not known; however, the Great Lakes Water Quality Improvement Plan (which includes the Myall lakes) identifies the need to 'reinstate natural wetland hydrology, particularly in acid sulfate landscapes' in the catchments of the Myall lakes, Smiths Lake and Wallis Lake (Great Lakes Council 2009).

Coastal sand deposits

The coastal sand deposits are composed of Pleistocene inner and Holocene outer barrier systems which have accreted around bedrock ridges. The inner barriers are different ages in the separate embayments along the coast, whereas the outer barrier is virtually a continuous deposit, separated only by outcropping headlands. The embayments from north to south are Seal Rocks, Eurunderee, Upper Myall–Bombah Broadwater and Fens (Thom et al. 1992). Perched wetlands occur in the large interdunal swales such as The Moors (Figures 5 and 10).

A dominant feature of the Ramsar site is the Eurunderee sand mass and associated coastal dunes, which are situated between the lakes and the ocean. This vast body of Pleistocene and Holocene sands is a major influence on much of the terrestrial vegetation types, and on the hydrology and the groundwater flow of the eastern half of the mainland part of the Ramsar site.

Sand deposits include the Dark Point dune sheet, a large, transgressive sand dune that is moving in a net north north-westerly direction under the action of predominant south-easterly winds. This large dune, part of the Ramsar site, is moving as a result of natural factors – onshore winds blowing across and against a large mass of unrestrained sand. The Dark Point dune sheet is approximately 250 ha in area and extends some 6 km along the northern edge of the Fens Embayment, an open coastal embayment between Hawks Nest and Dark Point. A number of substantial sand dunes up to approximately 50 metres high occur within this dune sheet (GBAC 2010). It appears that the inland edge of the dunes may have moved approximately 100 metres over the past 30 to 40 years, and that strong winds may have caused movements of up to eight metres within the last five years (Fiona Miller 2010, pers. comm.).

The dune sheet is currently about 27 metres (at its closest point) from Mungo Brush Road, the main access road between Hawks Nest and Bombah Point, and is expected to eventually reach the road and cover it. The NSW National Parks and Wildlife Service (NPWS) has undertaken studies to assess options for relocating Mungo Brush Road to the west of its current position. The dune sheet, which is encroaching at an average rate of between 3.5 and 4.9 m/yr (and up to 7 to 9 m/yr at its northern end), is expected to reach Mungo Brush Road by 2017 (GBAC 2010).

3.3 Hydrology

3.3.1 Water inflows and outflows

The water budget for the lakes may be described as a balance between inflows from direct rainfall, surface runoff, tidal flow, groundwater inflows, and outflows associated with discharges via the lower Myall River, evaporation, and groundwater discharges. Of those elements, there are relatively accurate records of surface runoff inflows, rainfall and evaporation while the groundwater exchange and inflow/outflow through the lower Myall River are calculated with a number of assumptions (MHL 1999).

In a typical year (one with average rainfall), runoff from the catchment represents the major freshwater inflow (133.8 GL) (MHL 1999). Most of the inflows come down the upper Myall River and enter Bombah Broadwater north of Nerong. Boolambayte Lake has freshwater input via Boolambayte Creek. Myall Lake has a very small catchment, and most waters entering the lake come through Boolambayte Lake from Bombah Broadwater with some small inputs from the lake fringe and Shingle Splitters Creek. The input of direct rainfall is relatively small (1.7 GL/yr) and the outflow via the lower Myall River could be the same magnitude as evaporation loss (MHL 1999).

The historical records of flood levels in the Myall lakes and lower Myall River are very limited, and are usually based on observations made by local residents. The highest floods observed by the Legge family at Bombah Point were in the 1890s, when the lake was estimated to rise to 3.7 m above its normal level, and in April 1927, when the level rose to 2.7 m (or 3.2 m according to Stroud Shire Council's estimates) after 600 mm of rain fell in 24 hours (Department of Public Works 1980).

Records of floods between 1977 and 1979 were collected using a gauge installed at Bombah Point. The highest floods were in May 1977, when 340 mm of rain fell at Bulahdelah and the lake level rose to 1.3 metres, and in March 1978, when 387 mm of rain fell at Bulahdelah and the lake level also rose to 1.3 metres (Department of Public Works 1980). The modelled one-in-100-year flood, based on rainfall intensity of 3.6 mm/hr over seven to 10 days (605-864 mm total rainfall), predicted a lake level of 3.0 metres and a discharge of 290 cumec (cubic metres per second) (Department of Public Works 1980).

Most of the groundwater inflow to the lakes comes from sand aquifers, with inflows estimated at 285 ML/day from sand aquifers and 2 ML/day from fractured rock aquifers (MHL 1999). The annual maximum estimated groundwater inflow to the lakes is estimated to be 104.7 GL (MHL 1999).

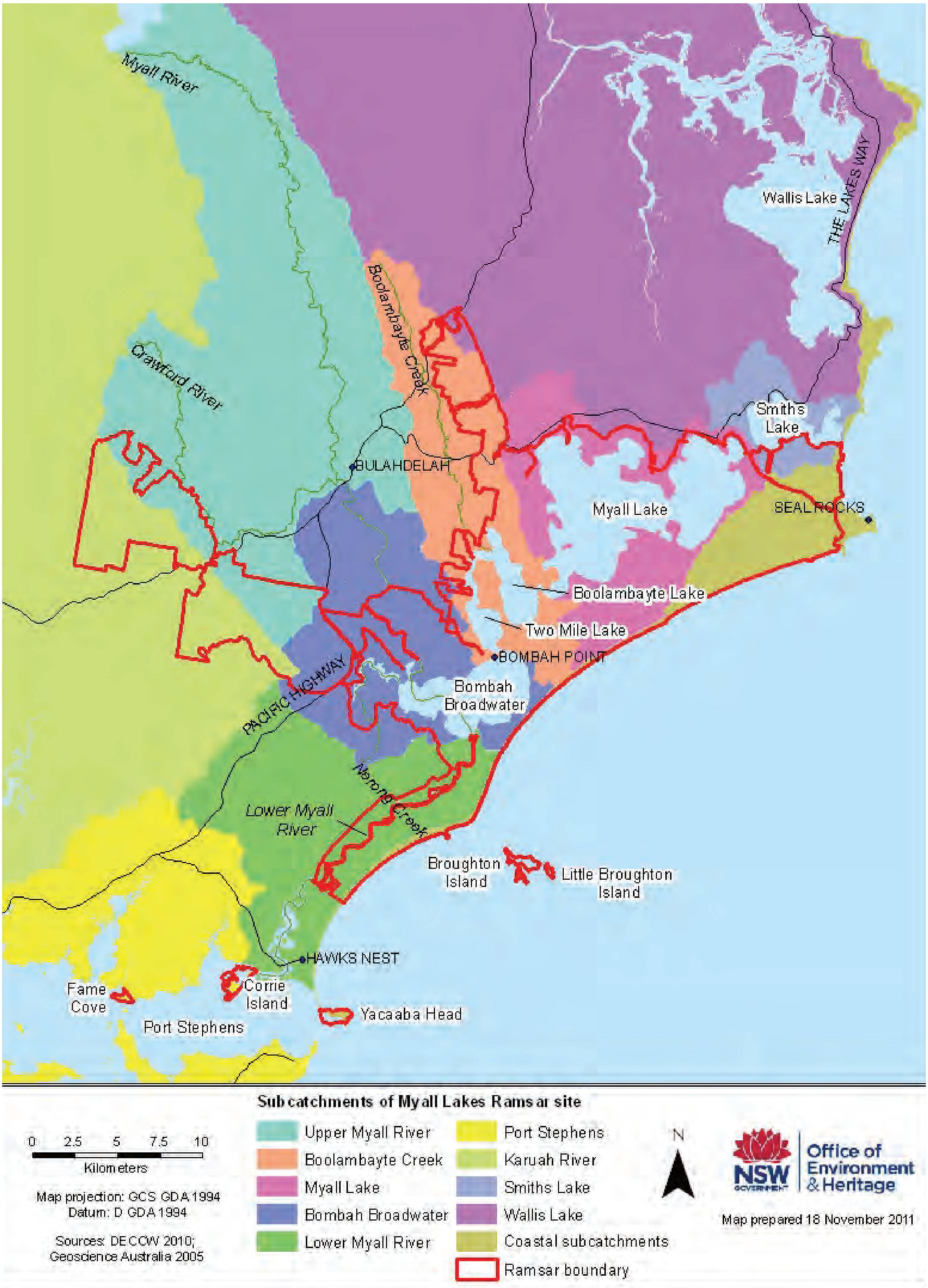
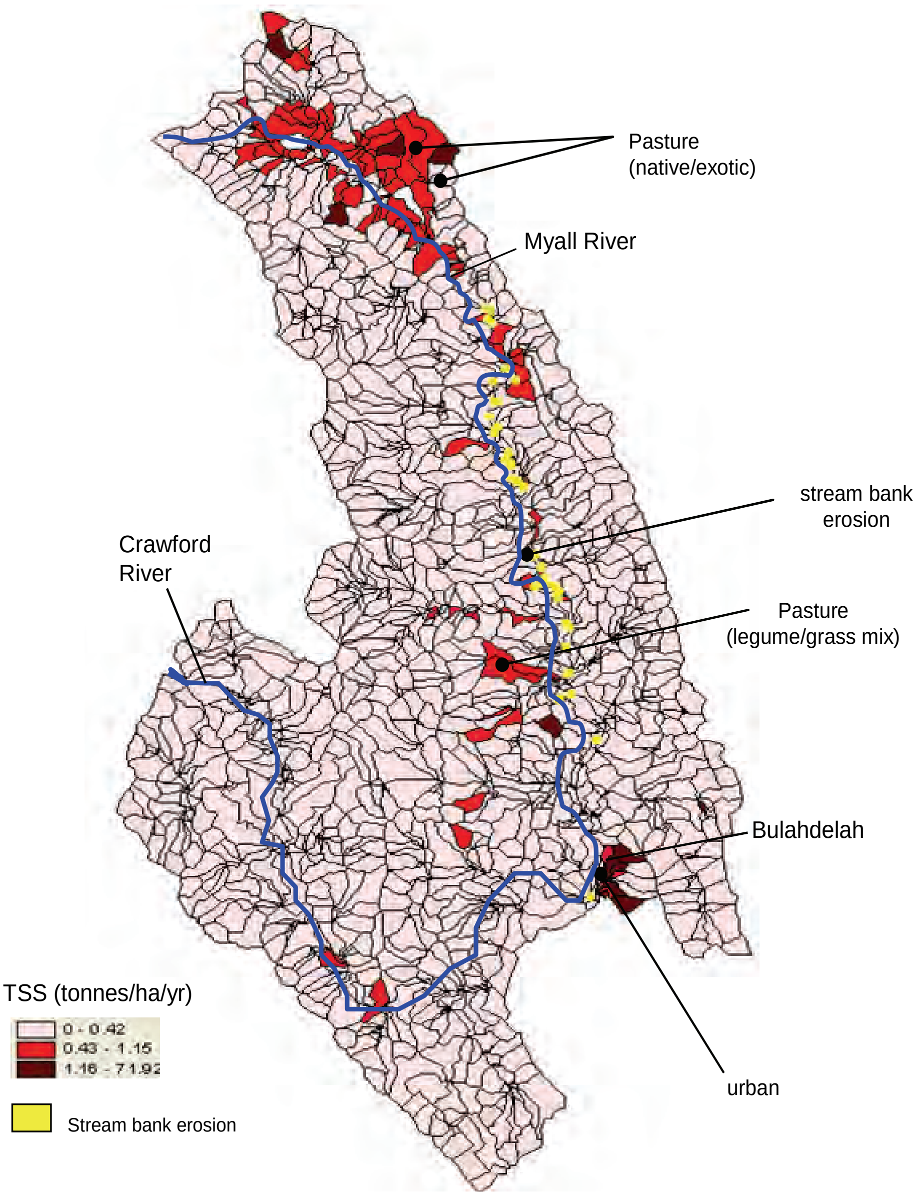


Figure 12 **Subcatchments of the Myall lakes**



Source: GLC (2008)
Sediment amounts are expressed as total suspended solids (TSS) in tonnes
Sites of active river-bank erosion identified by Rivercare are shown in yellow.

Figure 13 Upper Myall River subcatchment (including Crawford River) and hotspots for export of sediments by surface runoff

3.3.2 Lake levels

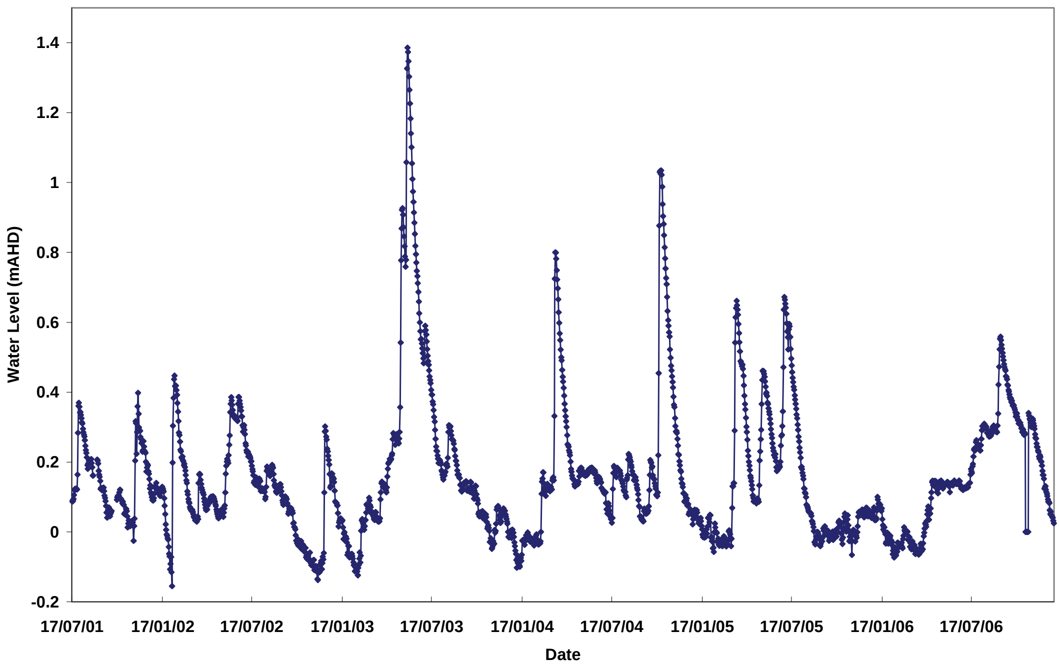
Generally, water levels in the lakes are higher than the ocean, reflecting the constricted entrance channel (lower Myall River) resulting in a comparatively slow dissipation of freshwater runoff from the lakes to the ocean. From 2000, Manly Hydraulic Laboratory (MHL) has continuously monitored the water level at Bombah Point on Bombah Broadwater (MHL 2007) (Figure 14). The following description of the current status of water levels is drawn from MHL records.

While the water levels in the lower Myall River show a strong semi-diurnal tidal pattern, there is little, if any, semi-diurnal tidal water level variations in the lakes. In order of importance, factors affecting water levels in the Myall lakes and an estimate of how much they affect lake levels are:

1 intermittent catchment runoff – magnitude +1 metre
2 low frequency (weeks) non-periodic/intermittent changes in offshore water level causing water-level changes in Myall Lake perhaps – sometimes as large as 100 mm but typically much smaller
3 small diurnal and semi-diurnal tides with maximum amplitudes of three to four millimetres
4 intermittent wind-driven seiching between/within lake basins – amplitude in order of 10–20 mm.

Catchment runoff and subtidal offshore forcing dominate water level variability in the Myall lakes. The magnitude of effects would be greatest in Bombah Broadwater, diminishing (but still observable) with distance upstream towards Myall Lake.

As Myall River and Boolambayte Creek (the main freshwater inflow channels) are free of dams and mostly free of weirs (with the exception of the Crawford subcatchment), the water level changes in the lakes are considered to be near natural and represent a rare example of near-natural flow regimes in NSW coastal rivers.



Source: MHL (2007)

Figure 14 Water level of Bombah Broadwater at Bombah Point

3.3.3 Replenishment of groundwater

The underlying Carboniferous and Permian rocks form fractured aquifers that commonly contain salty water unless recharged with rainwater (Realica 1999). This groundwater flows from north-east to south-west and discharges into the Myall lakes making a significant contribution to the lakes' water, estimated at 105 GL/yr (MHL 1999).

There are also small, perched aquifers (half a metre below the surface) in the Quaternary sand dune deposits at Myall Shores, Bombah Point and Mungo Brush that contain brackish water and are hydraulically connected with the lakes' water and the sea. Consequently the aquifers become a mixing zone for the lakes' water, groundwater and sea water. The groundwater from the perched aquifers flows east and west depending on the lakes and sea water level fluctuations. Depending on water levels in the lakes and sea, these Quaternary aquifers can be recharged by the lakes and the sea (Realica 1999).

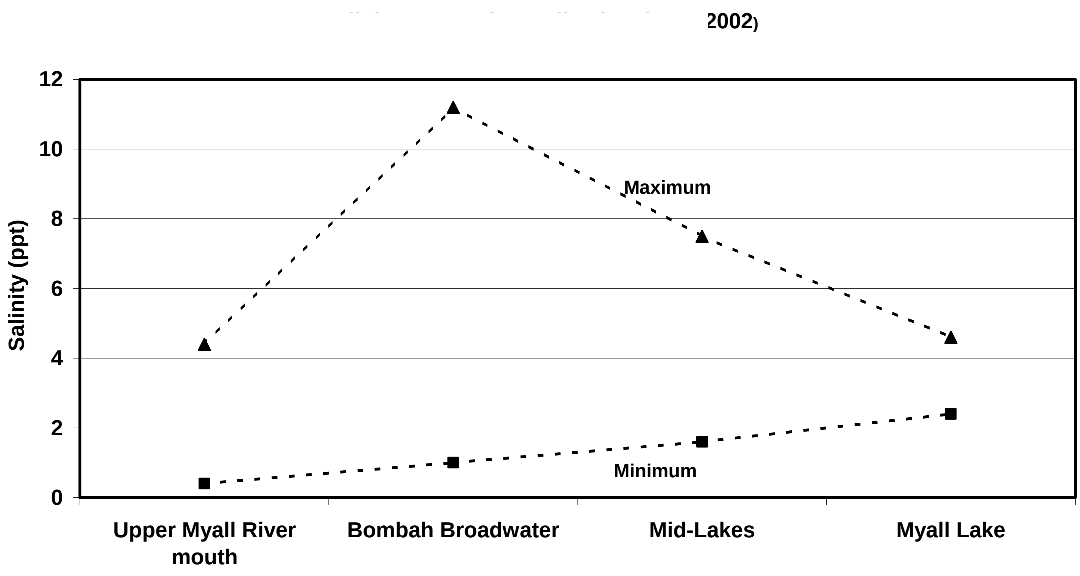
The role and significance of groundwater for the Ramsar site is poorly understood and is a knowledge gap.

3.3.4 Salinity

The mosaic of open-water, fringing and tidal wetlands is dependent on the lakes' salinity regime, which ranges from near fresh in Myall Lake and Boolambayte Lake, through brackish in Bombah Broadwater to estuarine/marine in the lower Myall River. The existing salinity regime is maintained by changing lake levels in response to variable rainfall and by sufficient inflow from rainfall to keep salinity levels low. Varying water levels are essential to the maintenance of the fringing wetlands, and low salinity in the lakes is necessary for the macrophyte beds and fringing wetlands (Figure 15). The presence of intertidal flats and maintenance of intertidal wetlands (mangrove and saltmarsh) depends on the current sea level remaining constant.

Salinity regimes throughout the Myall lakes are an important determinant of many of the aquatic biotic structures and processes. Figure 15 illustrates the dynamic nature of salinity throughout the system. Bombah Broadwater is directly affected by both freshwater flows from the upper Myall River and seawater intrusions from the lower Myall River and has a wide range of salinities, from 1 to 11 ppt (parts per thousand) (Dasey et al. 2004). However, Myall Lake is isolated from large-scale direct catchment inflows and saline intrusions and so has a more constant salinity, ranging from 2.4 to 4.6 ppt with a median of 3.9 ppt (MHL 1999). The mid-lakes, which have a relatively small freshwater input via Boolambayte Creek, have an intermediate response (1.5–7.5 ppt) (Dasey et al. 2004). The entire lower Myall River can become fully saline after a prolonged drought.

Ecological processes and water quality in Myall Lake (fresh) are largely influenced by its perimeter catchment, with only limited exchange with Boolambayte Lake. Boolambayte Lake (fresh) and Two Mile Lake (fresh) are strongly influenced by Boolambayte Creek, with limited exchange with Myall Lake in the north; the exchange between Two Mile Lake and Bombah Broadwater in the south is significant for water quality and ecology of Two Mile Lake. Ecological processes and water quality in Bombah Broadwater (brackish) are significantly influenced by the upper Myall River and its catchment. The southern portion of Bombah Broadwater and lower Myall River are the only parts of the lake system that are subject to significant tidal flushing (Atkinson et al. 1981; Great Lakes Council 2009).



Source: derived from data in Dasey et al. (2004)

Figure 15 Salinity ranges in the Myall lakes, 2000–02

3.3.5 Tidal regime

The tidal regime of the Myall lakes varies considerably among different locations within the site. Broughton Island offshore experiences a diurnal tidal regime typical of the east coast of southern Australia with a tidal range (between high and low tide) of up to two metres. Corrie Island and Fame Cove are located within Port Stephens and experience a similar tidal range with a slight tidal lag.

The lower Myall River connects the Myall lakes to Port Stephens, entering the bay near Corrie Island. The influence of tidal water for the Myall lakes is constricted by the narrow channel of this river, and only a relatively small volume of marine water enters the Myall lakes. The marine water enters the system via the southern-most lake, Bombah Broadwater. Marine waters are almost totally assimilated within Bombah Broadwater, but tidal forcing of water height can occur in the mid lakes. For most of the time the tidal limit is in Bombah Broadwater (and does not pass Bombah Point, 32 km upstream from Corrie Island and 37 km from the ocean), but during periods of low rainfall can extend to Neranie Bay, 70 km upstream of Corrie Island (MHL 1999).

3.4 Water quality

3.4.1 Oligotrophic clear water (low nutrient clear water)

Water clarity (measured as Secchi depth, turbidity or suspended solids), in particular the depth to which light can penetrate through the water column, determines the type of biota in an aquatic system. Clear shallow waters would generally support macrophytes, while deeper or more turbid waters would tend to be dominated by phytoplankton.

Light transmission in the Myall lakes is primarily influenced by two factors: suspended sediment particles (measured by turbidity), and water colour. Myall Lake and Boolambayte Lake, in particular, have highly coloured waters, resulting from a naturally high concentration of tannins and other inert organic nitrogen compounds. However, they have relatively small amounts of suspended particles.

During floods, catchment runoff and resuspension of sediment cause high turbidity which can last for a period of days or weeks. In a study of the effect of runoff on the ecology of the Myall lakes, Wilson (2003) found that the Secchi depth at the river entrance part of Bombah Broadwater was less than half a metre for two weeks.

Myall Lake is very stable in terms of salinity, turbidity and nutrient levels. The lakes can remove up to 90% of phosphorus deposited from catchment runoff; the removal rate for nitrogen is considered to be high given its long water residence time in the lakes (MHL 1999). The majority of nutrients are stored as plant biomass, detritus or sediment, with a small amount (7%) remaining in the lakes' waters (Sanderson et al. 2006; Sanderson 2008). Bombah Broadwater and Boolambayte Lake are the most productive of the lakes.

Data compiled for the Coastal Catchments Initiative (CCI) showed that in 2000–02 Bombah Broadwater had poorest water clarity (turbidity 29 nephelometric turbidity units (ntu); secchi depth less than one and a half metres); Boolambayte/Two Mile Lake had intermediate clarity (14 ntu; secchi depth two to three metres); and Myall Lake had the best clarity (4.3 ntu; secchi depth up to four metres) (Dasey et al. 2004; Great Lakes Council 2009). These water clarity measurements are supported by the distribution of submerged plants. The existence of large areas of submerged plants in the upper lakes, with macrophytes to a depth up to four metres, confirms good water clarity and light penetration in those lakes. In Bombah Broadwater, however, perennial submerged plants rarely occur in water depths greater than about one metre, despite suitable habitat at greater depths.

3.4.2 Sediments

Sediment sources

Sediments in the waterways are caused by erosion and overland transport of soil particles. Erosion is exacerbated when vegetation is removed from the landscape. In the context of the Myall lakes, sediment sources fall into two categories: sediments derived from sheet or surface erosion, and sediments derived from deeper erosion.

The volumes of sediment likely to enter the lakes by surface erosion were modelled in CCI studies (Great Lakes Council 2009). Pasture land uses along the Myall River valley were the main sources of surface sediments, and forested areas contributed relatively small amounts of sediments in the model (Figure 16). Anecdotal evidence suggests that after logging, the previously forested soils contribute large amounts of sediments to waterways. Sources of deep erosion are believed to occur as bed incision in partly confined reaches upstream of Markwell on the Myall River, as erosion gullies in the upper catchment, and eroding slopes within the Boolambayte Lake catchment (Figure 13) (Great Lakes Council 2009). Overall, agricultural land and gravel roads were the largest sources of sediments in the catchment, together contributing 79% of the total suspended solids (TSS) entering the lakes (Figure 16) (Great Lakes Council 2009).

Areas in the Ramsar site where there is contemporary sediment accumulation are the floodplains adjacent to the Myall River, and the Myall River delta in Bombah Broadwater. There are also catchment sediment sinks with very old deposits in the site, which formed via the deposition of sediment at the edges of the valley on the old floodplain during the Holocene period upstream of Bulahdelah (Thom 1965). Those sediment sinks are not part of the current sediment budget.

Sediment input modelling

CCI studies used catchment models to estimate the nutrient and sediment loads delivered to the Myall lakes system from its catchment (Great Lakes Council 2009) (Table 4). The model used was the Annualised Agricultural Non Point Source model (AnnAGNPS),calibrated with field data (flow, nutrient and sediment concentrations) collected from the catchment during run-off and base flow conditions. The model used land uses derived from 2005 SPOT satellite images and run-off coefficients based on land use. Spatial trends in the concentrations of TSS in runoff were less discernable, but the data did indicate greater TSS concentrations in samples collected adjacent to a quarry and a poultry farm.

Because there was no strong differentiation in land use among subcatchments, the average annual TSS load to the Myall lakes is predominantly related to the subcatchment area (Great Lakes Council

2009). Hence the largest subcatchment, the upper Myall River (which includes its major tributary, the Crawford River), contributed the largest annual nutrient and sediment loads, followed by the Bombah Broadwater subcatchment and then by the Boolambayte Creek subcatchment (Table 4). The CCI models estimated that for an average runoff volume of 4963.9 ML from the Bombah Broadwater subcatchment, the average TSS load was 535 kg km^{-2} (Great Lakes Council 2009).

Table 4 Estimated annual pollutant exports from the Myall lakes subcatchments

Subcatchment	Area		TSS		TN		TP	
	ha	%	Tonnes	%	kg	%	kg	%
Upper Myall River	23,956	31	3,385	52	20,947	45	1,548	29
Crawford River	11,926	15	271	4	6,394	14	991	18
Bombah Broadwater	12,095	15	617	9	5,467	12	870	16
Boolambayte Creek	11,131	14	451	7	5,140	11	300	6
Myall Lake	7,771	10	740	11	4,546	10	545	10
Lower Myall River *	11,615	15	1,040	16	3,667	8	1,106	21
Total	78,494	100	6,504	100	46,161	100	5,360	100

Source: Great Lakes Council (2009)
TSS = total suspended solids; TN = total nitrogen; TP = total phosphorus

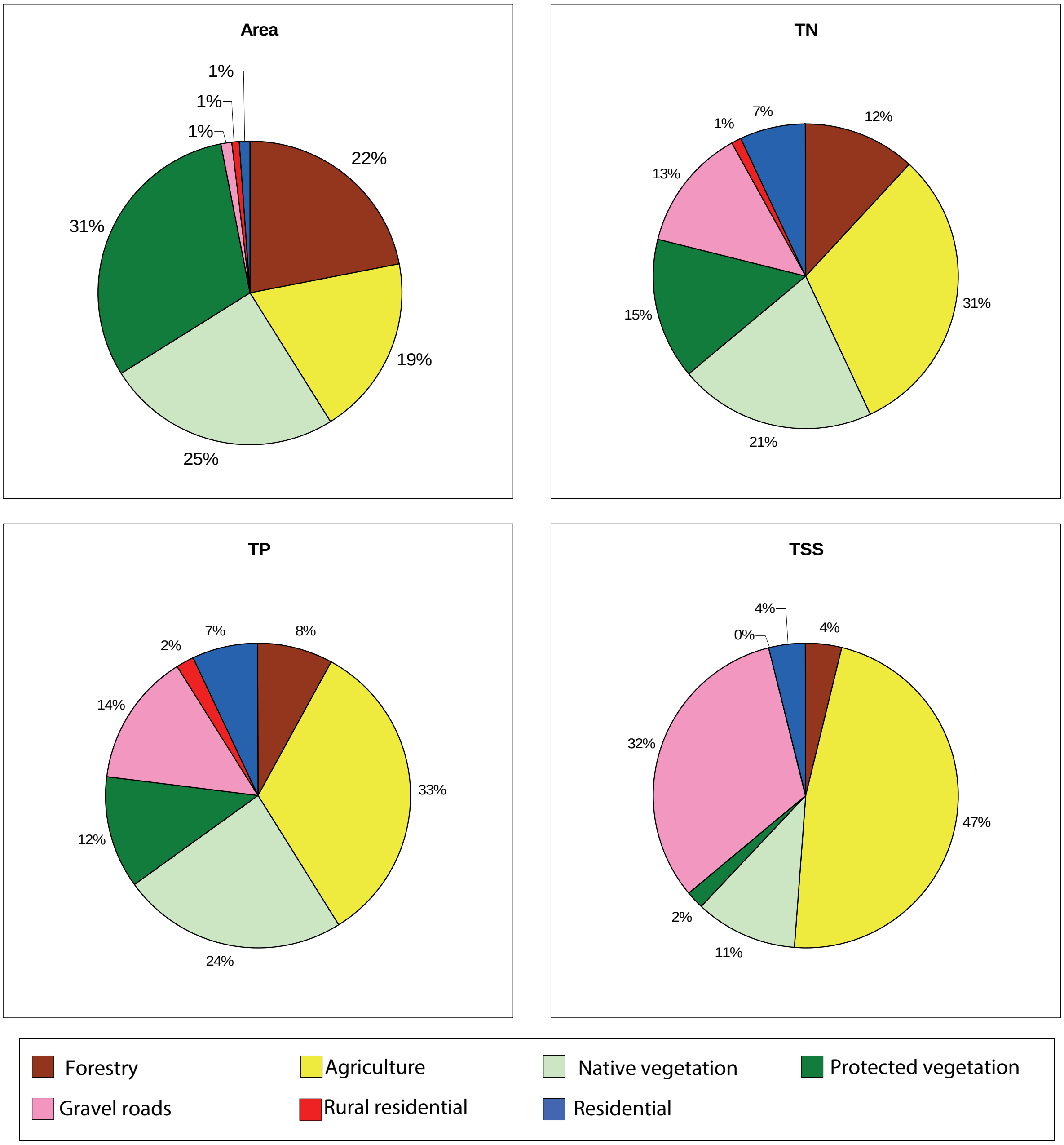
* **Note:** Catchment runoff into the lower Myall River has only a minor influence on Bombah Broadwater, due to limited tidal influence in Bombah Broadwater and therefore limited exchange between the lower Myall River and Bombah Broadwater. As a result the export of sediments and nutrients from the lower Myall River subcatchment has little influence on the levels of those pollutants in Bombah Broadwater.

Sediment organic matter

The organic matter in the sediments of the lakes is derived from mixed sources that include terrestrial material and phytoplankton. Phosphorus is largely adsorbed on the sediments while nitrogen is available in sediments and dissolved in the water column. The release of nitrogen from the sediments and nutrient enrichment of the water column can fuel algal blooms (Palmer et al. 2000).

The levels of total organic carbon (TOC), total phosphorus (TP) and total nitrogen (TN) in the sediments of the lakes were measured in 2001–02 as part of a study into the causes of blue–green algae blooms in the Myall lakes. The study found that the concentration of TN in sediments was highly correlated with TOC, and that the distribution of TN ‘mirrors’ the distribution of TOC. TOC and TN were highest in Myall Lake and Boolambayte Lake, with concentrations as high as 30 gN/kg in those two lakes (except in sandy areas which were less than 5 gN/kg), whereas sediments from the Broadwater and the upper Myall River contained less than 10 gN/kg (Dasey et al. 2004).

In contrast to TN, the concentration of phosphorus in benthic material was poorly correlated with sediment TOC, and the concentrations of TP were similar throughout the lake system. The highest concentrations of TP were generally found in the deeper parts of each lake system (>1 gP/kg dry sediment), whereas the lowest concentrations were found in shallow sandy areas (<0.01 gP/kg dry sediment). There was considerable variability in the concentrations of TP found in similar areas, with the concentration of TP ranging from 0.26 gP/kg to 0.82 gP/kg in two nearby locations in Myall Lake of similar depth (Dasey et al. 2004).



Source: Great Lakes Council (2009)
Land uses are based on Australian Land Use and Management (ALUM) classification (Bureau of Rural Sciences 2006).

Figure 16 Relative contributions of land uses to pollutants and sediments in the Myall lakes catchment

3.4.3 Nutrients

Nutrient input modelling

Field sampling undertaken as part of the CCI studies showed a distinct trend in the concentration of TN and TP in runoff associated with the level of land development (Great Lakes Council 2009). Specifically, runoff from forested areas had relatively smaller TN and TP than runoff from agricultural or urban areas. The dominant form of nitrogen in all areas was delivered as dissolved organic nitrogen (DON) (Great Lakes Council 2009). This reflects the large proportion of forest (~89%) in the upland contributing areas of the sampling locations.

TN in the Myall lakes is present in very high concentrations in the water column and appears to be relatively stable (Great Lakes Council 2009). This nitrogen is, however, mainly in the form of tannins and is not available to stimulate algal growth. In contrast to other nearby coastal lake systems, it is considered that chlorophyll-a concentrations in the Myall lakes are related to total phosphorus rather than total nitrogen (Great Lakes Council 2009).

Overall, agricultural lands are the largest source of nutrient loads, contributing 31% of TN and 33% of TP to the lakes (Figure 16) (Great Lakes Council 2009). Other major sources of nutrients are native vegetation, protected vegetation, gravel roads and residential (urban) areas, although native and protected vegetation contributed proportionally less nutrients than other land uses (Figure 16) (Great Lakes Council 2009). While the contribution of nutrients from urban areas is small – 7% of TN and 7% of TP – it is proportionally large considering the very small area (1%) of urban areas in the lakes' catchment.

Of particular interest however, is the greater proportion of DON in runoff samples collected from fully forested areas, and the progressive increase in the concentration of dissolved inorganic nitrogen (DIN) in runoff samples as the upland contributing area becomes more developed. Dissolved inorganic phosphorus (DIP) concentrations in runoff also progressively increase with land development. DIN and DIP are regarded as most bio-available to primary production and therefore the most likely contributors to algal blooms. Runoff samples collected adjacent to poultry farms or to areas that stockpile chicken litter or to industrial sites had the greatest concentrations of DIN and DIP. In contrast, the dominant form of phosphorus in runoff from forested areas was particulate phosphorus (Great Lakes Council 2009).

The average annual nutrient loads to the Myall lakes are predominantly related to the subcatchment area. The largest subcatchment, the upper Myall River (occupying 46% of the Myall lakes catchment) contributed the largest annual loads, followed by the Bombah Broadwater subcatchment (15% of catchment), and then by the Boolambayte Creek subcatchment (14% of catchment) (Table 4). The models used in the CCI studies estimated that for an average runoff volume of 4963.9 ML from the Bombah Broadwater subcatchment, the average nutrient loads were 12.6 kg/km^2 for TN and 2.2 kg/km^2 for TP (Great Lakes Council 2009).

Water column nutrients

Overall, the dynamics of nutrients in the Myall lakes is not well understood but it is apparently not typical of most estuarine systems in eastern Australia. The lakes' nutrient dynamics include high concentrations of organic nitrogen and occasionally very high concentrations of DIN.

Nutrient concentrations in the Myall lakes were sampled intensively between January 2000 and October 2002 (Dasey et al. 2004). For both TP and soluble reactive phosphorus, there is a concentration gradient from the lower Myall River mouth (~0.05 mg TP/L) to Myall Lake (~0.01 mg TP/L). This is what would be expected with the higher values in the parts of the system most affected by the runoff from the main catchment, the upper Myall River.

TN concentrations displayed the opposite pattern with the highest values (~0.9 g TN/L) in Myall Lake and lower values (~0.6 mg TN/L) at the lower Myall River mouth. Much of the difference can be attributed to very high concentrations of DON in Myall Lake. It is not known why this is, but it is likely that the high DON concentration is associated with the charophytes and gyttja in this lake (Dasey et al. 2004).

As with most NSW estuaries there is little relationship between ambient nutrient concentrations and algal abundances in the data for the Myall lakes (Scanes et al. 2007). Chlorophyll-a should be used as a proxy for phytoplankton and the risk of algal bloom.

Sediment nutrient concentrations and fluxes

Sediments play a major role in recycling nutrients (especially nitrogen), maintaining water column production and possibly sustaining algal blooms in Bombah Broadwater (Palmer et al. 2000). Sediment deposition is an important mechanism of nutrient delivery to the Myall Lakes, especially for phosphorus, and the sediments play important roles in nutrient retention and transformation within the system. Sedimentation, associated with catchment runoff, is an important source of both nitrogen (mainly linked to organic matter) and phosphorus (associated with organic matter and fine-grained clay materials) for the lakes (Dasey et al. 2004).

When organic matter in sediments is decomposed by microbes the nutrients build up in the water between grains of sediment. These nutrients are then able to diffuse through the sediment to the overlying waters. This flux of nutrients from sediment to water can, under certain circumstances, be very large, approaching the same annual amount as the loads that enter the lakes from the catchment. It must be recognised, however, that these loads from sediments are recycled and all 'new' nutrients to drive increased production – and algal blooms – come from the catchment.

Benthic microalgae on the sediment surface play an extremely important role in regulation of the transfer of nutrients from sediments to overlying water. Clear waters facilitate photosynthesis by benthic algae and thus interception of nutrients. If waters become turbid, the interception of nutrients is less effective allowing relatively greater amounts of nutrients into the water column to support and fuel algal growth.

3.5 Gyttja community of cyanobacteria

Some of the Myall lakes support the only known occurrence in Australia of gyttja – a natural sediment layer derived from the decomposition of charophytes, macrophytes, cyanobacteria and algae. Gyttja is a distinctive green–brown organic-rich sediment that is found in a small number of lakes worldwide, and has sometimes been associated with eutrophication (Lowe and Walker 1997; Rukminasari et al. 2004). The gyttja found in the Myall lakes is believed to be very important in structuring and maintaining the characteristic submerged aquatic vegetation of the lakes, and appears to be unique in Australia (Dasey et al. 2004, 2005).

Gyttja is ubiquitous throughout Myall Lake, Boolambayte Lake and to a lesser extent Two Mile Lake, but is not found in Bombah Broadwater (Figure 17) (Dasey et al. 2004). The reason that gyttja is absent from Bombah Broadwater is not clear; however, the higher turbidity of Bombah Broadwater compared to the other lakes results in macrophytes (a major source of gyttja) being restricted to the shallower margins of the lake, and higher nutrient levels in the lake can reduce macrophyte abundance (Dasey et al. 2004).

The gyttja layer appears to inhibit the colonisation of the lakes' floors by rooted macrophytes such as *Vallisneria* and *Potamogeton* species; however, charophytes and *Najas marina* are able to support themselves on top of the gyttja (Dasey et al. 2004). Extensive areas of gyttja, described as 'an uncompacted, anoxic and sulphurous 'ooze' were reported to be present in parts of the upper Myall lakes in 2001–02 (Dasey et al. 2004, 2005) (Table 5). In 2001–02 the extent of 'concentrated'[8] gyttja in Myall Lake was about 20%, with 'less concentrated' gyttja occupying the remaining 80% of the lake;

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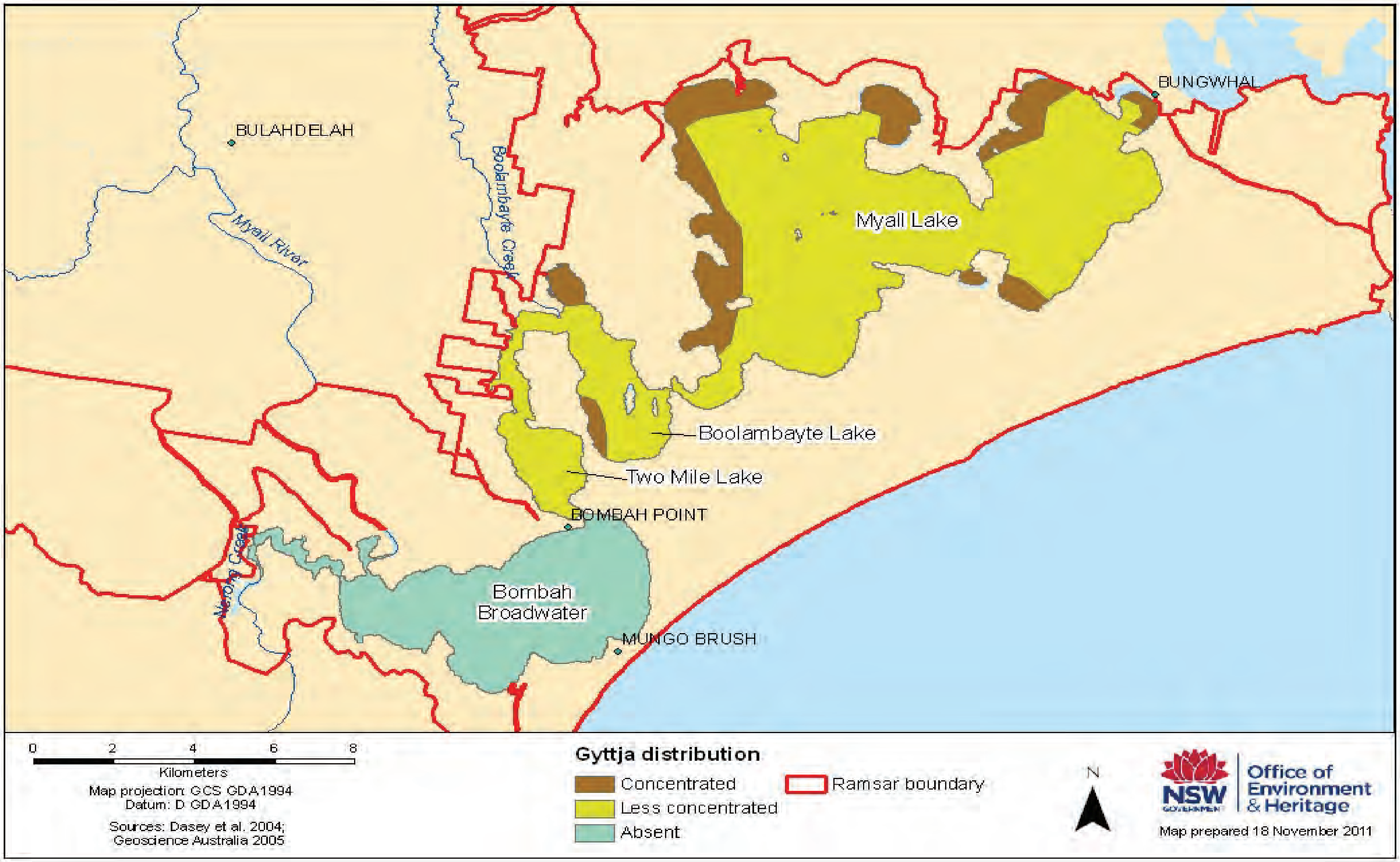
[8] The terms 'concentrated' and 'less concentrated' were not defined in Dasey et al. (2004).



Source: Dasey et al. (2004)

Figure 17 **Gyttja distribution**

Table 5 Extent of gyttja distribution in the Myall lakes, 2001–02

Lake	Area of lake (ha)	Extent of concentrated gyttja		Extent of less concentrated gyttja		Extent where gyttja is absent	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Myall Lake	6394	1247	19.5	5146	80.5	0	0
Boolambayte Lake (including Two Mile Lake)	1372	143	10.4	1229	89.6	0	0
Bombah Broadwater	2412	0	0	0	0	2412	100
Totals	**10,178**	**1390**	**13.%**	**6375**	**62.%**	**2412**	**23.%**

Source: Dasey et al. (2004)
Area of lakes and gyttja extent were derived from GIS data.

Boolambayte Lake had about 10% of concentrated gyttja and 90% of less concentratred gyttja (Dasey et al. 2004). The toxic cyanobacterial blooms that dominated the lower Myall lakes system in 1999 and 2000 did not impact the lakes where gyttja is abundant.

Gyttja is up to 70 cm thick in places and forms an integral part of the aquatic ecosystem of the Myall lakes (Figure 18) (Dasey et al. 2004). The relative contributions of charophytes and macrophytes

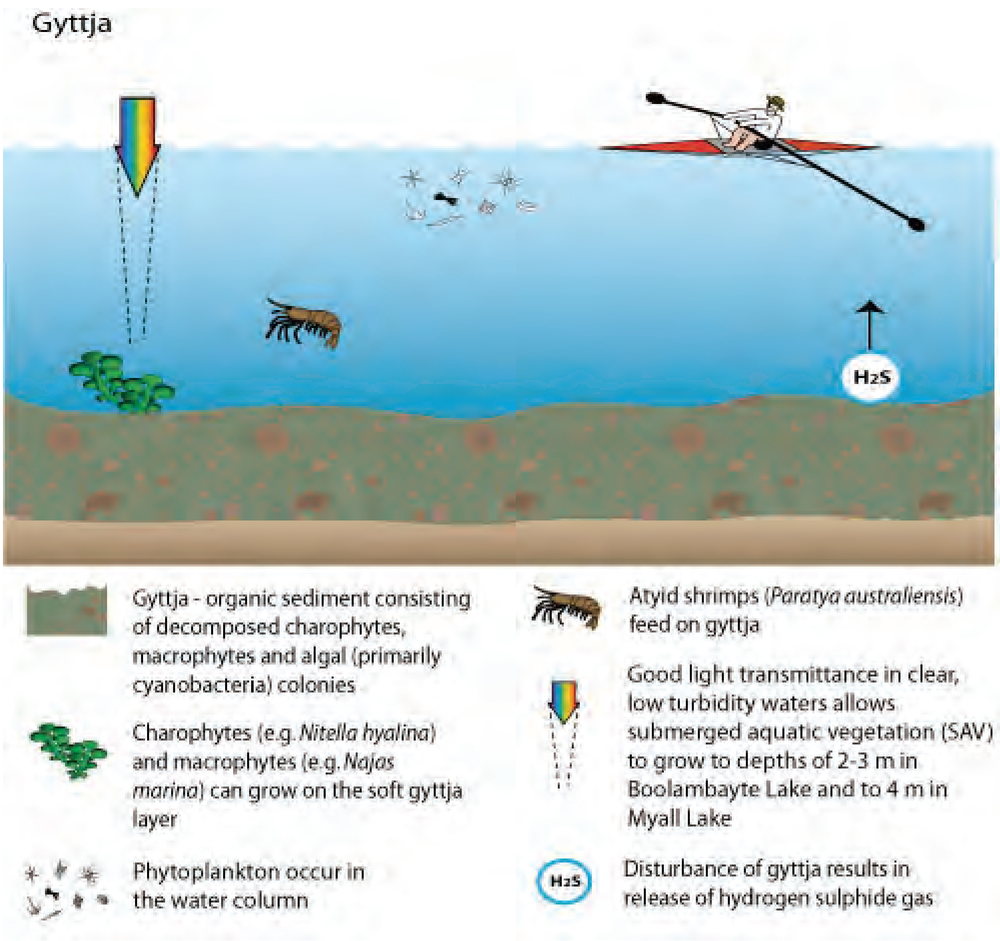


Figure 18 Formation and characteristics of gyttja in Myall Lake, Two Mile Lake and Boolambayte Lake

(*Najas*) is still being debated but it is clear that the continued existence of gyttja depends on seasonal decay of large macrophyte and charophyte biomasses (Dasey et al. 2004). In shallow water sections and during summer blooms, benthic cyanobacteria are abundant in the gyttja, but in deeper waters there is a greater proportion of charophytes (Matt Dasey 2008, pers. comm.). There is a mix of cyanobacteria species in the gyttja, with most species from the order Chroococcales, with two forms of the genus *Aphanothece* being dominant (Dasey et al. 2005).

The gyttja layer has been estimated to have been deposited as recently as around 240 years ago (Flett 2003; Drew et al. 2008). However, other studies have indicated that the gyttja layer commenced being deposited between 580 and 1180 years ago (Skilbeck et al. 2005, cited in Drew et al. 2008; Dick 2000).

3.6 Plants

This ECD includes information on the phytoplankton, submerged aquatic vegetation (SAV), emergent vegetation and terrestrial plant communities in the Ramsar site. The extent of SAV and the extent of saltmarsh and mangroves have been mapped (Williams et al. 2006; Dasey et al. 2004). However, maps of the distribution of emergent and terrestrial vegetation communities in Myall Lakes National Park have been made for only a few localised areas in the site, and have been prepared at differing scales and using differing criteria for classification. There is no standardised map of all the vegetation types for the Ramsar site. This is a knowledge gap.

The best available information for terrestrial vegetation communities is in Keith (2004). The vegetation formations and classes identified by Keith (2004) are generalised and broad in nature as they cover the whole of NSW, and therefore do not detail all the vegetation communities in the Ramsar site. Other information on vegetation has been used for some areas where it is available, for example the descriptions by Myerscough and Carolin (1986) have been used for the freshwater wetland communities on The Moors (Table 8).

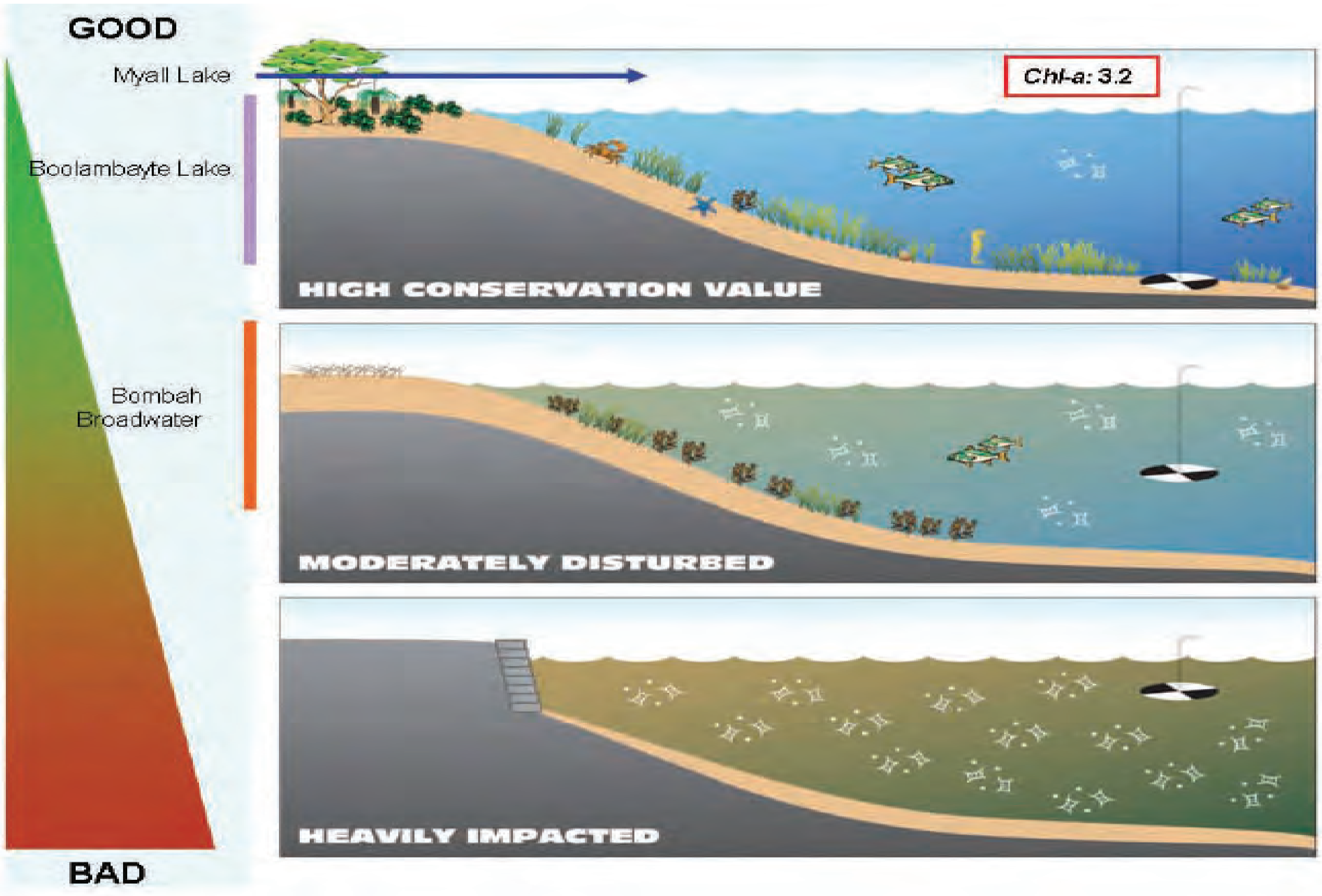
Using the maps in Keith (2004) it was concluded that there are 17 native vegetation classes (excluding SAV) in Myall Lakes Ramsar site (Table 10). There are also small areas of pine plantation within the site as well as some other areas dominated by exotic weeds.

3.6.1 Phytoplankton

As a whole, the phytoplankton of Australia is poorly known. There were no data and information on phytoplankton distribution and abundance in Myall Lakes Ramsar site prior to 1999. In 2000, in response to the presence of a toxic blue–green algal bloom in Bombah Broadwater, a study to investigate the spatial and temporal distribution of phytoplankton and other aspects of the ecology of the Myall lakes was carried out (Dasey et al. 2004). As phytoplankton assemblages are acknowledged to be very dynamic in space and time, the information presented below represents the situation in 2000–02.

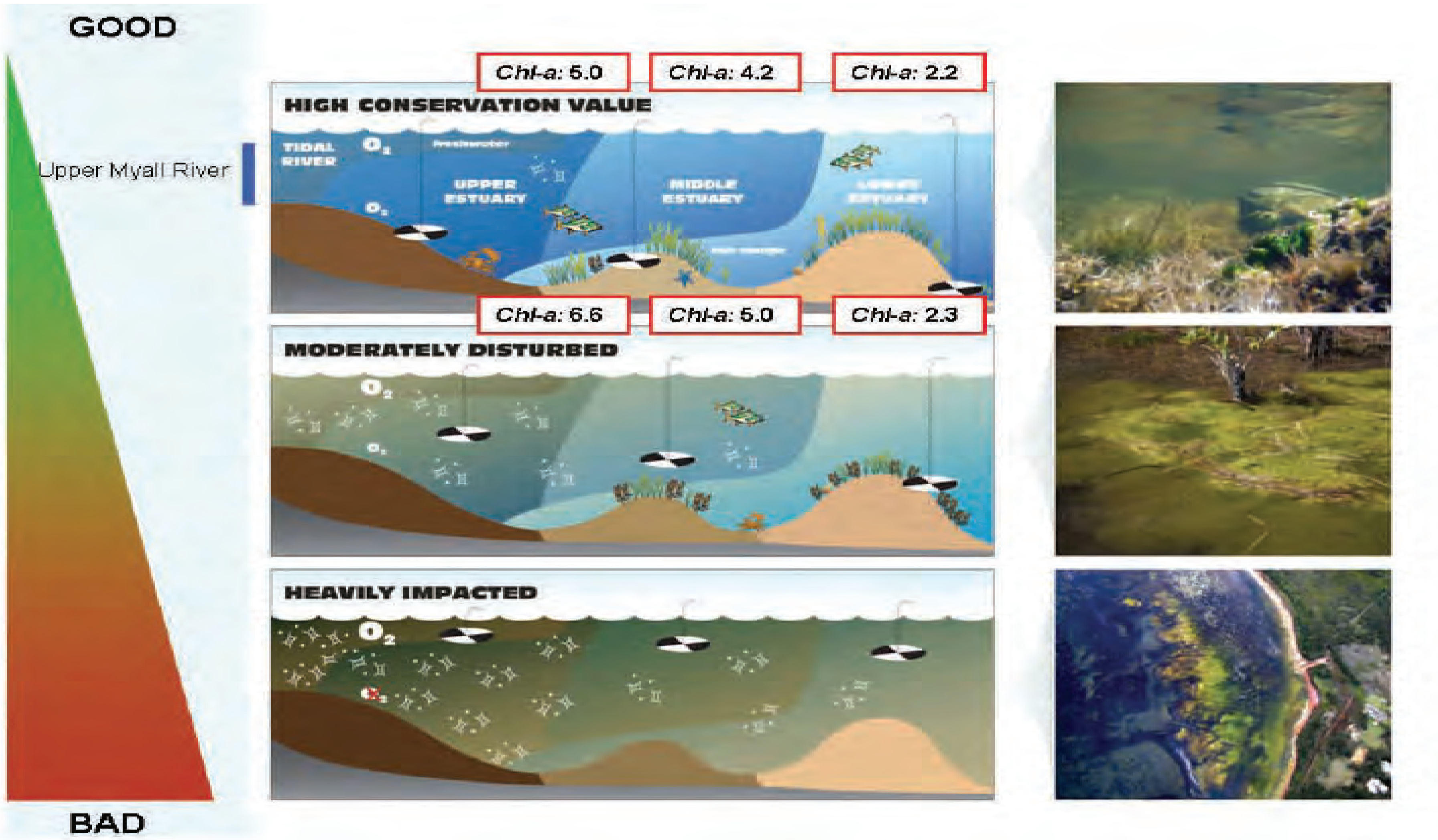
Measurement of the plant pigment chlorophyll-a is an accepted method of monitoring the total abundance of phytoplankton in water. Chlorophyll-a is an indicator of algal biomass, but may overestimate biomass during rapid growth phases. In addition, chlorophyll-a measurements tended to underreport the relatively large biovolume of very small cyanobacteria found in Myall Lake.

Chlorophyll-a has been monitored in the Myall lakes since 1999, and the data on chlorophyll-a levels for 1999–2007 was used in the Water Quality Improvement Plan (Great Lakes Council 2009). This plan sets targets for chlorophyll-a for lakes classified as high conservation value (e.g. Myall Lake and Boolambayte Lake, Figure 19), and for lakes and waters classified as moderately disturbed (e.g. Bombah Broadwater and the Myall River, Figure 20) (Great Lakes Council 2009). The overall mean concentrations of chlorophyll-a for 1999–2007 were 3.5 µg/L for Bombah Broadwater, 2.5 µg/L for Two Mile/Boolambayte Lake and 2.9 µg/L for Myall Lake (Figures 19 and 20). The long-term mean chlorophyll-a concentration for Bombah Broadwater was greater than the targets (3 µg/L) set in the Water Quality Improvement Plan (Great Lakes Council 2009).



Source: Great Lakes Council 2009

Figure 19 Ecological condition of Myall Lake, Boolambayte Lake and Bombah Broadwater (based on data collected 1999–2007), showing indicative level of chlorophyll-a for high conservation value lakes



Source: Great Lakes Council 2009

Figure 20 Ecological condition of upper Myall River estuary (based on data collected 1999–2007), showing levels of chlorophyll-a for high conservation value and slightly to moderately disturbed reaches of Myall River

Cyanobacteria (blue–green algae)

In 1999 and 2000, a large algal bloom dominated by the potentially toxic genera *Anabaena* and *Microcystis* occurred in the Ramsar site. The bloom was primarily confined to Bombah Broadwater, with some occurrences in Two Mile Lake. Cyanobacteria are commonly referred to as blue-green algae, which is the term used in this document.

It appears that, for a toxic blue-green algae bloom to form in the lakes, several factors need to occur at the same time (Dasey et al. 2004):

- freshwater inflows (floods) from the upper Myall River which are large enough to displace saline water in Bombah Broadwater and resulting in salinity levels lower than 1 ppt
- turbid water which gives toxic blue–green algae a competitive advantage over other phytoplankton species
- high levels of nutrients to fuel algal growth (including those delivered by flooding and potentially those released from sediments).

These factors were confirmed by the formation of the blooms in 1999–2000 when, after heavy rain and high inflow to the lakes, there were large nutrient inputs from the catchment, and salinity remained below 1 ppt for a prolonged period (Dasey et al. 2004).

During the 1999–2000 bloom there were high algal biovolumes (>2 mm^3/L) in all lakes, although the dominant taxa were different (Dasey et al. 2004). Toxic genera, such as *Anabaena* and *Microcystis*, were generally restricted to Bombah Broadwater and mid-lakes, while smaller-celled species, such as *Chroococcus*, dominated in Myall Lake. Inter-annual variability in the blue-–reen algal community was obvious, and was related to the distinct wet and dry cycles. There was an observed correlation between the occurrences of toxic blue–green algal bloom and low salinity. The salinity level above which blue–green algal blooms are unlikely is 1 ppt (equivalent to 2 mS/cm) (Ryan 2002).

Blue–green algal species richness was higher in the mid-lakes and Myall Lake compared to Bombah Broadwater. Myall Lake was mainly dominated by the freshwater algal community, but had some representatives of marine and brackish taxa. In contrast, the algal community in Bombah Broadwater was composed of a mixture of freshwater and marine species, depending on the salinity status at the time. It is also clear that Myall Lake has high green and blue–green phytoplankton richness with a continuing spring bloom of small-celled blue–green algae and green algae (Dasey et al. 2004).

There was a small algal bloom in 2005 affecting a lesser area than in 1999–2000, but no monitoring data are available to confirm salinity at the time. A small bloom occurred in 2008 when salinity was less than 1 ppt, which was broken down when salinity rose above 1 ppt (Peter Scanes 2010, pers. comm.).

The Hunter Regional Algal Coordinating Committee has prepared a contingency plan for guiding responses to marine and freshwater algal blooms, including blue–green algal blooms in fresh or brackish waters (Ryan 2008). The plan includes alerts and trigger levels for concentrations of potentially toxic cyanobacteria, including an alert and a trigger level at which recreational use of waters should be restricted. The 'red alert', at which recreational use of waters should not occur, is activated when any of the following triggers are reached:

- $\geq$10 µg L^{-1} of total microcystins
- $\geq$50,000 cells ml^{-1} of *Microcystis aeruginosa*
- biovolume equivalent of $\geq$4mm^3 L^{-1} for combined total of cyanbacteria where toxigenic taxa are dominant
- total biovolume of all cyanobacteria material in excess of 10mm^3 L^{-1}
- cyanobacterial scums consistently present.

Diatoms

The general spatial trend of diatoms was that the richness decreased from the upper Myall River mouth to Myall Lake. The dominant diatom in the river mouth, Bombah Broadwater and mid-lakes was *Thalassiosira*, a marine genus. This diatom occurred in smaller numbers in Myall Lake where the population was dominated by the freshwater diatom *Synedra* (Dasey et al. 2004).

Green algae

Green algae richness was highest in Myall Lake. *Oocystis*, a freshwater green alga, was the dominant genus. Species richness of green algae was similar in Bombah Broadwater and middle lakes and was dominated by the marine green alga, *Carteria*, in the river mouth and freshwater green alga, *Crucigenia*, in Bombah Broadwater and the mid lakes (Dasey et al. 2004).

Dinoflagellates

Bombah Broadwater experienced the highest richness of dinoflagellates with the genera observed mainly found in marine or brackish/marine habitats (for example *Gymnodinium*). The richness decreased with distance from the marine inflows, and Myall Lake contained a mixture of freshwater and marine dinoflagellates, dominated by the freshwater alga *Peridinium* (Dasey et al. 2004).

Benthic micro-algae

The presence of a healthy benthic micro-algal community on the surface of the lake-floor sediments is considered essential to maintaining a healthy balance between nutrient flux from sediments and abundances of water column algae. Reduced light penetration due to turbid waters threatens the efficiency of benthic algae and therefore encourages excessive algal growth (Dasey et al. 2004).

3.6.2 Submerged aquatic vegetation

SAV includes macrophytes, macroalgae, charophytes and sea grasses. It is the fundamental driver of many aspects of the ecology of the Myall lakes. It supports many of the aquatic and avian food webs, provides shelter and nursery grounds for vertebrate and invertebrate aquatic species, and is the basis of gyttja.

SAV assemblages are very dynamic in space and time, and the information presented below describes the SAV in 2000–02 as reported in Dasey et al. (2004) which contains a full summary of available information on the distribution of SAV species and temporal variation. Table 6 summarises the dominant SAV taxa in Myall Lakes Ramsar site at that time.

The SAV community of Myall Lakes Ramsar site reflects the different salinities in the lakes system, with marine seagrasses found in the region with higher salinities, and freshwater macrophyte and algal species found in the freshwater sections. Seagrass distribution is discussed in detail in section 3.6.8.

In Bombah Broadwater the SAV is dominated by *Ruppia megacarpa*, especially along the eastern shore. A mosaic of *R. megacarpa*, *Vallisneria gigantea* and charophytes flourishes along the northern shore. Typically, *Ruppia* spp. can be found in wide-ranging salinities from hypersaline (70,000 ppm) to brackish, and even freshwater (Sainty and Jacobs 1981, 2003). There were approximately 710 ha of *Ruppia* in Bombah Broadwater and Two Mile Lake in 2001 (Dasey et al. 2004). *Vallisneria gigantea* is a fresh to brackish water plant that grows in water with up to 1,500 ppm dissolved salts (Sainty and Jacobs 1981, 2003). *Potamogeton perfoliatus* was not found in Bombah Broadwater in 2001 but was reasonably abundant in 2002 (Dasey et al. 2004).

In Two Mile Lake, the salinity is brackish to freshwater and the SAV community is dominated by *Myriophyllum salsugineum* (milfoil) a freshwater plant, and the fresh to brackish water plants *Vallisneria gigantea* (ribbonweed), *Ruppia* spp. and *Najas marina* (prickly water nymph) (Dasey et al. 2004).

In Boolambayte Lake and Myall Lake, the water is dominated by freshwater plants: charophytes in the shore regions during winter and spring, and *Najas marina* in the deeper water regions during summer and autumn. There is also a small shoreline border of *Myriophyllum, Vallisneria* and *Ruppia* in solid sediments where gyttja is absent (Dasey et al. 2004).

Table 6 Submerged aquatic vegetation in the Myall lakes, 2000–02

Taxon	Life form	Occurrence
Vallisneria gigantea	Perennial – Angiosperm	Confined to shallow areas of Bombah Broadwater and Two Mile Lake and fringes of Boolambayte and Myall lakes.
Ruppia megacarpa	Perennial – Angiosperm	Confined to shallow areas of Bombah Broadwater and Two Mile Lake and fringes of other areas. Significant recruitment in deeper areas of Broadwater during 2001.
Potamogeton perfoliatus	Perennial – Angiosperm	Colonised bare shallow areas in Bombah Broadwater.
Myriophyllum salsugineum	Perennial – Angiosperm	Present in all lakes except Bombah Broadwater.
Najas marina	Annual – Angiosperm	Present in all lakes and in greater abundance in summer and autumn in Myall Lake.
Charophytes: *Nitella hyaline, Chara* spp.	Ephemeral – green algae	Present in all lakes, and in greater abundance in spring and winter in Myall Lake.
Macroalgal assemblage	Ephemeral – various algae	Present only in Bombah Broadwater on otherwise bare sediment and in conjunction with macrophytes.
*Zostera capricorni**	Perennial seagrass	Lower Myall River, Fame Cove, Corrie Island.
Halophila spp.*	Perennial seagrass	Port Stephens near the entrance of the lower Myall River.
*Posidonia australis**	Perennial seagrass	Port Stephens near the entrance of the lower Myall River, Corrie Island.

Sources: Dasey et al. (2004); * MHL (1999); Williams et al. (2006)

Table 7 Extent of submerged aquatic vegetation cover during 2001–02 for all lakes

Taxon	Area of cover (ha)			
	Spring	Summer	Autumn	Winter
Vallisneria gigantea	377	377	377	377
Ruppia megacarpa	710	710	710	710
Myriophyllum salsugineum	140	140	140	140
Potamogeton perfoliatus	0	191	382	568
Charophytes	2,310	4,159	4,159	2,186
Najas marina	1,412	5,443	5,443	526
Macroalgal assemblage	210	210	210	210

Source: Dasey et al. (2004)

Seasonal changes in SAV distribution and abundance in the lakes were reported by Dasey et al. (2004) for 2001–02. Table 7 is a summary of the seasonal differences in SAV coverage. Inter-annual variability in the distribution of SAV in the lakes is unknown and represents a knowledge gap.

There are no known established infestations of introduced water weeds, but both salvinia (*Salvinia molesta*) and parrot's feather (*Myriophyllum aquaticum*) are known to occur in the catchment. Salvinia has reached the lakes once but was successfully removed, and parrot's feather has been observed in the upper Myall River and Bombah Broadwater (Fiona Miller 2010, pers. comm.).

3.6.3 Emergent vegetation

The emergent vegetation of the freshwater wetlands in the Ramsar site is dominated by broad-leaved cumbungi (*Typha* spp.), common reedgrass (*Phragmites australis*), sedge (*Cladium procerum*), leptocarpus (*Leptocarpus tenax*) and scirpus (*Scirpus litoralis*) (Great Lakes Council 2009). Emergent vegetation grows in the shallow waters of the margins of Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater and in the freshwater lagoons in The Moors.

3.6.4 Freshwater fringing vegetation

The main fringing wetlands vegetation classes found in the Ramsar site are coastal swamp forests and coastal freshwater lagoons (Keith 2004) (Table 9). The coastal swamp forest class (called fringe forest in Myerscough and Carolin 1986) is located mainly on soils derived from lake sediments and is dominated by swamp she-oak (*Casuarina glauca*) and broad-leaved paperbark (*Melaleuca quinquenervia*).

The vegetation along the fringe of the freshwater lakes is also dominated by broad-leaved paperbark (*Melaleuca quinquinervia*) and swamp she-oak (*Casuarina glauca*); however, it forms a community distinct from the coastal swamp forests described in Keith (2004) (Baumann 2008). The *Melaleuca-Casuarina* fringe forest occurs on the slightly higher sandy soils of the lake margin and is dominated by large, older paperbarks with broad spreading canopies, whereas the coastal swamp forest tends to be at lower elevations with more densely grouped trees (Baumann 2008). The fringe forest community forms a narrow ecological zone and is adapted to changes in inundation, salinity and other factors resulting from varying lake levels (Baumann 2008). The fringe forest community is largely intact at the Myall lakes, and has a limited distribution in other NSW coastal lakes (Martin 2002).

Freshwater fringing vegetation dominated by swamp she-oak (*Casuarina glauca*) and broad-leaved paperbark (*Melaleuca quinquenervia*) also grows along the lower Myall River in areas subject to inundation by freshwater following high rainfall (Fiona Miller 2010, pers. comm.). This vegetation community is similar in floristic composition to the fringe *Melaleuca-Casuarina* forest around the lakes; however, it has not been mapped or described in detail. The descriptions of fringe forest in Myerscough and Carolin (1986) and Baumann (2008), although used for describing the vegetation on the lake fringes, is a guide to the fringing vegetation along the lower Myall River. The major species in the fringing vegetation along the river include *Melaleuca quinquenervia, Casuarina glauca, Baumea juncea, B. articulata* and *Cladium procerum* (Myerscough and Carolin 1986).

The distribution of freshwater fringing vegetation in the Ramsar site is a knowledge gap.

3.6.5 Wet heaths

Large areas of freshwater wetlands, The Moors, are located in the area between Bombah Broadwater and Myall Lake, as well as the area between the upper Myall River and the northern shore of Bombah Broadwater, and along both sides of the lower Myall River downstream of Bombah Broadwater (Figure 5). The freshwater wetlands on The Moors, an area which corresponds approximately with the Eurunderee sand mass (characterised by soils derived from Pleistocene sands), consist of several vegetation communities, principally dry heath forest, wet heath forest, swamp forest, swamp, dry heath and wet heath (Myerscough and Carolin 1986), and mostly correspond to coastal heath swamps in Keith (2004).

Vegetation on the Eurunderee sand mass exhibits a high level of variation both structurally and floristically as a result of the range of soil conditions, including the degree of soil nutrient enrichment and drainage (Myerscough and Carolin 1986). Drainage appears to be the most important factor determining the location of vegetation communities across the low-lying parts of the Eurunderee sand mass, with vegetation changing from dry heath forest or dry heath, wet heath, to swamp or swamp forest as the ground surface changes from freely drained ridges towards the water table (Myerscough and Carolin 1986). Vegetation communities in freshwater wetlands across the Eurunderee sand mass and their dominant plant species are shown in Table 8.

Table 8 Vegetation communities of freshwater wetlands on The Moors

Vegetation community [1]	Dominant species [1]	Equivalent vegetation class [2]
Dry heath forest	*Eucalyptus pilularis, Angophora costata, Corymbia gummifera, Melaleuca quinquenervia* *Dillwynia retorta, Dillwynia glaberrima, Calytrix tetragona, Kunzea capitata, Leptospermum attenuatum, Melaleuca nodosa*	North Coast Dry Sclerophyll Forests Wallum Sand Heaths
Wet heath forest	*Angophora costata, Eucalyptus robusta, Melaleuca quinquenervia*	Coastal Floodplain Wetlands
Swamp forest	*Melaleuca quinquenervia, Eucalyptus robusta*	Coastal Swamp Forests
Swamp	*Melaleuca quinquenervia, Banksia robur, Schoenus brevifolius, Lepyrodia muelleri, Baumea rubiginosa, Restio complanatus, Utricularia* spp.	Coastal Heath Swamps
Dry heath	Stunted specimens of *Corymbia gummifera* and *Angophora costata* *Dillwynia retorta, Dillwynia glaberrima, Calytrix tetragona, Kunzea capitata, Leptospermum attenuatum, Melaleuca nodosa*	North Coast Dry Sclerophyll Forests Wallum Sand Heaths
Wet heath	*Banksia oblongifolia, Hakea teretifolia, Xanthorrhoea fulva, Hakea teretifolia, Dillwynia floribunda, Leptospermum liversidgei, Leptospermum juniperinum*	Coastal Heath Swamps

[1] Myerscough and Carolin (1986)
[2] Keith (2004)

3.6.6 Vegetation associated with rivers, creeks and streams

The wetland flora of the rivers, creeks and streams is predominantly characterised by emergent rushes, coastal swamp forests and coastal floodplain wetlands.

Detailed information on the distribution and ecology of the riverine fringing vegetation in the Ramsar site is a knowledge gap.

3.6.7 Mangroves and saltmarshes

Mangroves and saltmarshes occur along the margins of the lower half of the lower Myall River and around Corrie Island. The two common NSW mangroves species (*Avicennia marina*, *Aegiceras corniculatum*) are present. Mangroves are common along the lower half of the lower Myall River and occur in isolated patches all the way to the confluence with Bombah Broadwater at Tamboy (Williams et al. 2006). The area of mangroves in the lower Myall River in 1985 was 102 ha, the area mapped in 2005 was 130 ha; this represents a gain of 28 ha of mangroves (Williams et al. 2006).

Saltmarsh occurs along the banks of the lower half of the lower Myall River, on Corrie Island and along the shores of Smiths Lake. There has been no census of saltmarsh species in the Ramsar site, but it is expected that many of the common species found on the NSW central coast would occur. These species are listed in Table 9, along with the possibility of their presence. Mangroves and saltmarshes are protected under the FM Act, and saltmarsh has been declared an endangered ecological community under the TSC Act (DECCW 2010a). The area of saltmarsh in the lower Myall River in 1985 was 178 ha, the area mapped in 2005 was 189 ha; this represents a gain of 11 ha of saltmarsh, which is not considered to be significantly greater than the measurement error (Williams et al. 2006).

Mangroves along the lower Myall River are important habitat for fish, crabs, birds and other animals. They provide large amounts of organic matter which is eaten by many small aquatic animals. In turn, these detritivores provide food for larger carnivorous fish and other animals. Mangroves also help maintain water quality by filtering silt from runoff and recycling nutrients.

Saltmarshes in the Ramsar site provide habitat for juvenile fish species such as bream and mullet. Crabs are common in saltmarsh communities, and are a significant food source for bream and other carnivorous species. Some species, such as *Galaxias maculatus*, deposit their eggs in saltmarsh vegetation.

3.6.8 Seagrasses

Seagrasses – *Zostera capricornia*, *Posidonia australis* and *Halophila* species – are found in the estuarine parts of the lower Myall River, Corrie Island and Fame Cove. *Zostera capricornia* and *Halophila* spp. are found along the lower Myall River to the confluence with Bombah Broadwater, and occasionally in Bombah Broadwater. *Posidonia australis* is confined to the more marine influenced areas around Corrie Island and the confluence of the Myall River and Port Stephens. Seagrasses are protected under the FM Act and are particularly valuable as nursery, feeding and shelter areas for many aquatic animals, including commercially and recreationally important fish, mollusc and crustacean species.

There has been an apparent decrease in area of seagrass between the 1980s and 2004, believed to be related to changes in the accuracy of mapping macrophytes (Scanes et al. 2010) (Figure 20). The area of seagrass in the lower Myall River apparently decreased from 273 ha in 1985 to 150 ha in 2004; the area of seagrass in the Myall lakes declined from 7.9 ha in 1985 to 2.6 ha in 2005 (Williams et al. 2006).

Table 9 Characteristic saltmarsh species on the NSW central coast

Family	Species	Likelihood
Chenopodiaceae	*Sarcocornia quinqueflora*	P
	Suaeda australis	P
Cyperaceae	*Baumea juncea*	M
Goodeniaceae	*Selliera radicans*	M
Juncaeae	*Juncus kraussii*	P
	Juncus acutus (introduced)	P
Juncaginaceae	*Triglochin striata*	P
Poaceae	*Phragmites australis*	P
	Sporobolus virginicus	P
Primulaceae	*Samolus repens*	P

Source: Kelleway et al. (2007); R. Williams (2008, pers. comm.)
P – species probably in the Ramsar site; M – species may be found in Ramsar site

In West et al. (1985) *Zostera* is shown to occupy the entire river channel from about Monkey Jacket to Bombah Broadwater, but in Williams et al. (2003) it is more accurately depicted as a very thin fringe along the river. Visual comparison of the beds shown downstream of Monkey Jacket suggests very little change in distribution, and therefore the difference is attributed to the accuracy of mapping (Scanes et al. 2010).

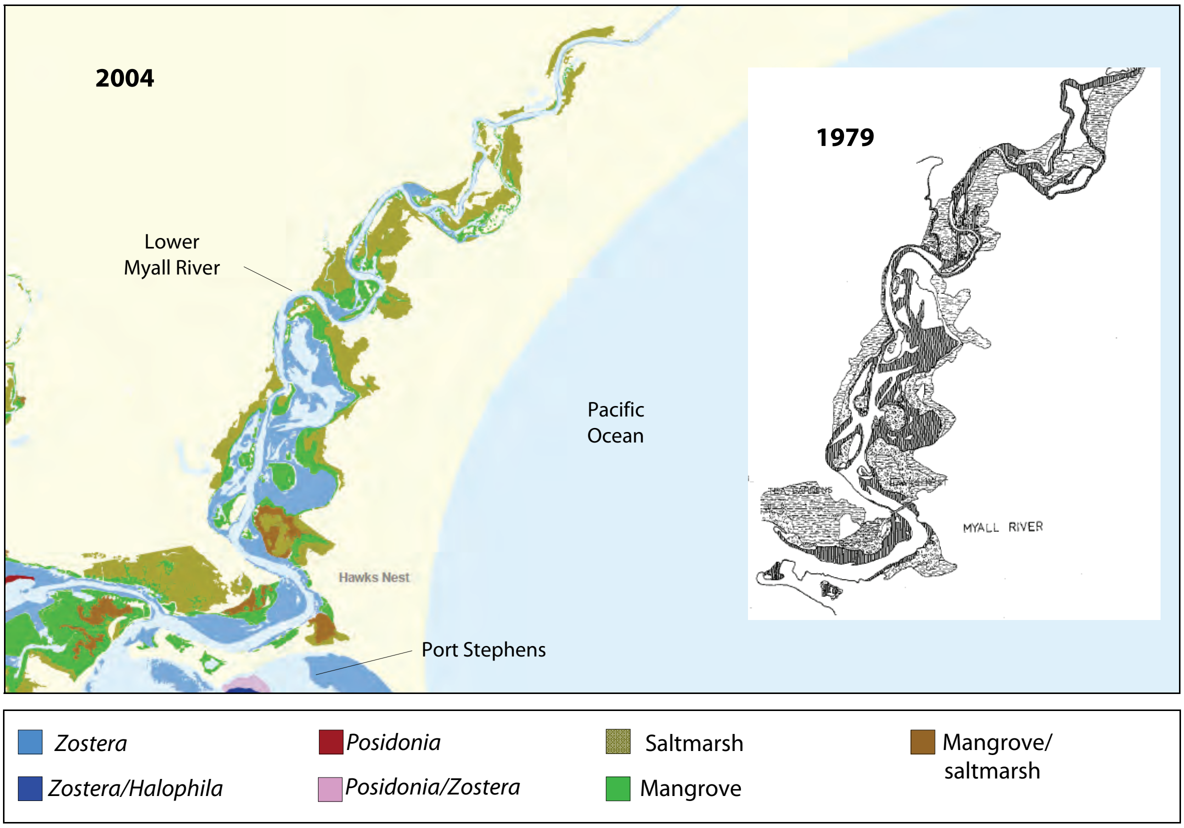
The distribution of seagrasses in the Ramsar site is now included in an updated atlas of estuarine macrophytes in NSW produced by the NSW Department of Primary Industries (DPI 2009).

The most recent observations suggest that the seagrass in the lower Myall River is dynamic, showing periods of stability and, at other times, of rapid change when the sandbanks in the river bed change. Despite this, it appears that most sediments of a suitable depth that are not actively shifting are colonised by seagrass (Scanes et al. 2010).

3.6.9 Marine coast vegetation

The marine coast is dominated by landforms such as beaches, dunes and rocky headlands. The primary terrestrial vegetation classes are maritime grasslands, coastal heaths and littoral rainforest (Table 10).

Marine intertidal vegetation is present on the rocky shores of the marine coast, and is entirely composed of marine algae. The marine algal assemblage of NSW rocky shores is well described and consists of many species of red, brown and green algae. It provides a valuable food resource for intertidal animals which, in turn, provide a food resource for a wide range of shorebirds and fish.



Sources: Creese et al. (2009) and West et al. (1985), cited in Scanes et al. (2010)
In 1979 the seagrasses Zosteraceae, indicated by the darker shading, are shown for the full width of the lower Myall River.

Figure 21 Comparison of macrophyte distributions in 2004 and 1979

Table 10 Emergent aquatic and terrestrial plant classes

Formation name	Class	Indicative species	Landscape position
Dry Sclerophyll Forests (Shrub/grass subformation)	Hunter–Macleay Dry Sclerophyll Forests	*Corymbia maculata, Eucalyptus moluccana, E. propinqua*	Covers large part of mainland Ramsar site including the coastal dunes, uplands and lake edges
Dry Sclerophyll Forests (Shrubby subformation)	North Coast Dry Sclerophyll Forests	*Eucalyptus pilularis, E. piperita, Angophora costata*	Northern part of mainland Ramsar site
	Sydney Coastal Dry Sclerophyll Forests	*Angophora costata, Corymbia gummifera*	Located around Port Stephens
Forested Wetlands	Coastal Floodplain Wetlands	*Angophora floribunda, A. subvelutina, Eucalyptus amplifolia, E. robusta, Melaleuca ericifolia, Alternanthera denticulata, Carex appressa*	Periodically inundated floodplain
	Coastal Swamp Forests	*Callistemon salignus, Eucalyptus robusta, Melaleuca quinquenervia, Banksia oblongifolia, Baumea arthrophylla*	Lake fringes
Freshwater Wetlands	Coastal Freshwater Lagoons	*Casuarina glauca, Utricularia australis, Villarsia exaltata*	Scattered around the margins of lakes and lagoons.
	Coastal Heath Swamps	*Banksia ericifolia, B. oblongifolia, B. robur, Bauera capitata, B. microphylla, Callistemon citrinus*	Restricted to poorly drained depressions associated with swales on coastal sand sheets or the headwater of creeks on coastal sandstone plateaus e.g. The Moors.
Grasslands	Maritime Grasslands	*Spinifex sericeus, Themeda australis, Sporobolus virginicus, Austrofestuca littoralis, Carpobrotus glaucescens, Canavalia rosea, Vigna marina*	Sand dunes and protected beaches in coastal areas and as tussocks among rocky outcrops
Grassy Woodlands	Coastal Valley Grassy Woodlands	*Angophora floribunda, Eucalyptus terreticonis, Desmodium varians, Dichondra laxiflora*	Coastal rain shadow valleys

Formation name	Class	Indicative species	Landscape position
Heathlands	Coastal Headland Heaths	*Leptospermum laevigatum or Melaleuca armillaris, Banksia integrifolia, Dianella caerulea, Westringea fruiticosa*	Exposed headlands and areas of coastal plateaus within the sea spray zone
	Wallum Sand Heaths	*Corymbia gummifera, Banksia aemula, Aotus ericoides, Dillwynia glaberrium*	Nutrient poor soils of the Eurunderee sand mass
Rainforests	Littoral Rainforests	*Acmena hemilampra, A.mithii, Banksia integrifolia, Breynia oblongifolia*	Small stands scattered on coastal sand dunes and headlands. Suitable substrates include deep sand dunes, basalts and rhyolites.
	Northern Warm Temperate Rainforests	*Acmena smithii, Ceratopetalum apetalum, Doryphora sassafras*	Hilly to steep terrain on coastal ranges and plateaus
Saline Wetlands	Mangrove Swamps	*Avicennia marina ar. australasia, Aegiceras corniculatum, Samolus repens*	Margins of coastal estuary on mudflats
	Saltmarshes	*Samolus repens, Sarcocornia quinqueflora* (samphire)	Estuarine mudflats exposed to intermittent tidal inundation.
Wet Sclerophyll Forests (Grassy subformation)	Northern Hinterland Wet Sclerophyll Forests	*Eucalyptus microcorys, E. pilularis, E. propinqua, Allocasuarina torulosa*	Extensive areas of low ranges, foothills and plateaus below 600 m
Wet Sclerophyll Forests (Shrubby subformation)	North Coast Wet Sclerophyll Forests	*Eucalyptus acmenioides, E. microcorys, E. pilularis, Breynia oblongifolia*	More fertile rocky substrates of coastal ranges and foothills or on alluvium in sheltered creek flats where rainfall exceeds 1,000 mm/yr.

Source: Keith (2004)

Vegetation formations and classes in Keith (2004) have been devised for use across NSW. More detailed descriptions of vegetation communities in Myall Lakes Ramsar site can be found in reports prepared for Myall Lakes National Park, for example Myerscough and Carolin (1986) and Myerscough et al. (1995).

Subtidal kelp beds (primarily *Ecklonia radiata*) are found on most areas of rocky reef adjoining the Ramsar site and are an important habitat and food resource for many marine fauna. These algal assemblages are important food and shelter for a large range of fish and invertebrates, and are used as shelter by many other aquatic animals and plants. Algae attached to the sea floor (commonly called seaweeds) are found at shallow depths where light can penetrate; large brown kelps, such as *Ecklonia radiata*, are commonly found in water depths from low tide to 20 m. Dead algae and seaweed which drift in the water also serve as food and shelter for fish and invertebrates, such as abalone.

Detailed information on the distribution and ecology of the marine coast vegetation in the Ramsar site is a knowledge gap.

3.6.10 Terrestrial vegetation

Terrestrial vegetation in the Ramsar site is very diverse, with 549 species of flora reported in 1999, of which 25 are introduced or exotic species (Appendix 5). A vegetation survey of Myall Lakes National Park in 2000 resulted in 580 flora taxa being recorded; these were compared with the 1999 flora list, resulting in a list of 946 species for the national park (Hunter and Alexander 2000). These plants range from rainforest/wet sclerophyll species to heathland/sand dune species. This represents an exceptional diversity of plant communities and is rare in the fragmented and agricultural landscape of the NSW north coast.

The main vegetation formations (*sensu* Keith 2004) present in the Ramsar site are dry sclerophyll forests, wet sclerophyll forests, grassy woodlands, maritime grasslands and littoral and temperate rainforest. There has, however, been no coordinated mapping of vegetation types using consistent methodology in the Ramsar site. Consequently the distribution of terrestrial vegetation in the Ramsar site is a knowledge gap.

3.6.11 Threatened ecological communities

There is one nationally threatened ecological community in the Ramsar site – littoral rainforest and coastal vine thickets of eastern Australia, listed as critically endangered under the EPBC Act. Locations within the Ramsar site where littoral rainforest occurs include Yacaaba Headland, Yagon, Big Gibber and Mungo Brush.

There are five endangered ecological communites listed under the TSC Act known in the Ramsar site (DECCW 2010a):

- Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions.

3.6.12 Threatened plants

Myall Lakes National Park includes three threatened plants listed under the EPBC Act: Guthrie's grevillea (*Grevillea guthrieana*), magenta lilly pilly (*Syzygium paniculatum*), and black-eyed Susan (*Tetratheca juncea*) (Table 11). There are 11 threatened plants listed under the TSC Act known or believed to occur within the Ramsar site (Appendix 5).

Information on threatened species in the Ramsar site is a knowledge gap. A thorough survey to determine their status in the Ramsar site is required.

Table 11 Threatened plants and ecological communities under the EPBC Act

Common name	Scientific name	Status
Plants		
Guthrie's grevillea	*Grevillea guthrieana*	Endangered
Magenta lilly pilly	*Syzygium paniculatum*	Vulnerable
Black-eyed Susan	*Tetratheca juncea*	Vulnerable
Ecological communities		
Littoral rainforest and coastal vine thickets of eastern Australia		Critically endangered

3.7 Animals

There have been no systematic surveys of fauna in the Ramsar site. As a consequence, data on the presence of birds, amphibians, mammals and reptiles come mainly from reported sightings recorded in the Atlas of NSW Wildlife. For most groups, the sightings that are reported to the Wildlife Atlas tend to be for rare or threatened species, and common species tend to get overlooked. Information on fauna species and their habitats is a knowledge gap, and a systematic survey of both is required.

3.7.1 Invertebrates

Marine, estuarine and brackish invertebrates

Although it is generally accepted that the benthic community (bacteria, fungi, algae, and macro-invertebrates) plays a critical structural and functional role in aquatic ecosystems (for example, nutrient cycling and food web), there is very limited information about benthic biota for the Ramsar site. This is a knowledge gap.

The extensive unvegetated sections of the lake floors of the Myall lakes and of the intertidal flats in the estuarine sections of the Ramsar site probably support a diversity of benthic invertebrate fauna, but there has been no published census. Information on benthic macroinvertebrates on beaches and the impacts of four-wheel drive vehicles on them are also knowledge gaps.

The aquatic invertebrates, such as crustaceans, molluscs and polychaete worms, in the Myall lakes are important food sources for many of the aquatic and terrestrial fauna, especially the shorebirds. There were eight species of decapods identified in the Myall lakes system, and three of these species are of commercial significance (Table 12). Anecdotal information suggests that many other decapods also occur, for example portunid crabs (such as *Portunus pelagicus*, the blue-swimmer crab), grapsid crabs and freshwater shrimps (such as *Paratya australiensis*).

The marine environment in or near the Ramsar site ranges from the intertidal zone to the open ocean. Rocky environments are home to an abundance of macrobenthos (algae and invertebrates – gastropods, limpets, barnacles, crabs, echinoderms) and fish communities. Some groups of species such as barnacles and sponges are attached to reefs and are commonly distributed in particular areas, while other species such as fish species can move between many marine habitats.

Sandy beaches occupy a dynamic position between sea and land. There is a diversity of animals such as crabs, amphipods, pipis (*Donax deltoides*) and worms living in or on the upper sand layers providing food for fish and other animals such as seabirds.

Freshwater invertebrates

There have not been any freshwater macroinvertebrate studies undertaken in the Ramsar site. As part of the Commonwealth Government's AusRivAS assessments in 1994–99, two locations in the Myall River valley were sampled for aquatic macroinvertebrates – Myall River at Markwell (KARU574),

Table 12 Marine decapods in the Myall lakes system

Scientific name	Common name	Number
Acetes sibogae australis	Shrimp	614
Amarinus spp.	Spider crab	4
Macrobrachium cf novaehollandiae	Long-armed shrimp	3
Macrobrachium intermedium	Long-armed shrimp	226
Metapenaeus bennettae	Greasyback prawn*	1
Metapenaeus macleayi	School prawn*	98
Palaemon spp.	Weed shrimp	2259
Penaeus plebejus	King prawn*	84

Source: Trudy Walford (2006, pers. comm. – unpublished data provided DPI NSW (Fisheries))
* Species of significance for commercial fishing

sampled in spring and autumn 1999, and Winns Creek at Purgatory Road (KARU602), sampled in spring and autumn 1997 (Hose and Turak 2004). It is considered that these sites are sufficiently representative of the riverine sections of Myall River that we can generalise from these results the condition of the rivers and creeks in the Ramsar site.

Macroinvertebrates that were collected from the sites were mostly identified to family level taxonomy, although some groups such as water mites were only identified to order. A good diversity of taxa was collected from the sites, with an average of 22 taxa collected from the Myall River site and 23 taxa from Winns Creek. When compared to AusRivas reference sites, the combined season macroinvertebrate communities of both sites were equal to reference condition.

It can be inferred from this study that freshwater macroinvertebrate communities, and by extension the general condition of rivers, are quite healthy in the Myall River catchment, including the Ramsar site. The absence of data on freshwater macroinvertebrates for the Ramsar site is a knowledge gap.

Terrestrial invertebrates

There was no information on terrestrial invertebrates, with the exception of one report of the endangered giant dragonfly (*Petalura gigantea*), listed as threatened under the TSC Act. This species is more commonly found in wetlands that have some flow (Gunther Theischinger 2008, pers. comm.), but has been seen in still-water wetlands. It is well within its range in Myall Lakes Ramsar site (Theischinger and Hawking 2006). It would most likely be found in the paperbark swamp areas (McKay 2002). Information on terrestrial inverterbrates is a knowledge gap.

3.7.2 Fish

The vast water bodies in Myall Lakes Ramsar site support a diversity of fish habitats, which include mangroves, seagrasses, saltmarshes, coastal freshwater and brackish lagoons bordered by dense stands of reeds (*Typha* spp. and *Phragmites australis*), with dense submerged vegetation beds (*Chara fibrosa, Najas marina, Ruppia* spp. and *Myriophyllum salsugineum*), shallow sandy floors, and deeper mud and marine waters as well. The Myall lakes system offers a range of habitat, salinity and tidal conditions that set environmental envelopes suitable for distinct groups of species.

Sampling of fish assemblages in the lakes by the Department of Primary Industries NSW (DPI) showed that the number of species increased as average salinity increased: from 15 species in Myall Lake to 32 species in Bombah Broadwater, and 49 species in the lower Myall River (Trudy Walford 2006, pers. comm.; Appendix 3). Whilst the assemblages, which are typical of NSW estuaries and tidal rivers, include a normal range of feeding strategies from small grazers and foraging fish to larger predatory fish, they are dominated by small benthic species and do not include any large piscivores. A notable omission from the survey results is the long-finned eel (*Anguilla reinhardtii*), which is known to occur in the Ramsar site but was not recorded during this survey.

Fifteen species of economic significance were collected and these were mostly found in the Myall River – in marine waters – with some in Bombah Broadwater. Fish found in the principally freshwater Myall Lake were the Pacific blue-eye (*Pseudomugil signifer*) and various gudgeon species (*Hypseleotris* spp.). Two protected species of pipefish were also collected from the lakes (Appendix 3).

Extended wet and dry intervals, as well as any rise in sea level, can be expected to modify the existing distribution of fishes in the system.

Sixty two species of marine fish were recorded in a survey of the marine waters of the Port Stephens – Great Lakes Marine Park (both within and outside the Ramsar site) (Malcolm et al. 2007; Appendix 4).

3.7.3 Birds

There are 298 species of birds recorded in Myall Lakes Ramsar site, indicating a high diversity of birds (Appendix 1). This includes 22 species of migratory shorebirds under international agreements (JAMBA, CAMBA and ROKAMBA), and three species either nationally threatened or on the IUCN Red List (Tables 13 and 14).

Waterbirds

Forty-six species of waterbirds have been recorded from the Ramsar site (Appendix 1). Many of these waterbirds nest and breed in the Ramsar site's shoreline rushes, reeds and riparian vegetation. They include 200–1000 black swans (*Cygnus atratus*), hundreds of Pacific black ducks (*Anas superciliosa*) and up to 100 dusky moorhens (*Gallinula tenebrosa*) (David Turner 2006, pers. comm.). They use the rushes and reeds in quieter parts of the lakes, especially in Bombah Broadwater. Flocks of black swans form when SAV becomes abundant, and they breed when sufficient vegetation can be uprooted and dragged to form a substantial platform for their nest. Pacific black ducks prefer deep permanent wetlands with low salinity and dense vegetation, and breed during the spring throughout the site but especially at Bombah Point (Blakers et al. 1984; David Turner 2006, pers. comm.).

The Myall lakes system is included in the annual eastern Australia waterbird surveys, which have been conducted since 1983. In 1999, 464 individuals of nine waterbird species were observed in Myall Lake, Boolambayte Lake, Bombah Broadwater and Myall River (John Porter 2010, pers. comm.). Since that time annual counts have varied from 472 individuals of nine species in 2000, to 4811 individuals of 15 species in 2002. The mean annual count between 1999 and 2009 was 1384 individuals.

Hundreds of cormorants (*Phalacrocorax* spp.) are residents of the Ramsar site and can be observed using rocks and trees on shore edges as roost sites. There are also many waterbirds that are residents and roost within the shoreline vegetation. Large numbers of waterbirds have been observed eating SAV, especially in Bombah Broadwater and Two Mile Lake. The waterbirds include resident species such as black swan, Pacific black duck, dusky moorhen and thousands of occasional visitors including hardhead and Eurasian coots (*Fulica atra)*.

Ribbonweed (*Vallisneria gigantea*) is regularly dug up and eaten by black swans and this can be found in the northern parts of Boolambayte Lake and Two Mile Lake, as well as large stands in Bombah Broadwater (MPA 2007). Similarly, large stands of *Ruppia* spp. and *Potamogeton* spp. are found in Bombah Broadwater and these plants are significant food sources for waterbirds (Sainty and Jacobs 1981; Bortolus et al. 1998). The Pacific black duck feeds by filtering shallow water for the seeds of grasses, sedges and other aquatic plants, as well as by taking water insects. The dusky moorhen is associated with reed beds in freshwater locations, and feeds on aquatic vegetation (Blakers et al. 1984).

The Eurasian coot (*Fulica atra)* is an occasional visitor to the Ramsar site. Thousands of Eurasian coots have been observed gathering on the shorelines (Kendell 2002; David Turner 2006, pers. comm.) and feeding on SAV, which they gather by diving or pecking while swimming on the surface (Blakers et al. 1984).

Large flocks (2,000–15,000 birds) of white-eyed (hardhead) ducks (*Aythya australis*) are also occasional visitors to the Ramsar site. They feed on SAV and invertebrates, especially molluscs (Blakers et al. 1984).

The purple swamp hen (*Porphyrio porphyrio*) is found around freshwater swamps, streams and marshes where it feeds on the soft shoots of reeds and rushes and small animals, such as frogs and snails.

The Australasian bittern (*Botaurus poiciloptilus*) is occasionally sighted in the Ramsar site, and was originally recorded in Myall Lakes National Park between 1977 and 1980 (Atlas of NSW Wildlife). This species inhabits terrestrial and estuarine wetlands, generally where there is permanent water, and prefers wetlands with dense vegetation, including sedges, rushes and reeds. Freshwater is generally preferred, although dense saltmarsh vegetation in estuaries and flooded grasslands is also used by the species. It is listed as endangered in both the EPBC Act and the IUCN Red List.

Migratory shorebirds protected under international agreements

Twenty-two species of migratory birds protected under international agreements (CAMBA, JAMBA and ROKAMBA) have been recorded in Myall Lakes Ramsar site (Table 13). Migratory birds travel many thousands of kilometres from their breeding grounds to non-breeding grounds, generally flying from one hemisphere to the other and back again in a single year. Migratory birds which visit Australia migrate along the East Asian – Australasian Flyway, which stretches from the breeding grounds of Siberia and Alaska southwards through east and south-east Asia, to the non-breeding grounds of Australia and New Zealand.

The Myall lakes system provides habitat for many of the flyway's migratory bird species at the terminus of their migration. Most of the available information suggests that intertidal habitats are the most important for the majority of shorebird species. Myall Lakes Ramsar site provides a wide range of intertidal habitats for shorebirds, including coastal mudflats, sandy beaches, saltmarshes, brackish marshes, mangroves and swamp forests, as roosting and feeding sites (Lane 1987).

Resident shorebirds and seabirds

Shorebirds observed in the Ramsar site are listed in Appendix 1. Many shorebirds form flocks during high tide in specific areas called roost sites when their feeding areas are inundated (Hayman et al. 1986). They are usually highly restricted to specific areas for roosting and feeding (Minton 2005). The little tern (*Sterna albifrons*), pied oystercatcher (*Haematopus longirostris*), crested tern (*Sterna bergii*), eastern curlew (*Numenius madagascariensis*), red-necked stint (*Calidris ruficollis*) and bar-tailed godwit (*Limosa lapponica*) roost periodically in the beaches and sand dunes of the Ramsar site (David Turner 2006, pers. comm.). The little tern and sooty oystercatcher are known to breed in the Ramsar site (Fiona Miller 2010, pers. comm.). Nevertheless, the number of birds using the Ramsar site as a roost site is unknown and surveys are required during high tide when birds are concentrated into roost areas.

Seabirds such as the short-tailed shearwater (*Puffinus tenuirostris*), sooty shearwater (*P. griseus*) and wedge-tailed shearwater (*P. pacificus*), which are not wetland dependent, are known to breed on Little Broughton Island and Broughton Island.

No shorebird feeding habitat studies have been conducted within the Ramsar site and this presents a significant knowledge gap. However, the invertebrate community, both within the sediments and the adjacent wetlands, would be expected to contribute significantly to food resources for shorebirds, as invertebrates form the major component of shorebird food (Lane 1987).

Terrestrial birds and raptors

There are at least 190 terrestrial bird species (non-waterbirds) from 53 families within Myall Lakes Ramsar site, of which only five are introduced species (Appendix 1) (Atlas of NSW Wildlife). Those species cover a wide range of lifestyles – seed eaters, honeyeaters, raptors, parrots, cockatoos, insect eaters and many others. This wide diversity is largely a consequence of the diversity and naturalness of vegetation within the Ramsar site. Raptors such as white-bellied sea eagles, whistling kites and ospreys have been included here in the terrestrial birds but it is acknowledged that much of their feeding is in the waters of the Ramsar site.

Table 13 Migratory birds protected under international agreements

Family	Scientific name	Common name	Legal status
Accipitridae	*Haliaeetus leucogaster*	White-bellied sea-eagle	C
Apodidae	*Hirundapus caudacutus*	White-throated needletail	C
Ardeidae	*Ardea alba**	Great egret	J, C
	*Ardea ibis**	Cattle egret	J, C
	Egretta sacra	Eastern reef egret	C
Charadriidae	*Charadrius veredus*	Oriental plover	R
Laridae	*Sterna albifrons*	Little tern	J, C, R
	Sterna bergii	Crested tern	J
	Sterna caspia	Caspian tern	C
	Sterna hirundo	Common tern	J, C, R
Procellariidae	*Puffinus griseus*	Sooty shearwater	J, C
	Puffinus pacificus	Wedge-tailed shearwater	J
	Puffinus tenuirostris	Short-tailed shearwater	J, R
Scolopacidae	*Arenaria interpres*	Ruddy turnstone	J, C, R
	*Calidris acuminata**	Sharp-tailed sandpiper	J, C
	Calidris alba	Sanderling	J, C, R
	*Calidris ruficollis**	Red-necked stint	J, C, R
	Gallinago hardwickii	Latham's snipe	J, C, R
	*Heteroscelus brevipes**	Grey-tailed tattler	J
	*Limosa lapponica**	Bar-tailed godwit	J, C, R
	*Numenius madagascariensis**	Eastern curlew	J, C, R
	*Numenius phaeopus**	Whimbrel	J, C, R

C = CAMBA, J = JAMBA, R = ROKAMBA
* Listed in the *Wildlife Conservation Plan for Migratory Shorebirds* (DEH 2006).
Sources: Atlas of NSW Wildlife; David Turner (2011, pers. comm.); Nick Carlile (2011, pers. comm.)

3.7.4 Mammals

Extensive small mammal surveys have concluded that Myall Lakes Ramsar site has a high diversity of small terrestrial mammals such as native mice and rats, antechinus and melomys (Higgs and Fox 1993; NPWS 2002). Forty-five species of terrestrial mammals (including the dingo) have been recorded, including five species of glider, five macropods and twelve bats, with two species listed as threatened under the EPBC Act: spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) (Appendix 2; Table 14) (Atlas of NSW Wildlife).

Eight species of marine mammals have been sighted within, or in waters adjacent to, the marine coast of the Ramsar site, including whales of various species, fur seals, and dugongs (Port Stephens) (NPWS 2006).

3.7.5 Amphibians

Twenty-nine species of amphibians have been recorded in the Ramsar site, including two nationally threatened species: the green and golden bell frog (*Litoria aurea*) and the stuttering frog (*Mixophyes balbus*) (Table 14; Appendix 2). Broughton Island is particularly important for green and golden bell frog habitat as the population there is free of the chytrid fungus that affects populations of this species on the mainland. Three amphibians in the site are also on the IUCN Red List: the green and golden bell frog (*Litoria aurea*), Freycinet's frog (*Litoria freycineti*) and the green-thighed frog (*Litoria brevipalmata*) (Table 14; IUCN 2010). The number of amphibian species is exceptionally high as the Ramsar site provides a large permanent body of fresh to brackish water and associated swamps, creeks and rivers in a near-natural condition.

3.7.6 Reptiles

Thirty-seven species of reptiles from 12 families have been recorded within the Ramsar site, including one threatened species under the TSC Act: Stephens' banded snake (*Hoplocephalus stephens*) (Appendix 2).

Reptiles known in the Ramsar site wetlands are the marsh snake (*Hemiaspis signata*), eastern water-dragon (*Physignathus lesueurii*), red-bellied black snake (*Pseudechis porphyriacu*) and tortoises (*Chelodina* spp.) (Atlas of NSW Wildlife; (Fiona Miller 2010, pers. comm.).

Information about reptiles in the Ramsar site is a knowledge gap.

3.7.7 Threatened animals

Seven animal species listed as threatened under the EPBC Act have been recorded in Ramsar site (Table 14). There are five animal species listed as internationally threatened in the IUCN Red List, including three of the species listed under the EPBC Act, which are known in the site (Table 14). There are 46 animals listed under the TSC Act (Appendix 6).

Table 14 Threatened animals recorded in Myall Lakes Ramsar site

Common name	Scientific name	Status under EPBC Act	IUCN Red List category
Birds			
Australasian bittern	*Botaurus poiciloptilus*	Endangered	Endangered
Gould's petrel	*Pterodroma leucoptera leucoptera*	Endangered	Not listed
Swift parrot	*Lathamus discolor*	Endangered	Not listed
Mammals			
Grey-headed flying-fox	*Pteropus poliocephalus*	Vulnerable	Vulnerable
Spotted-tailed quoll	*Dasyurus maculatus*	Endangered	Not listed
Amphibians			
Freycinet's frog	*Litoria freycineti*	Not listed	Vulnerable
Green and golden bell frog	*Litoria aurea*	Vulnerable	Vulnerable
Green-thighed frog	*Litoria brevipalmata*	Not listed	Endangered
Stuttering frog	*Mixophyes balbus*	Vulnerable	Not listed

Sources: IUCN (2010); EPBC Act

A summary of the significance of the Myall lakes wetlands to the species listed under the EPBC Act and in the IUCN Red List is provided below. The wetland-dependent species are:

- Australasian bittern (*Litoria aurea*)
- Freycinet's frog (*Litoria freycineti*)
- green and golden bell frog (*Litoria aurea*)
- green-thighed frog (*Litoria brevipalmata*)
- stuttering frog (*Mixophyes balbus*).

Other species in the Ramsar site which are not wetland dependent are Gould's petrel *(Pterodroma leucoptera leucoptera)*, grey-headed flying-fox (*Pteropus poliocephalus*), spotted-tailed quoll (*Dasyurus maculatus*) and swift parrot (*Lathamus discolor*).

Australasian bittern (*Botaurus poiciloptilus*)

The Australasian bittern inhabits terrestrial and estuarine wetlands, generally where there is permanent water. The species prefers wetlands with dense vegetation, including sedges, rushes and reeds. Freshwater is generally preferred, although dense saltmarsh vegetation in estuaries and flooded grasslands are also used by the species (DECC 2006).

This species was originally recorded in the Ramsar site between 1977 and 1980 (Atlas of NSW Wildlife). It is occasionally sighted in the Ramsar site. It is listed as endangered under both the EPBC Act and in the IUCN Red List.

Freycinet's frog (*Litoria freycineti*)

Freycinet's frog is found in heaths, paperbark swamps and forest habitats in coastal areas from central NSW to south-eastern Queensland (Cogger 2000).

There are 23 records of Freycinet's frog in the Ramsar site between 1974 and 2008 (Atlas of NSW Wildlife). It is listed as vulnerable in the IUCN Red List.

Green and golden bell frog (*Litoria aurea*)

The green and golden bell frog is found in eastern NSW and east Gippsland in Victoria in small, coastal or near-coastal populations; however, its former distribution included the far north coast of NSW and inland parts of south-eastern NSW (Cogger 2000; DECC 2006). It lives in large, permanent, open-water swamps or ponds that have a variable water level and dense vegetation, bulrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.) (DECC 2006). There are several populations of the species in the Ramsar site: at Mungo Brush, on The Moors, on Broughton Island, and at Neranie Bay in Myall Lake. The population on Broughton Island is believed to be free of chytrid fungus affecting populations of the species on the mainland (Susanne Callaghan 2010, pers. comm.).

Green-thighed frog (*Litoria brevipalmata*)

The green-thighed frog is found in a range of habitats from rainforest and moist eucalypt forest to dry eucalypt forest and heath, typically in areas where surface water gathers after rain (DECC 2006; DECCW 2010b). It is found in isolated localities along the coast and ranges from just north of Wollongong to south-east Queensland (DECC 2006; Cogger 2000).

There are eight records of the species in the Ramsar site between 1995 and 1996 (Atlas of NSW Wildlife). It is listed as endangered in the IUCN Red List.

Stuttering frog (*Mixophyes balbus*)

The stuttering frog is found in rainforest and wet, tall open forest in the foothills and escarpment on the eastern side of the Great Dividing Range, from southern Queensland to north-eastern Victoria. It breeds in streams during summer after heavy rain, and eggs are laid on rock shelves or shallow riffles in small, flowing streams (DECC 2006).

Between 1993 and 2001 there were nine recorded sightings of this species in the Ramsar site; however, there is no data to estimate the population size and habitat extent (Atlas of NSW Wildlife).

Gould's petrel *(Pterodroma leucoptera leucoptera)*

Gould's petrel has been recorded breeding on Cabbage Tree Island (off Port Stephens and outside the Ramsar site) for many years. In 2009 Gould's petrel was observed breeding in the Ramsar site on Broughton Island (Nick Carlile 2010, pers. comm.). This species is expected to continue to use Broughton Island for breeding, and will continue to be included in annual surveys of seabirds on Broughton Island, Little Broughton Island and other islands off the coast of the Ramsar site.

Grey-headed flying-fox (*Pteropus poliocephalus*)

The grey-headed flying-fox occurs in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops (DECC 2006). Their roosting camps are commonly in gullies, close to water and in vegetation with a dense canopy, and within 20 km of a regular food source. They feed on the nectar and pollen of eucalypts and *Melaleuca* and *Banksia*, as well as the fruits of rainforest trees and vines (DECC 2006).

There is an established flying-fox camp in the Ramsar site in the Mayers Range (west of Myall Lake) and other camps are located near the site at Hawks Nest, Smiths Lake and Forster. The Ramsar site contains patches of forest with canopy trees that provide suitable breeding and sheltering habitat. The coastal scrub, riparian and estuarine vegetation of the site also provides suitable foraging habitat (DECC 2006).

Spotted-tailed quoll (*Dasyurus maculatus*)

The spotted-tailed quoll has been recorded across a range of habitat types in NSW, including rainforest, open forest, woodland, coastal heath and inland riparian forest from the subalpine zone to the coastline (DECC 2006). There have been 16 recorded sightings in the Ramsar site, most recently in 2006 (Atlas of NSW Wildlife). Spotted-tailed quolls have been observed by NPWS staff and campers since 2006, including in 2009 when a camper was attacked by a quoll (Fiona Miller 2010, pers. comm.).

Swift parrot (*Lathamus discolor*)

The swift parrot breeds in Tasmania during spring and summer, migrating in the autumn and winter months to south-eastern Australia from Victoria and from the eastern parts of South Australia to south-east Queensland (DECC 2006). In NSW the species mostly occurs on the coast and on the south west slopes (DECC 2006). The swift parrot's favoured feed trees include winter flowering species such as swamp mahogany (*Eucalyptus robusta*), spotted gum (*Corymbia maculata*), red bloodwood (*C. gummifera*), mugga ironbark (*E. sideroxylon*), and white box (*E. albens*) (DECC 2006).

In the Ramsar site, swift parrots occur in areas where eucalypts are flowering profusely, and potentially are attracted to the spotted gum dominated dry open forests that cover more than 10,000 ha of the site (NPWS 2002). They also occur where there are abundant lerp[9] infested blackbutt (*E. pilularis*) (DECC 2006). The swift parrot was recorded in the Ramsar site in 1997 (Atlas of NSW Wildlife).

[9] A structure produced by larvae of psyllid insects as a protective cover.

3.8 Fire

Fire plays an important role in determining the diversity, distribution and abundance of flora and fauna in Myall Lakes Ramsar site (NPWS 2002). Fire can be due to natural and human activities, and in pre-European times the Worimi people used intermittent fire to increase the prevalence of grasses such as blady grass (*Imperata cylindrica* var. *major*), kangaroo grass (*Themeda australis*), threeawn grass (*Aristida vagans*) and plains grass (*Austrostipa aristiglumis*) (Hunter and Alexander 2000). However, in present times, arson is considered to be involved in more than half of fires caused by unknown circumstances (NPWS 2002).

Bushfires have occurred in the park every fire season since 1968 and there have been over 201 bushfires burning a total of more than 40,000 ha. Some areas of Myall Lakes National Park have been burnt by bushfire nine times since 1968, while large areas have been burnt four times, particularly in the area stretching north from Bombah Broadwater to Seal Rocks on the eastern side of Myall Lake.

There is little information on the relationship between fire regimes and the Ramsar site's vegetation communities and habitats, particularly in the heath vegetation on the eastern side of the lakes where fires have been more frequent. There is some evidence that some plants found in wet and dry heath communities, for example *Banksia* species, do not always establish successfully after fire by setting seed, and that *Banksia* seedlings require a lignotuber to have formed in order to survive a fire (Myerscough 2009). Another study found that there was little difference in the way that two heathland communities and their constituent species regenerated after fire, even though there was considerable variation between the floristic composition of the heath vegetation on ridges and that on slopes (Myerscough et al. 1995).

4 Ecosystem services

Under the Ramsar Convention, ecosystem services are defined as 'the benefits that humans receive from ecosystems' (Ramsar Convention 2005). However, the benefits for humans rely on the underlying ecological components and processes of ecosystems, and those components and processes provide important ecological services even though they may not benefit humans directly (DEWHA 2008). There are four main categories of ecosystem services (Millennium Ecosystem Assessment 2005):

1 supporting services
2 regulating services
3 provisioning services
4 cultural services.

The ecosystem services that support the ecological character of Myall Lakes Ramsar site are described below and, where appropriate, refer to the values that support the relevant Ramsar listing criteria (Table 15).

Table 15 Ecosystem services of the Myall lakes

Type of service	Service relating to Myall Lakes Ramsar site	Ramsar criteria
Supporting services		
Mosaic of natural or near-natural wetlands	The largely unmodified coastal lakes system ranges from fresh to estuarine with the streams that flow into the lakes mostly free of dams and weirs.	1
Significant biodiversity and habitats	Diversity of habitats provides for fish, shorebirds, migratory birds, terrestrial fauna and invertebrates.There is a high diversity of terrestrial and aquatic flora and fauna. Permanent waters of wetlands and lakes provide habitats for waterbirds and other fauna.	2, 3
Wetland-dependent threatened species	The Ramsar site supports five threatened wetland species	2, 3
Special ecological, physical or geomorphic features	The lakes support the only known occurrence in Australia of gyttja.	1
Priority wetland species	Myall lakes support 22 species of migratory birds listed under JAMBA, CAMBA and ROKAMBA.	3
Ecological connectivity	The Myall lakes provide important connectivity between terrestrial and wetland ecosystems, both within and outside the Ramsar site.	3
Primary production and food webs	The wetlands' primary production and food webs support significant biodiversity and habitats.	3
Hydrological processes	Natural hydrological processes are critical for supporting connected wetlands that provide habitat for biodiversity.	1

<table>
<tr><th>Type of service</th><th>Service relating to Myall Lakes Ramsar site</th><th>Ramsar criteria</th></tr>
<tr><td colspan="3">Regulating services</td></tr>
<tr><td>Water quality – clear waters and nutrient cycling</td><td>The lakes maintain high water quality by effectively retaining, recycling and removing suspended solids, organic and inorganic nutrients.

The lakes act as a sink for nutrients, organic matter and sediments, due to very long flushing times.</td><td>1</td></tr>
<tr><td>Shoreline stabilisation and protection</td><td>Vegetated sand dunes hold dune landforms in place and trap sand blown from exposed areas.

Large water bodies intercept and store runoff from storms, allowing slower discharge.</td><td>No applicable criterion</td></tr>
<tr><td>Maintenance of hydrological regimes</td><td>The Myall lakes and associated wetlands regulate the Ramsar site’s hydrological regimes through:
• maintaining the lakes’ near-natural changes in water levels
• maintaining the ecological processes, water quality and range of salinity levels
• ensuring that nutrients are utilised and turbidity is minimised in the lakes, principally by uptake of nutrients by aquatic vegetation and adsorption of nutrients onto sediments
• intercepting runoff from storms and heavy rainfall to reduce floods and to ensure slower discharges over a longer period of time
• maintaining the perched aquifers in the site’s sand deposits, thus allowing groundwater to flow naturally between the lakes and the sea.</td><td>1</td></tr>
<tr><td colspan="3">Provisioning services</td></tr>
<tr><td>Fisheries production</td><td>Approximately 521 tonnes of fish, prawns and crabs were harvested from the Myall lakes and Port Stephens in 2005–06, valued at A$2.18 million.</td><td>3</td></tr>
<tr><td colspan="3">Cultural services</td></tr>
<tr><td>Recreational and aesthetic amenity</td><td>Extensive waterways, dune systems and beaches provide opportunities for camping, boating, four-wheel driving on beaches, fishing, and other recreational activities.</td><td>No applicable criterion</td></tr>
<tr><td>Cultural heritage</td><td>Evidence of Worimi people’s occupation is in the form of shell and stone middens, campsites and burials.

Evidence of European occupation remains from subsistence farming, timber mills, fishing, tourism and sandmining.</td><td>No applicable criterion</td></tr>
</table>

4.1 Supporting services

4.1.1 Mosaic of natural or near-natural wetlands

The Myall lakes contain a relatively unmodified large coastal brackish lake system. The main streams flowing into the lakes (Myall River and Boolambayte Creek) are free of dams and mostly free of weirs. Consequently, the water level changes in the lakes are considered to be close to natural and represent a rare example of near-natural flow regimes in NSW coastal rivers.

The Ramsar site encompasses a series of ecologically linked wetland types, ranging from a marine coast, to estuarine, brackish open water, fringing swamps, freshwater swamps and riverine ecosystems, which are surrounded and supported by a near-natural terrestrial ecosystem. As a consequence of the size and range of wetlands and the complex variety of habitats they provide, the site supports a rich biodiversity. The site plays an important role in linking key fauna habitats to the north and west and is a drought refuge for waterbirds. It is also an important food source, spawning ground and nursery for many fish species.

4.1.2 Significant biodiversity and habitats

Biodiversity

Myall Lakes Ramsar site is very biologically diverse, supporting 968 species of terrestrial and aquatic flora, 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species (Atlas of NSW Wildlife) (Appendices 1, 2, 3 and 5). The site supports a wide diversity of physical habitats for plants, animals and invertebrates, including:

- wetlands with fresh, brackish or saline waters supporting macrophytes, charophytes, algae and seagrasses and providing habitats for invertebrates
- SAV providing nurseries for marine and estuarine fish
- intertidal areas and adjoining vegetation providing habitat for shorebirds such as the little tern (*Sterna albifrons*), pied oystercatcher (*Haematopus longirostris*) and sooty oystercatcher (*Haematopus fuliginosus*)
- vegetation types ranging from wet and dry sclerophyll forests, wet and dry heaths, and swamp forests to rainforests, mangroves and saltmarsh
- coast and islands providing habitat for migratory birds
- terrestrial ecosystems providing tree hollows and other habitats for nesting by birds and mammals.

The site supports ten threatened species and one threatened ecological community under the EPBC Act (Table 11 and Table 14); five animals listed as threatened on the IUCN Red List (Table 14); and 57 threatened species (46 animals and 11 plants) under the TSC Act (Appendices 4 and 6).

Habitats for waterbirds

The lakes and many of the wetlands of the Ramsar site are a permanent water source and provide habitats for waterbirds and other fauna. As for other coastal lakes in the bioregion, there is an increase in the number of shorebirds during drought at the Myall lakes, especially waterfowl (David Turner 2006, pers. comm.). The large flocks of Eurasian coots (*Fulica atra)* that visit the site are attributed to the birds using the site as a drought refuge (Kendell 2002). Similarly, the great crested grebe (*Podiceps cristatus*) usually frequents inland lakes and wetlands, but has been seen at the Myall Lakes during drought.

Rainfall over much of inland Australia is unpredictable and therefore the movement of most Australian shorebirds is somewhat irregular (Lane 1987). During the drier times of the year (spring, summer and autumn) inland shorebirds can move to the coastal regions, including the Myall lakes, which is one of many coastal lakes used by waterbirds. This normal cycle of coastal to inland movement can be interrupted by drought or inland flood. During a drought cycle, the shorebirds are forced to concentrate on the permanent coastal wetlands that act as a drought refuge (Lane 1987). However, when the inland floods, most of the birds will leave the coast until the ephemeral or intermittent inland wetlands dry out.

4.1.3 Wetland-dependent threatened species

The Ramsar site supports five wetland-dependent threatened species which are listed under the EPBC Act or are on the IUCN Red List: the Australasian bittern (*Botaurus poiciloptilus*), Freycinet's frog (*Litoria freycineti*), green and golden bell frog (*Litoria aurea*), green-thighed frog (*Litoria brevipalmata*) and stuttering frog (*Mixophyes balbus*). The freshwater lakes with reeds, sedges and rushes provide suitable habitat for the Australasian bittern, and the freshwater swamps and streams with high quality water in the Ramsar site provide suitable habitat for the amphibian species.

4.1.4 Special geomorphic, physical or ecological features – gyttja

The Myall lakes support the only known occurrence in Australia of gyttja – a green–brown organic sediment derived from the decomposition of charophytes, macrophytes and cyanobacterial algae. It is found in a small number of lakes worldwide, and has sometimes been associated with eutrophication (Lowe and Walker 1997; Rukminasari et al. 2004).

Gyttja is ubiquitous throughout Myall Lake, Boolambayte Lake and to a lesser extent Two Mile Lake, but is not found in Bombah Broadwater (Figure 18). The gyttja found in the Myall lakes is believed to be important in structuring and maintaining the characteristic SAV of the lakes. It determines the distribution of macrophytes by preventing the growth of macrophytes on the lake beds (Dasey et al. 2004, 2005).

4.1.5 Priority wetland species

Twenty-two species of migratory birds protected under international agreements (JAMBA, CAMBA, ROKAMBA) have been recorded in the Ramsar site, including a number of shorebird species (Table 13). Some shorebirds have not been sighted for 20 years or longer, including the red knot (*Calidris canutus*) and the marsh sandpiper (*Tringa stagnatilis*), both of which were last recorded in 1980 (David Turner 2010, pers. comm.).

Most of the shorebird sightings have been on Broughton Island, Corrie Island, Myall River and in the northern section of the Myall lakes.

Intertidal habitats are the most important for the majority of shorebird species. The Myall lakes provide extensive habitat for many of the East Asian – Australasian Flyway's migratory bird species at the end of their migration. The site provides a wide range of intertidal habitats for shorebirds including coastal mudflats, sandy beaches, saltmarshes, brackish marshes, mangroves and swamp forests, as roosting, nesting, breeding, and feeding sites (Lane 1987).

4.1.6 Ecological connectivity

Connectivity describes the interconnectedness of ecosystem types, both in the Ramsar site and between the Ramsar site and external areas.

The Ramsar site provides important connectivity between terrestrial and wetland ecosystems, and between the lakes and other wetland ecosystems, both within and outside the Ramsar site. The only human-made barriers in the site are the Pacific Highway and some minor roads, and aquatic connectivity is not impeded by weirs or other unnatural barriers. The site adjoins further areas of undisturbed native vegetation to the north, and healthy estuarine systems to the south (for example Port Stephens) and to the north (for example Smiths Lake and Wallis Lake), enhancing connectivity between the Ramsar site and external ecosystems. The connectivity between aquatic ecosystems within the site is generally good. Consequently, the Ramsar site is an extremely important part of the connectivity among ecosystems in the region.

4.1.7 Primary production and food webs

Primary production is the conversion by plants of sunlight and nutrients to carbon and energy which then sustains all the ecosystems on Earth. Significant disruptions to these fundamental processes have great potential to disrupt many higher order ecosystems.

The wetlands in the Myall lakes support a diverse and apparently healthy aquatic ecosystem, indicating that fundamental ecosystem processes such as primary production and food webs are still functioning in a near-natural state. The maintenance of a largely uncleared catchment is important for limiting the input of high levels of nutrients, which can significantly impact the ecosystem's primary production and food webs.

There has been one occasion where algal abundances exceeded what was believed to be normal and acceptable levels. This indicates that the system is somewhat delicately poised and external influences (such as excessive nutrient inputs) may cause the primary production and food webs to become abnormal, with potentially dire consequences for many of the higher order biota.

4.1.8 Hydrological processes

The Ramsar site's hydrological processes are relatively natural and support permananent wetlands which maintain habitat for biodiversity, provide flood control and ensure replenishment of groundwater. The water level changes in the lakes are considered to be near natural, as a result of Myall River and Boolambayte Creek (the main freshwater streams into the lakes) being free of dams and mostly free of weirs (with the exception of the Crawford subcatchment).

4.2 Regulating services

4.2.1 Water quality

The lakes maintain oligotrophic clear waters by effectively retaining, recycling and removing suspended solids, organic and inorganic nutrients, and other pollutants from water that flows through the lakes via several mechanisms, including:

- reduction in water velocity favouring sedimentation
- a variety of anaerobic and aerobic processes promoting denitrification, chemical precipitation, and other reactions that influence nutrient availability
- a high rate of productivity that leads to high rates of mineral uptake by vegetation and subsequent burial in sediments when plants die
- a diversity of decomposition agents and processes in sediments
- a large contact surface of water with sediment resulting from shallow waters, leading to significant sediment–water exchange
- an accumulation of gyttja that permanently buries carbon.

The Myall lakes, which cover an area of 100–150 km^2 (depending on water levels) and drain a catchment of 780 km^2, hold a large volume of the catchment's runoff and groundwater, and slowly release this water into Port Stephens via the constricted entrance channel in the lower Myall River (NPWS 2002).

Retention of sediment and associated nutrients

The lakes act as a sink for nutrients, organic matter and sediments, due to very long flushing times. The major sources of sediment in the Myall lakes catchment are erosion from areas with low vegetation cover, erosion of stream beds and banks of the tributaries of the Myall River, and a small input from cleared gullies (Great Lakes Council 2009). Significant quantities of nutrients from the catchment are transported into the lakes by the upper Myall River, and can contribute to the formation of toxic algal blooms (Figure 13) (Great Lakes Council 2009).

The long water retention times allow sediments to settle out and allow primary producers (algae and macrophytes) to convert nutrients to plant biomass, thus trapping them in internal nutrient cycling. The mean residence time for waters in Bombah Broadwater is 140 days; the median residence time is 118 days for Boolambayte Lake and 535 days for Myall Lake (Sanderson 2008).

The lakes can remove up to 90% of phosphorus deposited from catchment runoff; the removal rate for nitrogen is considered to be high given its long water residence time in the lakes (MHL 1999). The majority of nutrients are stored as plant biomass, detritus or sediment, with a small amount remaining in the lakes' waters.

4.2.2 Shoreline stabilisation and protection

Stabilisation of coastline

The vegetated sand dunes of the Ramsar site are important for holding dune landforms in place and for trapping sand blown from exposed areas. When unvegetated, dunes can become very mobile with wind forcing; vegetated dunes, however, are much more stable.

In the Ramsar site there are three main zones of dune vegetation, running roughly parallel to the coastline. Those zones reflect changes in the nutrient status and moisture content of dune soils, which increase in a landward direction, and changes in the degree of exposure to strong winds, salt spray and sandblast, which decrease in a landward direction. The zones of dune vegetation in sequence from the coastline are:

1. herbaceous stabilising plants tolerant of strong winds, sandblast, salt spray and occasional inundation by seawater which form the pioneer zone nearest the sea; for example pig face (*Carpobrotus glaucescens*), beach spinifex (*Spinifex sericeus*), guinea flower (*Hibbertia* spp.) and goat's foot (*Ipomoea pes-caprae*)
2. scrub or woodland plants on frontal sand dunes, including windswept shrubs and stunted trees (such as *Allocasuarina* species), vines and a smaller number of herbs
3. coastal heath or forest plants consisting of stunted trees and low shrubs (such as *Melaleuca* species in swampy areas and *Eucalyptus* and *Acacia* species on higher ridges), behind the frontal dunes.

Dune vegetation traps windblown sand and holds it on the foredunes. The loss of dune vegetation is a major trigger for dune erosion. The exposed, dry sand is easily mobilised by high-velocity winds and large volumes of sand can be rapidly transported, sometimes forming large depressions, termed blowouts. Currently, blowouts are occurring in the Ramsar site in the vicinity of the Mungo Brush area, and at Yagon and Big Gibber (Stephen Smith 2012, pers. comm.).

4.2.3 Maintenance of hydrological regimes

The Myall lakes' large surface area regulates the Ramsar site's hydrological regimes through:

- maintaining the lakes' water levels
- maintaining the ecological processes, water quality and range of salinity levels in the lakes
- intercepting runoff from storms and heavy rainfall to reduce floods and to ensure slower discharges over a longer period of time
- maintaining the perched aquifers in the site's sand deposits, thus allowing groundwater to flow naturally towards the lakes and the sea.

The groundwater in the underlying Carboniferous and Permian rocks flows from north-east to south-west and discharges into the Myall lakes making a significant contribution to the lakes' water, estimated at 105 GL/yr. (MHL 1999). The groundwater in the perched aquifers in the Quaternary sand dune deposits flows east and west depending on the lakes and sea water level fluctuations. Depending on water levels in the lakes and sea, these Quaternary aquifers can be recharged by the lakes and the sea (Realica 1999).

4.3 Provisioning services

4.3.1 Fisheries production

Commercial prawning with pocket nets occurs mostly in the lower Myall River, with eel trapping and mesh netting for fish in the lakes. Fish catches in the lake system include sea mullet (*Mugil cephalus)*, longfin eel (*Anguilla reinhardtii*), yellowfin bream (*Acanthopagrus australis*), luderick (*Girella tricuspidata*), silver biddy (*Gerres subfasciatus*) and sand whiting (*Sillago cilliata)*. School prawns dominate the crustacean catch; blue swimmer crabs (*Portunus pelagicus*) and mud crabs (*Scylla serrata*) are also important. Commercial beach fish catches include mullet, luderick, bream and hand collecting of beach worms and pipis (NPWS 2002).

The annual catch for Port Stephens and the Myall lakes in 2005–06 was approximately 521 tonnes, valued at A$2.18 million (Hunter Valley Research Foundation 2008). Since 1997–98 the annual catch for the estuaries has fluctuated, ranging from 422 tonnes in 2003–04 to 723 tonnes in 2001–02. The annual mean catch over the period from 1997–98 to 2005–06 was 573 tonnes, and the annual mean value of the catch over that period was A$2.04 million. The total catch for the region (which includes Hunter River, Smiths Lake and Wallis Lake) comprises around 20% of the total estuarine catch in NSW (Hunter Valley Research Foundation 2008). The proportion of the region's catch that comes from Myall Lakes Ramsar site is unknown, but is presumed to be relatively small.

In 2004, parts of Myall River (upstream of Bulahdelah) and Boolambayte Creek were closed to all types of net fishing in order to conserve and protect the fish and prawn stocks. In other areas (Myall Lake, Boolambayte Lake and Bombah Broadwater), prawn netting (except by hand) was prohibited but other types of fishing, such as gill and seine netting, are still practised. Commercial fishing is not permitted in the sanctuary zones of Port Stephens – Great Lakes Marine Park, which was declared in 2005 (Figures 2 and 3).

4.4 Cultural services

4.4.1 Recreation and aesthetic amenity

Myall Lakes Ramsar site receives an estimated 100,000 visitors annually, and offers a wide range of recreational opportunities that are provided by the extensive waterways, dune systems and beaches of the site. Recreational activities in the Ramsar site include camping, boating, four-wheel driving on beaches, swimming, bushwalking, cycling, fishing, commercial tourism, car touring, picnicking, nature appreciation and bird watching.

The most popular activity in the Ramsar site is camping (Stephen Smith 2010, pers. comm.). There are 22 camping areas in the Ramsar site providing over 380 camping sites. In addition Myall Shores Resort (previously called Legges' Camp), situated on the foreshore of Bombah Broadwater on land leased from NPWS, provides camping and holiday cabins.

Boating activities on the lake and river systems include canoeing, sailing and the use of power boats for waterskiing, wakeboarding, fishing and for overnight accommodation (houseboats, cruisers and yachts). NSW Maritime and NPWS have developed a waterway plan for the lakes which restricts boating activities in certain areas (for example the use of jet skis in shallow water). NSW Maritime also supplies a barge to pump sewage from the holding tanks of boats used for overnight accommodation. Aesthetic amenity is impacted when there are blue–green algae blooms.

Four-wheel drive vehicles are permitted to use approximately 20 km of the beaches on the mainland parts of the Ramsar site, for recreational driving and to access fishing locations. Vehicles are permitted to drive only on the beach between mean high and mean low tide levels, and are prohibited from driving on vegetation and dunes.

Recreational fishing is undertaken on the beaches and headlands of the Ramsar site and on Broughton Island. Some recreational prawn netting takes place in the lakes system. Recreational fishing is prohibited in those parts of the Ramsar site gazetted as sanctuary zones in Port Stephens – Great Lakes Marine Park (Figure 3).

4.4.2 Cultural heritage

Aboriginal heritage

Myall Lakes Ramsar site is within the traditional lands of the Worimi people. The varied wetlands, environments and abundant resources of the Myall lakes area provided an ideal living environment for the Worimi, and evidence of their occupation survives in many places in the form of shell and stone middens, campsites and burials. Systematic surveys for Aboriginal objects have been undertaken at Broughton Island and along the Myall coastline. However, other wetland environments (such as the lakeshore) and terrestrial environments have not been surveyed and would be expected to yield further evidence of occupation.

The Worimi people maintain an active interest in the management of the Ramsar site, particularly in areas that are spiritually or historically significant. Dark Point (Little Gibber) was used as the launching point for travelling to Broughton Island, which is regarded as spiritually significant by Aboriginal people. The significance of the Myall coast to Aboriginal culture has been recognised by the declaration of over 600 ha around Dark Point as an Aboriginal place under the NPW Act.

Historic heritage

Myall Lakes Ramsar site has a cultural landscape which reflects the area's varied history, unique natural features and use of the region's natural resources. Significant historical phases include occupation by the Worimi people, the timber and fishing industries and associated settlements, small scale and subsistence farming in the area, sandmining and its physical and sociopolitical impacts, and use of the lakes and surrounding areas for recreational activities and as a holiday destination. Since the 1970s, when Myall Lakes National Park was established, there has been a change in the use of the area now covered by the Ramsar site from resource utilisation to conservation. Each activity or phase has taken advantage of the natural resources of the Ramsar site and has left a mark on the cultural landscape.

Evidence of European occupation in the Ramsar site remains through historic sites and relicts, such as graves associated with villages and subsistence farming, timber mills and their associated infrastructure including wrecks of timber droghers (barges used for transporting timber or logs), Tamboy fishing village (which is still occupied), Myall Shores Resort (formerly Legges Camp), and the roads, camps and refuse associated with sandmining.

5 Critical components, processes and services

ECDs are required to identify the components, processes and services which most strongly determine the ecological character of a Ramsar site that existed at the time of Ramsar listing (DEWHA 2008). A description of the critical components, processes and services should include those that:

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

In this ECD the critical components, processes and services are those core attributes that define the site's character (values for which the site was listed) and enable the ecological system to function, including:

- a mosaic of natural or near-natural wetlands
- good water quality – oligotrophic clear waters and nutrient loads which are not elevated through catchment disturbance
- a natural salinity regime ranging from fresh to brackish to estuarine/marine
- a wide range of wetland vegetation types
- significant biodiversity and habitats
- five wetland-dependent threatened species
- gyttja community of cyanobacteria, characteristic of some of the lakes
- recreational and aesthetic amenity – a reflection of the lakes' high water quality.

The critical components, processes and services summarised in Table 16 reflect current understanding and should be further developed as understanding of the complexity of the Myall lakes wetlands increases.

A basic conceptual model for the relationships between the critical components, processes and services of the wetlands in Myall Lakes Ramsar site is shown in Figure 22.

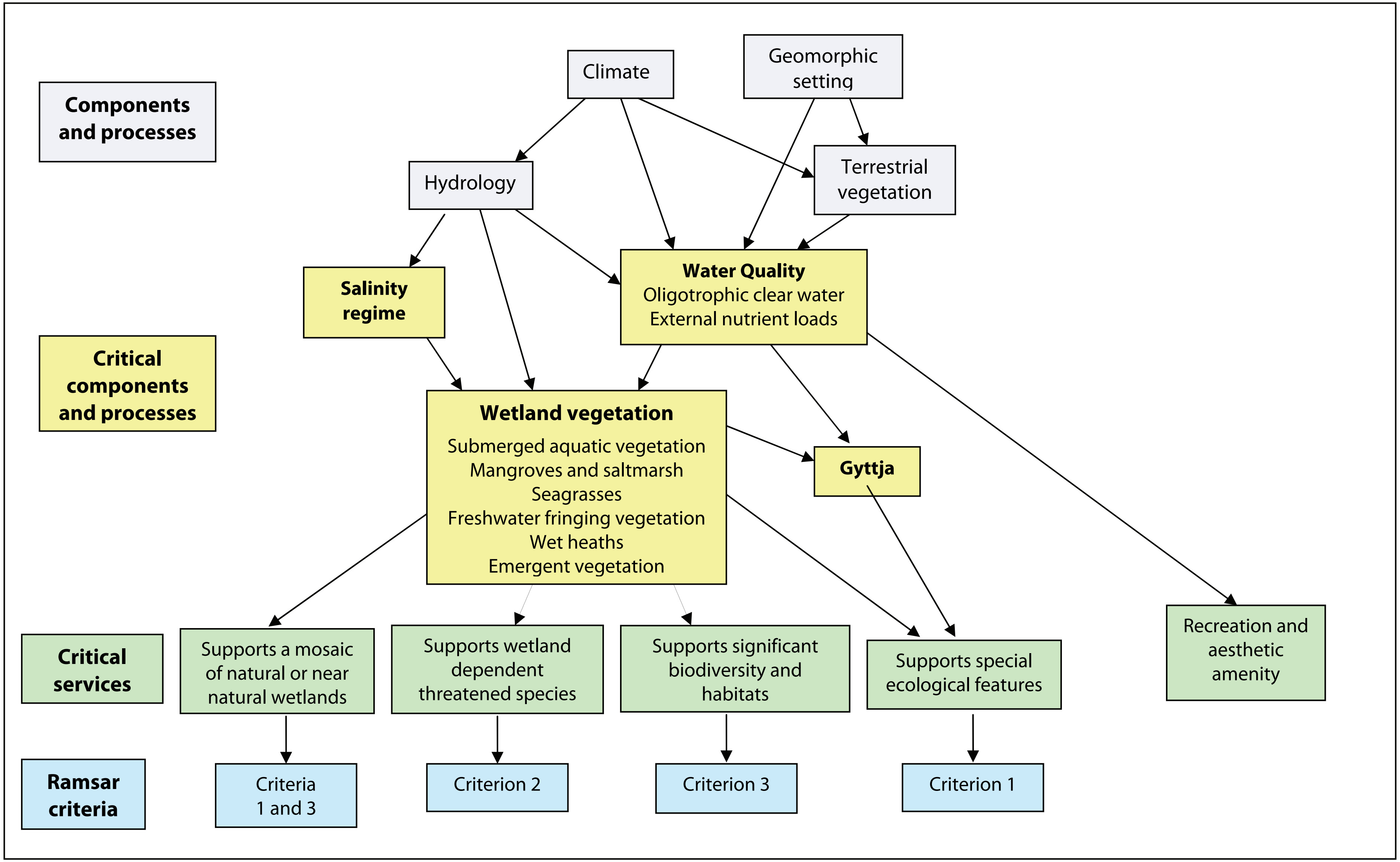


Figure 22 Basic conceptual model for critical components, processes and services for Myall Lakes Ramsar site

Table 16 Critical components, processes and services of Myall Lakes Ramsar site

Component, process or service	Description	Ramsar criteria
Mosaic of natural or near-natural wetlands: • freshwater and fringing wetlands • brackish waters • mangroves and intertidal flats • rivers, creeks and streams • marine coast.	The lakes' 18 different wetland types form an inter-connected mosaic of fresh to brackish and saline habitats: • freshwater and fringing wetlands – coastal heath swamps, coastal swamp forests, and paperbark and she-oak forests on lake margins • brackish waters – characterised by submerged and emergent aquatic vegetation • mangroves and intertidal flats • rivers, creeks and streams • marine coast – saline areas on rocky shores and beaches.	1, 3
Water quality: • oligotrophic clear waters • external nutrient loads.	**Oligotrophic clear waters** Clear waters with low nutrient levels in the lakes are critical for ecosystem function and primary production. Good water quality of the lakes is maintained through effective retention, recycling and removal of suspended solids, organic and inorganic nutrients, and other pollutants from water that flows through the lakes. **External nutrient loads** Maintaining the right balance of nutrients imported into the lakes is critical for the site's ecological character. The intensification of land use and removal of native vegetation in catchments leads to increases in the amount of nutrients and sediments entering the lakes. Excessive nutrients stimulate the growth of phytoplankton and increased sediment loads reduce water clarity.	1
Salinity regime and salinity levels	The mosaic of open-water, fringing and tidal wetlands is dependent on the lakes' salinity regime, which ranges from near fresh through brackish to estuarine/marine. Salinity levels are also an important determinant of many of the lakes' aquatic biotic structures and processes.	1
Wetland vegetation: • submerged aquatic vegetation • mangroves and saltmarsh • seagrasses • wet heaths • freshwater fringing vegetation • emergent vegetation.	The wetlands support a range of vegetation types which are important for defining the ecological character and wetland habitats of the Myall lakes: • submerged aquatic vegetation – includes macrophytes, macroalgae, charophytes and seagrasses, and is the basis of gyttja; SAV reflects range of salinity in lakes, with marine seagrasses in areas with higher salinities, and macrophytes and algae in freshwater lakes • mangroves and saltmarsh – mangroves provide habitats for fish, crabs, birds and other animals, and maintain water quality by filtering silt from runoff and recycling nutrients; saltmarshes provide habitat for juvenile fish such as bream and mullet, for fish such as common galaxias to deposit eggs, and for crabs • seagrasses – valuable as nursery, feeding and shelter areas for many aquatic animals, including fish, mollusc and crustacean species • wet heaths – consist of several wetland vegetation	1, 3

Component, process or service	Description	Ramsar criteria
	communities on The Moors, principally dry heath forest, wet heath forest, swamp forest, swamp, dry heath and wet heath • freshwater fringing vegetation – occurs on higher sandy soils along margins of freshwater lakes, and is dominated by broad-leaved paperbark (*Melaleuca quinquinervia*) and swamp she-oak (*Casuarina glauca*) • emergent vegetation – grows in the shallow waters of the lakes, and is dominated by broad-leaved cumbungi (Typha spp.), common reed (Phragmites australis), sedge (Cladium procerum), leptocarpus (Leptocarpus tenax) and scirpus (Scirpus litoralis).	
Significant biodiversity and habitats	The Myall lakes support 946 terrestrial plant, 22 aquatic plant, 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species. The Myall lakes provide a wide range of intertidal habitats for shorebirds including coastal mudflats, sandy beaches, saltmarshes, brackish marshes, mangroves and swamp forests, used for roosting, nesting, breeding, and feeding. Many of the migratory bird species under international agreements (JAMBA, CAMBA and ROKAMBA) recorded from the Ramsar site use intertidal habitats. The Myall lakes also provide drought refuge for waterbirds.	2, 3
Wetland-dependent threatened species	The Ramsar site supports five wetland-dependent species listed as threatened under the EPBC Act and in the IUCN Red List: • Australasian bittern (*Botaurus poiciloptilus*) • Freycinet's frog (*Litoria freycineti*) • green and golden bell frog (*Litoria aurea*) • green-thighed frog (*Litoria brevipalmata*) • stuttering frog (*Mixophyes balbus*).	2, 3
Special ecological features – gyttja	Myall Lake, Boolambayte Lake and Two Mile Lake support gyttja which determines the distribution of macrophytes in the upper lakes.	1
Recreational and aesthetic amenity	The Myall lakes' appeal for recreation and their aesthetic amenity is determined by maintaining good water quality in the lakes and other wetlands, together with the site's naturalness. The Myall lakes are highly valued for their aesthetic amenity and as a place that offers a wide range of recreational opportunities provided by the extensive waterways, dune systems and beaches, including camping, boating, four-wheel driving on beaches, and fishing.	No applicable criterion

5.1 Mosaic of natural or near-natural wetlands

The 18 different wetland types form a mosaic of fresh to brackish and saline habitats variously interconnected across time (driven by hydrology) and space (determined by geomorphology). Those wetland types have been combined into five groups as described below (Table 3).

Freshwater and fringing wetlands

These wetlands are characterised by emergent vegetation, and include coastal heath swamps (e.g. The Moors) occupying low-lying areas in the Eurunderee sand mass, and coastal swamp forests dominated by paperbarks and swamp mahogany, and by casuarinas along the lake margins.

Brackish waters

These are the large, relatively undisturbed brackish to fresh lakes connected to the sea by the lower Myall River and Port Stephens. They are located in an embayment between hills to the west and the coastal dune system to the east. They are characterised by submerged and emergent aquatic vegetation, provide waterbird habitat and drought refuge, maintain hydrological processes and nutrient cycling, and support habitat for fish, macroinvertebrates, plankton and gyttja.

Mangroves and intertidal flats

There are intertidal sand and mud flats on Corrie Island; mangroves and saltmarsh are found in the lower Myall River and at Fame Cove. Intertidal habitats are important to migratory shorebirds as feeding habitat, and provide roosting habitat at high tide.

Rivers, creeks and streams

These include Myall River and Boolambayte Creek, which flows into Boolambayte Lake. The upper Myall River and Boolambayte Creek provide freshwater inflows into the lake system. The lower Myall River is brackish and is important for euryhaline species (i.e. those able to tolerate a wide range of salinities) and estuarine fish species.

Marine coast

The marine coast wetlands include permanent shallow waters associated with Fame Cove and Corrie Island; seagrass beds of Myall River and Bombah Broadwater; rocky shores associated with the Myall lakes coastline, Yacaaba Head, Broughton Island and Little Broughton Island; and sandy shores, including beaches, dunes and Corrie Island. Rocky and sandy shores provide significant breeding and feeding habitat for shorebirds such as the little tern (*Sterna albifrons*) and pied oystercatcher (*Haematopus longirostris*).

5.2 Water quality

5.2.1 Oligotrophic clear waters

Clear waters with low nutrient levels are critical for ecosystem function and primary production. The Myall lakes act as a trap for nutrients, organic matter and sediment, and since the flushing time is very long, they act as a sink for nutrients, organic matter and suspended solids. The good water quality of the lakes is maintained through effective retention, recycling and removal of suspended solids, organic and inorganic nutrients, and other pollutants from water that flows through the lakes.

5.2.2 External nutrient loads

Maintaining the right balance of nutrients imported into the Myall lakes is critical to the ecological character of the site. The intensification of land use and removal of native vegetation in the catchment of the Myall lakes leads to increases in the amount of nutrients and sediments entering the lakes. Nutrients stimulate the growth of algae and the increased sediment loads reduce water clarity. Field sampling in subcatchments of the Myall lakes showed that the concentration of total nitrogen and total phosphorus in runoff is associated with land use, with agriculture contributing the highest amounts (31% of TN and 33% of TP) (Great Lakes Council 2009). Total annual sediment and nutrient loads are proportional to the subcatchment area. The largest catchment, the upper Myall River, contributed the largest average annual nutrient and sediment loads. Proportionally, however, urban areas contribute large loads (7% of the total load) relative to their area (1% of the total area) (Great Lakes Council 2009).

Sediments play a major role in recycling nutrients (especially nitrogen), maintaining water column production and possibly sustaining algal blooms in Bombah Broadwater (Palmer et al. 2000). Sediment deposition is an important mechanism of nutrient delivery to the Myall lakes, especially for phosphorus, and the sediments play important roles in nutrient retention and transformation within the system. Long water retention times allow sediments to settle out and allow primary producers (algae and macrophytes) to convert the nutrients to plant biomass, thus trapping them in internal nutrient cycling. The majority of nutrients in the lakes are stored as plant biomass, detritus or sediment, with a small amount remaining in the lakes' waters. It should be recognised that there is a flux of nutrients from sediment to the water column which are recycled, and that all new nutrients to drive increased water column production and algal blooms come from the catchment.

5.3 Salinity regime

The mosaic of open-water, fringing and tidal wetlands is dependent on the lakes' salinity regime, which ranges from near fresh in Myall Lake and Boolambayte Lake, to brackish in Bombah Broadwater, to estuarine/marine in the lower Myall River. The existing salinity regime is maintained by lake levels which change in response to variable rainfall and by sufficient inflow from rainfall to keep salinity levels low.

The salinity levels in Myall Lake, Two Mile Lake and Bombah Broadwater are largely influenced by freshwater inflows resulting from rainfall in the lakes' catchment. The salinity of Bombah Broadwater is determined by both freshwater inflow and estuarine influence, as the southern portion of Bombah Broadwater and lower Myall River are the only parts of the lake system that are subject to significant tidal flushing (Atkinson et al. 1981; Great Lakes Council 2009).

Salinity levels are also an important determinant of many of the lakes' aquatic biotic structures and processes. Low salinity in the lakes is necessary for the macrophyte beds and fringing wetlands (Figure 15). The presence of intertidal flats and maintenance of intertidal wetlands (mangrove and saltmarsh) depends on the current sea level remaining constant.

5.4 Wetland vegetation

Lake water levels, water quality and salinity determine wetland plant community structure. Varying water levels are essential to the maintenance of fringing wetlands which are flooded during periods of high runoff, whilst high water quality and low salinity is necessary for macrophyte beds and fringing wetlands.

5.4.1 Submerged aquatic vegetation

The submerged aquatic vegetation communities of the Ramsar site reflect the different salinities within the lakes system, with marine seagrasses in areas with higher salinities, and macrophytes and algae in freshwater lakes.

SAV is the fundamental driver of many aspects of the ecology of the Myall lakes. It supports many of the aquatic and avian food webs, provides shelter and nursery grounds for vertebrate and invertebrate aquatic species and is the basis for the formation of gyttja. The extent of submerged aquatic vegetation is dependent on sufficient light penetrating through the water column, requiring clear water and low turbidity.

5.4.2 Mangroves and saltmarsh

Mangroves along the lower Myall River are important habitats for fish, crabs, birds and other animals (Jelbart et al. 2007; Saintilan et al. 2007). They provide large amounts of organic matter, which is eaten by many small aquatic animals. In turn, these detritivores provide food for larger carnivorous fish and other animals. Mangroves also help maintain water quality by filtering silt from runoff and recycling nutrients.

Saltmarshes along the lower Myall River, at Corrie Island and along the shore of Smiths Lake play an important role as juvenile habitat for species such as bream and mullet (Connolly 2009). Crabs are common in saltmarsh communities, and are a significant food source for bream and other carnivorous species. Some species, such as common galaxias (*Galaxias maculatus*), deposit their eggs in saltmarsh vegetation.

5.4.3 Seagrasses

Seagrasses are particularly valuable as nursery, feeding and shelter areas for many aquatic animals, including commercially and recreationally important fish, mollusc and crustacean species (Jelbart et al. 2007).

5.4.4 Wet heaths

Large areas of freshwater wetlands are located in the area between Bombah Broadwater and Myall Lake (The Moors), the area between the upper Myall River and the northern shore of Bombah Broadwater, and along both sides of the lower Myall River downstream of Bombah Broadwater (Figure 5).

Vegetation on The Moors (on soils derived from Pleistocene sands) exhibits a high level of variation both structurally and floristically as a result of the range of soil conditions, including the degree of soil nutrient enrichment and drainage (Myerscough and Carolin 1986). Drainage appears to be the most important factor determining the location of vegetation communities across the low-lying parts of the Pleistocene sands, with vegetation changing from dry heath forest or dry heath, to wet heath, to swamp or swamp forest as the ground surface changes from freely drained ridges down towards the water table (Myerscough and Carolin 1986).

5.4.5 Freshwater fringing vegetation

The vegetation along the fringe of the freshwater lakes is dominated by broad-leaved paperbark (*Melaleuca quinquinervia*) and swamp she-oak (*Casuarina glauca*); it occurs on the slightly higher sandy soils of the lake margin and is dominated by large, older paperbarks with broad spreading canopies (Baumann 2008). The *Melaleuca–Casuarina* fringe forest community forms a narrow ecological zone and is adapted to changes in inundation, salinity and other factors resulting from varying lake levels (Baumann 2008).

5.4.6 Emergent vegetation

The emergent vegetation of the freshwater wetlands in the Ramsar site is dominated by broad-leaved cumbungi (*Typha* spp.), common reed (*Phragmites australis*), sedge (*Cladium procerum*), leptocarpus (*Leptocarpus tenax*) and scirpus (*Scirpus litoralis*) (Great Lakes Council 2009). Emergent vegetation grows in the shallow waters of the margins of Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater.

5.5 Significant biodiversity and habitats

Myall Lakes Ramsar site supports a high biodiversity, with 946 terrestrial plant, 22 wetland plant, 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species recorded (Atlas of NSW Wildlife; Appendices 1–5). The terrestrial species occur in a wide range of vegetation communities, from rainforest and wet sclerophyll vegetation to heathland and sand dune vegetation.

The Myall lakes provide a wide range of intertidal habitats for shorebirds, including coastal mudflats, sandy beaches, saltmarshes, brackish marshes, mangroves and swamp forests, as roosting, nesting, breeding, and feeding sites (Lane 1987). There are 298 species of birds recorded within Myall Lakes Ramsar site, including 22 species of migratory shorebirds under international treaties (JAMBA, CAMBA and ROKAMBA) (Table 13; Appendix 1). Intertidal habitats are the most important for the majority of shorebird species and are used by many migratory bird species. The little tern and sooty oystercatcher are known to breed in the Ramsar site (Fiona Miller 2010, pers. comm.).

5.6 Wetland dependent threatened species

The Ramsar site supports five wetland dependent species listed as threatened under the EPBC Act and in the IUCN Red List:

- Australasian bittern (*Botaurus poiciloptilus*)
- Freycinet's frog (*Litoria freycineti*)
- green and golden bell frog (*Litoria aurea*)
- green-thighed frog (*Litoria brevipalmata*)
- stuttering frog (*Mixophyes balbus*).

5.7 Special ecological features – gyttja

Gyttja is a layer of sediment formed from the decomposition of aquatic plants, and the Myall lakes system is the only location where it occurs in Australia. Gyttja is believed to be largely a product of the decay of charophytes and macrophytes (*Najas* spp.) and algal (primarily cyanobacterial) colonies. The critical processes that support gyttja are the development of macrophyte beds and an absence of physical disturbance of the gyttja layer. Gyttja is important for determining the distribution of macrophytes in Myall Lake, Boolambayte Lake and Two Mile Lake.

5.8 Recreational and aesthetic amenity

The Myall lakes' attractiveness for recreation and their aesthetic amenity is determined by maintaining high water quality in the lakes and other wetlands, together with maintaining the site's naturalness. One of the primary reasons for establishing Myall Lakes National Park was to protect the area's naturalnesss and the lakes' attractiveness for recreation, so that recreational opportunites could continue to be provided on the natural waterways with their high water quality.

Recreational use is highly variable and is based on individual preference. Probably the three most important values of the Ramsar site for recreational attraction are its naturalness (largely due to terrestrial biota), fishing (abundance of fish), and clean water (clarity and low nutrient levels). Perhaps the largest possible interruption to recreational amenity comes from the irregular development of harmful cyanobacterial blooms. Critical processes thought to contribute to bloom development are sustained high flows from the catchment which simultaneously reduce the salinity in Bombah Broadwater to very low levels and provide large loads of sediments which reduce water clarity and deliver external nutrients to stimulate algal growth.

6 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 or services, 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 diversity of wetland types makes it difficult to develop a single, detailed conceptual model for this Ramsar site. In order to demonstrate the components, processes and services of some of the site's major wetland types (Figure 22), detailed conceptual models have been developed for freshwater and fringing wetlands (Figure 23), brackish waters, rivers, creeks and streams (Figure 24), and beaches and rocky shores (Figure 25).

The principal components and processes of the Ramsar site which determine the character of the wetlands are climate, geomorphic setting, hydrology and terrestrial vegetation. Climate, through precipitation, wind, evaporation and transpiration, influences surface and groundwater flows and hydrology. Geomorphic setting (or geomorphology) determines the size, shape and location of wetlands in the landscape, as well as water sources, the physicochemical properties of each wetland, and soils. Hydrology determines the flow of water into and out of the wetlands, the nature of each wetland (fresh, brackish or saline), and lake levels. Terrestrial vegetation in the lakes' catchment influences the input of sediments and nutrients to the lakes, thereby helping to maintain water quality, and reduces the variability of flows in the rivers and streams in the Ramsar site.

The lakes' water quality and macrophyte beds, which dominate the lakes' vegetation, are critical to ecosystem functioning, and are important for driving the food web and maintaining habitat for macroinvertebrates, fish and waterbirds. Vegetation communities in the lakes and freshwater wetlands are derived from the frequency, regularity, depth and duration of inundation. In turn these provide habitat for waterbirds and frogs. The annual macrophytes are thought to be the major source of material for gyttja, which is a key feature and is believed to have a considerable influence on the presence and distribution of many other biota in the lakes.

The associated fringing wetlands are much more strongly associated with terrestrial flora, and consist largely of low-lying lands which are inundated when lake levels rise due to either tidal forcing during spring tides or high flows from the catchment. The perched dune wetlands (wet heaths) of The Moors form in the interdune swales along the eastern margin of the Ramsar site. They are also dominated by terrestrial vegetation and would be used by a wide range of avian and amphibian fauna (Figure 23).

The open ocean beaches and dunes also provide extensive inter- and supratidal habitat for resident and migratory shorebirds (Figure 24). Intertidal wetlands consist of unconsolidated tidal flats composed of sands and muds, usually backed by mangroves and saltmarsh, and are also important for resident and migratory shorebirds. The terrestrial vegetation surrounding the wetlands provides habitat for a wide range of biota, including many threatened species.

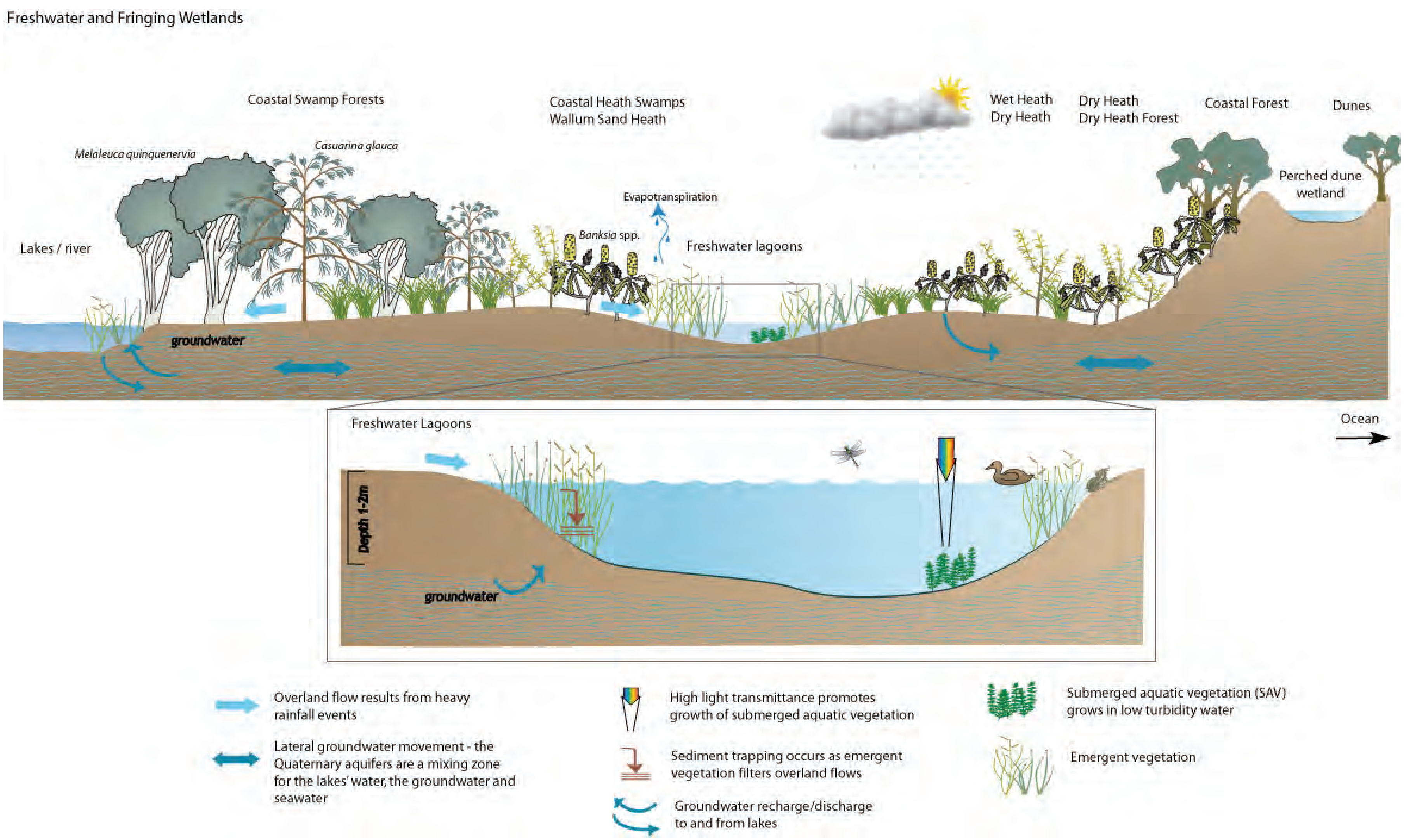


Figure 23 **Conceptual model of freshwater and fringing wetlands**

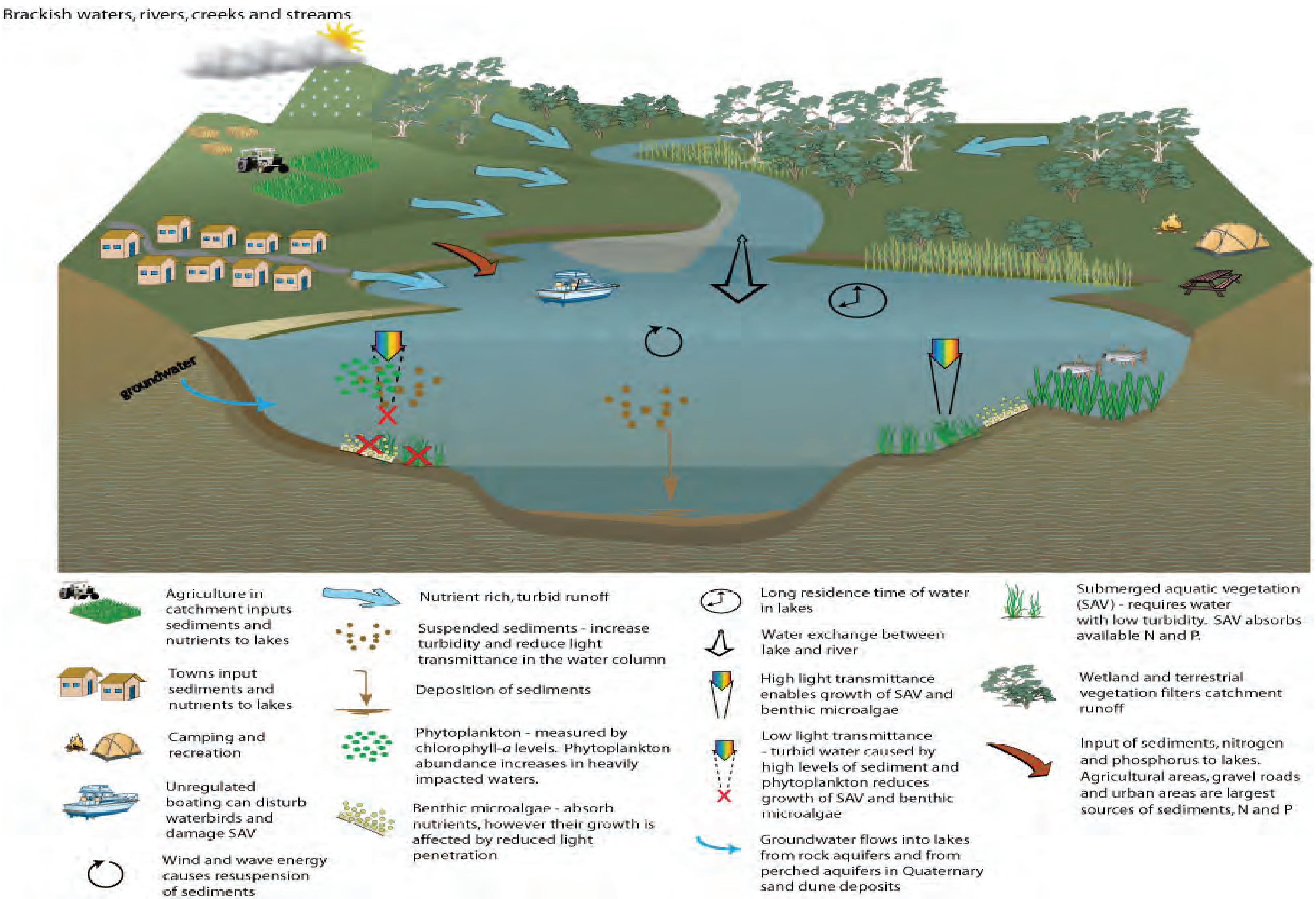


Figure 24 Conceptual model of brackish waters, rivers, creeks and streams

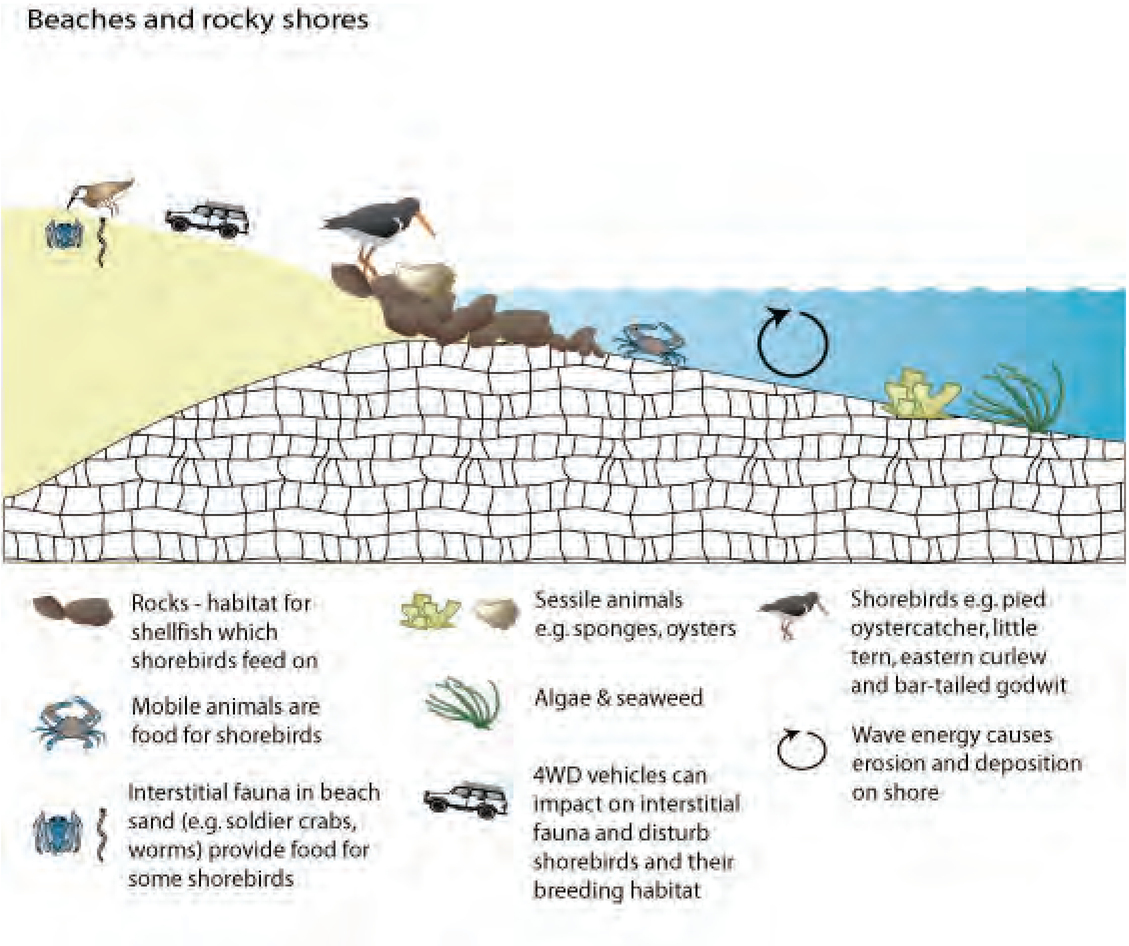
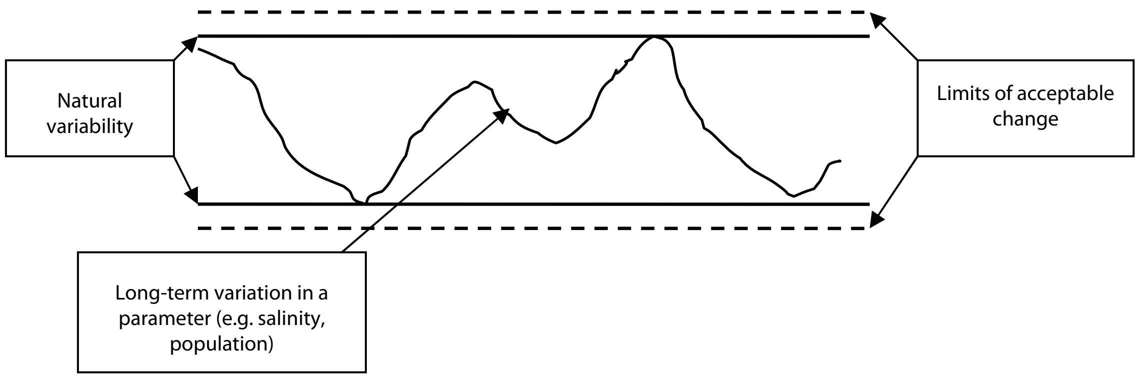


Figure 25 Conceptual model of beaches and rocky shores

7 Limits of acceptable change

A key requirement of an ECD is to define limits of acceptable change (LACs) for the critical components, processes and services of the wetlands. Limits of acceptable change are defined as 'the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland' (DEWHA 2008) (Figure 26).



After Philips and Muller (2006)

Figure 26 Limits of acceptable change

As a signatory to the Ramsar Convention, Australia is obliged to manage its Ramsar sites to maintain the ecological character of each site. LACs are intended to provide thresholds for critical components, processes or services of the wetlands that can be used to indicate when and by how much the ecological character of a site has changed or is changing.

LACs should be based on quantitative information from relevant monitoring programs, scientific papers, technical reports, or other publications and information about the wetlands or input from wetland scientists and experts. In most cases, however, the datasets are not ideal but enough information may be available to set LACs based on expert judgement. Confidence levels for LACs for Myall Lakes Ramsar site have been based on the reliability of the data used to determine each LAC (duration of data collection, number of measurements, consistency of sampling over time) and the known or expected variability of each measure. High, medium and low confidence levels indicate the following:

- high – reliable or long-term data for baseline condition; LACs derived from other reputable studies or guidelines, for example, Water Quality Improvement Plan (Great Lakes Council 2009), ANZECC and ARMCANZ guidelines (ANZECC & ARMCANZ 2000); variability of measure well understood
- medium – less long-term data for baseline condition, or data available but some uncertainty about direct applicability of LACs to measure; variability of measure understood to certain extent
- low – little long-term data or insufficient data collected using consistent methodology; LACs largely based on expert opinion; variability of measure not well understood.

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 LAC does not necessarily indicate that there has been a change in ecological character.
- While the best available information has been used to prepare this ECD and define LACs for the site, in many cases only limited information and data are available.
- LACs in Table 17 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.

It should also be noted that there may be a range of processes occurring outside of the site that could affect the exceedance of a particular LAC. For example, the abundance or diversity of migratory species that use Myall Lakes Ramsar site maybe impacted by activities elsewhere in the flyway.

The primary data that has been used for setting LACs for Myall Lakes Ramsar site includes information on water quality from the Great Lakes Water Quality Improvement Plan (Great Lakes Council 2009) and presence/absence of information on threatened species. There is generally little reliable long-term data that can be used to establish baselines and set LACs for most of the site's critical components, processes and services. Where there is little data or information for a particular component, process or service, a LAC has not been set and 'insufficient data' has been entered in the 'Limit of acceptable change' column in Table 17. The monitoring activities and programs detailed in Table 19 are intended to primarily address the knowledge gaps for such critical components, processes or services and provide data for possibly defining LACs in the future.

LACs that have been derived in this ECD should be reviewed and revised over time with improved data and understanding.

Table 17 Limits of acceptable change for critical components, processes and services

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Mosaic of natural or near-natural wetlands			
Freshwater and fringing wetlands	Area of wetlands and vegetation communities – data gaps.	Insufficient data LAC should be set in future when better information becomes available.	
Brackish waters	See **Water quality** and **Submerged aquatic vegetation** (SAV) in this table for decription of baseline condition. Water quality and SAV have been recommended as surrogates, as health of brackish water wetlands can be best measured using these characteristics.	See LACs for **Water quality** and **Submerged aquatic vegetation** in this table.	
Mangroves and intertidal flats	See **Mangroves and saltmarsh** in this table for description of baseline condition. The extent of mangrove and saltmarsh is considered to be an appropriate measure of this wetland type.	See LACs for **Mangroves and saltmarsh** in this table.	
Rivers, creeks and streams	No information	LAC should be set in future when better information becomes available.	
Marine coast	No information	LAC should be set in future when better information becomes available.	

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Water quality			
Oligotrophic clear water (low nutrient clear water)	**Chlorophyll-a** Mean concentrations of chlorophyll-a over 1999–2007 collated from a range of data sources by Great Lakes Council (2009) are: Myall Lake: 2.9 µg/L Boolambayte Lake: 2.5 µg/L Bombah Broadwater: 3.5 µg/L. (Note: maximum and minimum data are not available.)	LACs are based on 80th percentile values as per ANZECC guidelines. Annual mean concentrations of chlorophyll-a in three consecutive years should not exceed: Myall Lake: 3.2 µg/L Boolambayte Lake: 3 µg/L Bombah Broadwater 3 µg/L. Note: Myall Lake and Boolambayte Lake are classified as high conservation value lakes, and Bombah Broadwater is classified as a moderately disturbed lake (Great Lakes Council 2009).	Medium
	Turbidity Turbidity levels were measured on four occasions over 1999–2002 (P. Scanes 2011, pers. comm.). Sampling periods were April–July 1999, April–July 2000, December 2001, and January 2002. It must be noted that this was a very wet period. n* / Median (NTU) / Range (NTU) Myall Lake: 20 / 4.2 / 1.0–19.0 Boolambayte Lake: 31 / 6.5 / 1.0–39.7 Bombah Broadwater: 46 / 18.5 / 3.4–160.0 * number of measurements	LACs are based on 80th percentile values as per ANZECC (2001) guidelines. Annual median concentrations in three consecutive years should not exceed: Myall Lake: 2.6 NTU Boolambayte Lake: 2.6 NTU Bombah Broadwater: 2.6 NTU.	Low

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
	Secchi depth Macrophytes are limited by light availability. Secchi depth measures light penetration into water. Secchi depths for each lake over 1999–2002 (data provided by NSW Office of Water) are presented below. n* / Median (m) / Range (m) Myall Lake 34 2.0 0.8–3.5 Boolambayte Lake 29 2.5 0.5–4.5 Bombah Broadwater 51 1.75 0.5–3.25 * number of measurements	LACs are based on expert opinion of the expected depth of light penetration to enable growth of macrophytes. Note: these LACs are based on a Secchi depth ratio of 1:1 for plant response to light, which is relevant for seagrasses, but has not been proved for macrophytes (Peter Scanes, pers. comm. 2010). Annual median Secchi depth should not be less than: Myall Lake: 1.75 m Boolambayte Lake: 1.75 m Bombah Broadwater: 1.75 m.	High High Low
External nutrient load	External nutrient loads govern nutrient availability for plankton growth. The Great Lakes Water Quality Improvement Plan (GLC 2009) modelled annual average loads to the Myall lakes for total nitrogen, total phosphorus and total suspended solids to be (in tonnes): TN / TP / TSS Myall Lake 4.6 0.55 754 Boolambayte Lake 5.2 0.30 462 Bombah Broadwater 43.6 4.61 8165	The Water Quality Improvement Plan did not establish the range of variability based on these models. It did however model desired reductions in load to achieve chlorophyll-a targets. These indicate that no change is required for the Myall and Boolambayte lakes and that a reduction of 22% for TN, 30% for TP and 15% for TSS is desired to improve the health of the Broadwater. From this study it is therefore interpreted that the LAC be defined as no increase from the modelled average annual loads for all lakes as defined in the baseline. The LAC for chlorophyll-a levels can also be used as an indirect measure of nutrient loads.	Low

<table>
<tr><th>Critical component, process or service</th><th>Baseline condition and range of natural variation where known</th><th>Limit of acceptable change</th><th>Confidence in LAC</th></tr>
<tr><td colspan="4">Salinity regime</td></tr>
<tr><td>Salinity levels</td><td>Variable salinity levels in response to climatic conditions (predominantly rainfall) are characteristic of the Myall lakes and should be maintained. Salinity levels were recorded several times a month over 1999–2002 at 12 locations in the lakes (P. Scanes 2011, pers. comm.).

Salinity level (measured as electrical conductivity in milliSiemens per centimetre – mS/cm) was recorded for each site.

<table><tr><th></th><th>n*</th><th>Median (mS/cm)</th><th>Range (mS/cm)</th></tr><tr><td>Myall Lake</td><td>128</td><td>4.5</td><td>1.7–5.8</td></tr><tr><td>Boolambayte Lake</td><td>181</td><td>4.4</td><td>0.4–15.0</td></tr><tr><td>Bombah Broadwater</td><td>360</td><td>4.0</td><td>0.1–50.6</td></tr></table>
*The number of measurements (n) was not consistent between the lakes.

The sample sites in the Myall lakes included Mid-Myall, Myall Lake at Bungwahl and Shellys, Neranie Bay.

The sample sites in Boolambayte Lake included Boolambayte Creek, Korsmans Landing and Violet Hill.

The sample sites for Bombah Broadwater included Bombah Point, Mid-Broadwater, Mungo Brush, upper Myall River mouth (at Broadwater), Tamboy and White Tree Bay.</td><td>There should be no change in salinity for all the lakes in the Ramsar site outside the natural variability. Currently, natural variability in mS/cm has been defined as (P. Scanes 2011, pers. comm.):

Myall Lake: 1.7–5.8

Boolambayte Lake: 0.4–15.0

Bombah Broadwater: 0.1–50.6.</td><td>Low</td></tr>
</table>

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Wetland vegetation			
Submerged aquatic vegetation	Extent of SAV in 2001–02 for all lakes – maximum extents provided as some species have strong seasonal fluctuations (Dasey et al. 2004): *Vallisneria gigantea*: 377 ha (max. – all seasons) *Ruppia megacarpa*: 710 ha (max. – all seasons) *Myriophyllum salsugineum*: 140 ha (max. – all seasons) *Potamogeton perfoliatus*: 568 ha (max.), 0 ha (min.) Charophytes: 4159 ha (max.), 2186 ha (min.) *Najas marina*: 5443 ha (max), 526 ha (min.) Macroalgal assemblage: 210 ha (all seasons) Distribution maps for 2001–02 show seasonal patterns but there are no data to assess the inter-annual changes.	Insufficient data There is limited understanding of the natural variability of the extent of SAV, both within seasons and between seasons in the Myall lakes. LAC should be set when more data becomes available.	
Mangroves and saltmarsh	Area of mangroves in the Ramsar site at time of listing is not known. Area of mangroves increased by 28 hectares between 1985 and 2005, from 102 ha in 1985 to 130 ha in 2005 (Williams et al. 2006).	Insufficient data There is limited baseline information and little understanding of what would constitute a significant change in mangrove extent to result in a change in character. LAC should be set in the future when better information becomes available.	
	Area of saltmarsh in Ramsar site at time of listing is not known. Area of saltmarsh increased by 11 hectares between 1985 and 2005, from 178 ha in 1985 to 189 ha in 2005 (Williams et al. 2006).	Insufficient data There is limited baseline information and little understanding of what would constitute a signiciant loss in saltmarsh extent to result in a change in character. LAC should be set in the future when better information becomes available.	

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Seagrasses	The area of seagrass in the lower Myall River in 1985 was 273.6 ha, the area mapped in 2005 was 150.3 ha, representing a loss of 123.3 ha of seagrass (Williams et al. 2006). These studies were for a larger area and it is not evident how much of seagrass area is within the Ramsar site. No data are available to assess changes in area between years and within years. It is, however, known that abundance declines in winter.	Insufficient data. No data are available to assess changes in area between years and within years. It is, however, known that abundance declines in winter. There is limited baseline information and little understanding of what would constitute a signiciant loss of sea grass extent to result in a change in character. LAC should be set in the future when better information becomes available.	
Wet heaths	Freshwater wetlands on The Moors are comprised of several vegetation communities, principally dry heath forest, wet heath forest, swamp forest, swamp, dry heath and wet heath (Myerscough and Carolin 1986). Extent of wet heaths at time of listing is not known.	There is no baseline information. LAC should be set in the future when better information becomes available.	
Freshwater fringing vegetation	Occurs on slightly higher sandy soils of lake margins and is dominated by broad-leaved paperbark (*Melaleuca quinquinervia*) and swamp she-oak (*Casuarina glauca*) (Baumann 2008). Community is adapted to changes in inundation, salinity and other factors resulting from varying lake levels (Baumann 2008). Extent at time of listing is not known.	There is no baseline information. LAC should be set in the future when better information becomes available.	
Emergent vegetation	Emergent vegetation grows in the shallow waters of the lakes' margins, and is dominated by broad-leaved cumbungi (*Typha* spp.), common reedgrass (*Phragmites australis*), sedge (*Cladium procerum*), leptocarpus (*Leptocarpus tenax*) and scirpus (*Scirpus litoralis*) (Great Lakes Council 2009). Extent at time of listing is not known.	There is no baseline information. LAC should be set in the future when better information becomes available.	

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Significant biodiversity and habitats			
Plants	There are 946 terrestrial and 22 wetland plant species recorded in the Ramsar site from vegetation surveys since 1999 (Hunter et al. 2000). Comprehensive information on vegetation communities in the Ramsar site is a knowledge gap.	Insufficient data. LAC should be set in the future when better information becomes available.	
Animals	There are 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species recorded in the Ramsar site, based on partial fauna surveys and other records (Atlas of NSW Wildlife). Comprehensive information on fauna in the Ramsar site is a knowledge gap.	Insufficient data. LAC should be set in the future when better information becomes available.	
Habitat for birds	**Migratory shorebirds – habitat and diversity** The number of shorebird species in Ramsar site at time of listing is not known. Twenty-two species of migratory shorebirds are known from Ramsar site in 2010 (Atlas of NSW Wildlife; David Turner 2011, pers. comm.; Nick Carlile 2011, pers. comm.).	There is insufficient data on the extent of shorebird habitat. There is little understanding of what would constitute a significant change in shorebird species diversity to result in a change in character for this site. LAC should be set in the future when better information becomes available.	
	Migratory shorebirds – abundance Abundance of shorebirds at time of listing and in 2010 is not known.	Insufficient data LAC should be set in the future when better information becomes available.	

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
Wetland dependent threatened species			
Diversity and abundance of wetland dependent threatened species	**Australasian bittern (*Botaurus poiciloptilus*)** There are eight records from the Ramsar site in 1977–80 (Atlas of NSW Wildlife). The species is cryptic and very difficult to observe and confirm presence in site. It is occasionally sighted in the Ramsar site. Population size is not known.	Species is recorded three out of every five years when appropriate surveys have been undertaken. Population size – insufficient data LAC should be reviewed in the future if more data become available on abundance of species.	Low – lack of long-term data on population numbers
	Freycinet's frog (*Litoria freycineti*) There are 23 records from the Ramsar site in 1974–2008 (Atlas of NSW Wildlife). Population size is not known.	Species is recorded three out of every five years when appropriate surveys have been undertaken. Population size – insufficient data LAC may be reviewed in the future if more data become available on abundance of species.	Low – lack of long-term data on population numbers
	Green and golden bell frog (*Litoria aurea*) There are 17 records in the Ramsar site in 1971–99 (Atlas of NSW Wildlife). These were recorded from four locations in 2000–10: Mungo Brush, The Moors, on Broughton Island, and at Neranie Bay in Myall Lake (Susanne Callaghan 2010, pers. comm.). The species is known to breed on Little Broughton Island where the population is not infected with chytrid fungus (Susanne Callaghan 2010, pers. comm.). Population size is not known.	Species is recorded three out of every five years when appropriate surveys have been undertaken. Populations continue to be recorded at Mungo Brush, The Moors, on Broughton Island, and at Neranie Bay in Myall Lake. Population size – insufficient data LAC may be reviewed in the future if more data become available on population numbers and breeding frequency.	Low – lack of long-term data on population numbers and breeding events at all locations.
	Green-thighed frog (*Litoria brevipalmata*) There are eight records from the Ramsar site between 1995 and 1996 (Atlas of NSW Wildlife). Population size is not known.	Species is recorded three out of every five years when appropriate surveys have been undertaken. Population size – insufficient data LAC may be reviewed in the future if more data becomes available on population numbers and breeding frequency.	Low – lack of long-term data on population numbers

Critical component, process or service	Baseline condition and range of natural variation where known	Limit of acceptable change	Confidence in LAC
	Stuttering frog (*Mixophyes balbus*) There are nine records from the Ramsar site in 1993–2001 (Atlas of NSW Wildlife). Population size is not known.	Species is recorded three out of every five years when appropriate surveys have been undertaken. Population size – insufficient information LAC may be reviewed in the future if more data becomes available on population numbers and breeding frequency.	Low – lack of long-term data on population numbers
Special ecological features - gyttja			
Extent of gyttja beds	Gyttja occurred in Myall Lake, Boolambayte Lake and Two Mile Lake at the time of listing. Estimated extent of gyttja in all lakes in 2001–02 (measured by GIS) (Dasey et al. 2004) is: • concentrated gyttja: 1390 ha • less concentrated gyttja: 6375 ha • total area of gyttja: 7765 ha Variation in the extent of gyttja both within years and between years is not known.	Occurrence of gyttja. Insufficient data to estimate significant changes in extent of gyttja.	Low – extent of gyttja estimated only or measured by GIS
Recreational and aesthetic amenity			
Number of visitors Good water quality	Visitors are generally attracted to the Myall lakes for water sports and the lakes' aesthetic amenity. Visitor rates are relatively constant unless conditions are unsuitable, for example when there are cyanobacterial blooms. Actual number of visitors not known – estimated at 100,000 per annum. See **Water quality** in this table for description of baseline condition.	Visitor numbers – insufficient data. Water quality – see LACs for **Water quality** in this table.	

8 Threats to ecological character

The primary threats to the ecological character of Myall Lakes Ramsar site are catchment land uses, introduced species, fire, human access and recreational use, and climate change.

Changes in land use in the lakes' catchment can lead to increased sediment and nutrient loads entering the lakes. Higher sediment and nutrient levels in the lakes can affect water quality. Increased turbidity will lead to reduced growth of SAV and benthic microalgae, impact on the foodweb and habitats for threatened species such as amphibians, and may contribute to outbreaks of blue–green algae.

Introduced plants can compete with aquatic plants and invade terrestrial vegetation communities such as coastal heaths, and vertebrate pests can invade habitat for shorebirds and impact directly on threatened species and migratory birds.

High frequency fires can affect vegetation communities by changing species composition and reducing species diversity, and can adversely affect fauna habitats.

Human access and recreational use can directly affect fauna habitats such as shorebird habitats on beaches and dunes, disturb submerged aquatic vegetation and gyttja, lead to more frequent wildfires, and facilitate the introduction of weeds and pathogens.

Climate change, in particular increased temperatures and more varied rainfall, can affect many of the site's components and processes, including the lakes' hydrology, as a result of more intense rain and longer droughts, the fire regime in terrestrial vegetation communities, and plant and animal habitats.

8.1 Catchment land uses

The periodic excessive phytoplankton growth, including toxic blue–green algal blooms, shows that the system is very sensitive to increases in nutrient levels. External nutrient loadings (associated with runoff from the catchment upstream of the Ramsar site) contribute to the nutrient levels in the lakes and, if in excess, pose a growing threat to the integrity of the system. The extent of SAV in the lakes is dependent on sufficient light penetrating through the water column. Increased water turbidity, which is associated with inflow carrying excessive nutrients and sediments from the catchment, will decrease the area of suitable habitat for SAV.

Coastal Catchment Initiative (CCI) studies found that pasture land use along the Myall River valley was the main source of surface sediments, and that forested areas contributed relatively small amounts of sediments in the model (Figure 16) (Great Lakes Council 2009). Overall, agricultural lands and gravel roads are the largest sources of sediments in the catchment, together contributing 79% of TSS entering the lakes (Figure 13) (Great Lakes Council 2009).

The average annual TSS load to the Myall lakes is predominantly related to the subcatchment area (Great Lakes Council 2009). The largest subcatchment, the upper Myall River (which includes its major tributary, the Crawford River), contributed the largest annual nutrient and sediment loads, followed by the Bombah Broadwater subcatchment and then by the Boolambayte Creek subcatchment (Table 4).

There is a distinct trend in the concentration of nutrients in runoff associated with the level of land development, with agricultural land contributing the highest loads (31% of TN and 33% of TP) to the lakes (Figure 16) (Great Lakes Council 2009). Whilst the contribution of nutrients from urban areas is small – 7% of TN and 7% of TP – it is proportionally large considering the very small area (1%) of urban areas in the lakes' catchment.

Sediments play a major role in recycling nutrients (especially nitrogen), maintaining water column production and possibly sustaining algal blooms in Bombah Broadwater (Palmer et al. 2000). Sediment deposition is an important mechanism of nutrient delivery to the Myall lakes, especially for phosphorus, and the sediments play important roles in nutrient retention and transformation in the system. Sedimentation, associated with catchment runoff, is an important source for both nitrogen (mainly linked to organic matter) and phosphorus (associated with organic matter and fine-grained clay materials) for the lakes (Dasey et al. 2004).

The Water Quality Improvement Plan proposed remediation actions for land uses that are major sources of sediments, in order to reduce sediment and nutrient loads entering the lakes, and thereby reduce the potential for growth of blue–green algae and reduction in light availability to submerged aquatic vegetation (Great Lakes Council 2009). Those remediation actions include groundcover management (sustainable grazing), nutrient management (fertilisers), dam management (refurbishment and decommissioning), riparian remediation, and unpaved road remediation (Great Lakes Council 2009).

As agricultural activities are the major source of sediments, it is expected that expansion of such activities, as well as poor agricultural practices such as excessive fertiliser use, excessive grazing and use of fire, would increase sediment and nutrient loads to the lakes (Stephen Smith 2011, pers. comm.). Clearing associated with residential developments and roadworks in the lakes' catchment would also increase sediment and nutrient loads; however, there are few areas in the catchment where significant urban development is expected to occur (Great Lakes Council 2009).

Hunter–Central Rivers Catchment Management Authority and Great Lakes Council are working in partnership with the community, industry and the NSW Government to deliver on-ground actions to improve land management activities in the Myall lakes catchment.

Coal seam gas exploration and mining

The catchment of the Myall lakes is within the boundaries of two petroleum exploration licences issued by the NSW Government for the purposes of exploring (seismic testing, sample drilling) for coal seam gas reserves. Exploration is currently being undertaken under the licences, and extraction in the catchment is proposed by one of the licence holders.

Potential impacts of coal seam gas exploration and extraction include (US EPA 2010):

- pollution of water resources by chemicals and fluids used in the hydraulic fracturing process, and on-site runoff of chemicals and fluids
- reduction in local drinking water resources by the withdrawal of water for use during hydraulic fracturing
- cross-contamination of hydraulic connections between ground and surface waters.

Concerns about the extraction of coal seam gas in NSW have resulted in a current moratorium on the use of potentially harmful chemicals such as BTEX used in hydraulic fracturing, and a temporary ban on the use of hydraulic fracturing to release coal seam gas. Concerns about extraction of groundwater as part of resource exploration activities has resulted in the introduction of the Aquifer Interference Regulation 2011 by the NSW Government. The Regulation requires that petroleum exploration licence holders undertaking new mining and petroleum exploration that take more than three megalitres per year from groundwater sources hold a water access licence. The Regulation applies to activities associated with coal seam gas exploration.

As a result of the exploration in the Ramsar site's catchment, coal seam gas extraction and associated activities, such as the removal of groundwater and the disposal of waste water, are considered to be an emerging threat to the wetland values of the Ramsar site.

8.2 Introduced species

8.2.1 Weeds

There are a number of aquatic weeds which are present in the Ramsar site or occur within the lakes' catchment, potentially threatening the site's values. Salvinia (*Salvinia molesta*) and parrot's feather (*Myriophyllum aquaticum*) have been found within the Ramsar site and require monitoring outside of the site to establish their extent. There is a risk of other aquatic weeds being introduced to the lakes, such as *Sagittaria graminae* which is known to occur in the upper Myall River catchment, especially after heavy rain and floods.

Encroachment and competition from aggressive introduced weeds is the main threat to existing terrestrial vegetation. The main concerns are bitou bush (*Chrysanthemoides monilifera*) and slash pine (*Pinus elliotii*). Bitou bush occurs in the eastern part of the Ramsar site along much of the coastline dune systems, on headlands, around the river and lake edges and is encroaching into the Eurunderee sand mass between the lakes and coastline. It has the potential to spread further into native vegetation communities growing on sands, particularly after fire or other types of disturbance. Slash pine occurs in the southern part of the Ramsar site around the lower Myall River. A relict plantation remnant adjacent to the river has generated pine wildlings which are spreading into native vegetation communities.

Other weeds of concern include lantana (*Lantana camara*), climbing asparagus and prickly asparagus (*Protasparagus* spp.). There are many other weeds in the Ramsar site requiring control, including a number of isolated patches of noxious weeds such as blackberry (*Rubus fruiticosus*) and Noogoora burr (*Xanthium* spp.), and environmental weeds such as cassia (*Senna pendula*).

Weeds in the Ramsar site are controlled by OEH under the provisions of the *NPWS Hunter Region Pest Management Strategy 2008-2011* (DECC 2007b). OEH also works in cooperation with Hunter – Central Rivers Catchment Management Authority and Great Lakes Council in identifying invasive weeds in the lakes' catchment which could threaten the Ramsar site's values.

Myrtle rust

Myrtle rust (*Uredo rangeii*), an introduced fungus known to infect plants in the Myrtaceae family, has recently been discovered in national parks and state forests on the NSW Central Coast (about 150 km south of the Myall Lakes Ramsar site). It has now been recorded on the NSW coast from the Shoalhaven region near Jervis Bay to the Queeensland border.

Myrtle rust's hosts include several plants known in the Ramsar site, including broad-leaved paperbark (*Melaleuca quinquenervia*, a dominant tree in the freshwater fringing wetlands), willow bottlebrush (*Callistemon salignus*), turpentine (*Syncarpia glomulifera*), and scrub turpentine (*Rhodamnia rubescens*) (I&I NSW 2010).

Its impacts on native *Myrtaceae* species is not well known; however, quarantine measures introduced in 2010 to halt its spread in Gosford and Wyong local government areas do not appear to have been effective (I&I NSW 2010). It is considered an emerging threat to vegetation in the Ramsar site at this stage.

8.2.2 Vertebrate pests

The main vertebrate pests in the Ramsar site are foxes, pigs, cats and rats (for example, on Broughton Island).

Foxes are a threat to ground-dwelling mammals, amphibians and shore birds, including the pied oystercatcher (*Haematopus longirostris*), which breeds in dunes on the beaches of the Ramsar site, and migratory birds such as the little tern (*Sterna albifrons*), which is predated on by foxes.

Feral cats and introduced rats are also threats to migratory birds and other ground-dwelling animals. Rats on Broughton Island are a threat to nesting birds, including the short-tailed shearwater (*Puffinus tenuirostris*), sooty shearwater (*P. griseus*) and wedge-tailed shearwater (*P. pacificus*), which are known to breed on the island.

Pigs are a threat to amphibians through their disturbance to swamps and other wetland areas which provide habitat for several threatened frogs. Pigs also cause freshwater streams to become muddy, resulting in reduced water quality in some areas of the site's wetlands due to increased turbidity.

Vertebrate pests in the Ramsar site are controlled by OEH under the provisions of the *NPWS Hunter Region Pest Management Strategy 2008-2011*, which identifies pigs and foxes as priorities for control in Myall Lakes National Park (DECC 2007b).

8.3 Fire

The impacts of inappropriate fire regimes (frequent, severe fires) across the Ramsar site include:

- changes to vegetation communities and therefore fauna habitats
- reductions in abundance or local extinction of endemic species
- extinction of threatened species from the site
- increased runoff and sediments and nutrients into the lakes
- invasion of introduced species.

Inappropriate fire regimes are a significant threat to native vegetation communities, and high frequency fire is listed as a key threatening process under the TSC Act. Vegetation communities can be altered and species eliminated if the frequency of fire is too great to enable species to maintain their life cycles. The alteration of vegetation communities by frequent fire also has an impact on animals that depend on habitats in those vegetation communities for their survival.

Frequent fires as the result of arson, particularly in parts of the Ramsar site accessible by vehicle, are a threat to vegetation communities, reducing species abundance and diversity (for example, in heathland) and impacting on fauna habitats (for example, for birds and ground dwelling mammals).

Significant fire seasons occurred in 1968–69 (>10,800 ha burnt), 1980–81 (12 fires, >5015 ha burnt), 1990–91 (33 fires, 5924 ha burnt), 1997–98 (two fires, 4200 ha burnt) and 2000–01 (eight fires, 5876 ha burnt) (NPWS 2002). Bushfires starting in the reserves have caused considerable property damage, particularly to adjacent pine plantations, and have required the evacuation of adjacent towns or of more than 2000 campers on at least three occasions. Suspected arson and unknown causes account for 81% of bushfires, with few bushfires being started by lightning. Since 2004, when Old Mining Road (between Mungo Brush and Seal Rocks) was closed to public access, there has been one wildfire caused by lightning in that part of the Ramsar site, and no instances of arson (Fiona Miller 2010, pers. comm.).

Management of fire in the Ramsar site is undertaken by OEH under the provisions of the *Rural Fires Act 1997* and under the fire management strategy for Myall Lakes National Park, Corrie Island Nature Reserve and Little Broughton Island Nature Reserve (NPWS 2003).

8.4 Human access and recreational use

The major threats caused by human access and recreational use are impacts of boating on aquatic vegetation, gyttja and fauna; impacts on birds and other fauna of four-wheel driving on beaches; changes to vegetation communities resulting from higher fire frequency; and introduction of weeds and pathogens to native vegetation communities.

Inappropriate boating activities (such as use of motor boats at high speeds and too close to lake edges) present a threat to the site's ecological character, including damage to submerged aquatic vegetation and to gyttja, disturbance of waterbirds, and re-suspension of sediments resulting in increased turbidity (Stephen Smith 2011, pers. comm.).

Shorebirds such as the pied oystercatcher (*Haematopus longirostris*) and little tern (*Sterna albifrons*), which breed in sand dunes and feed on beaches, are directly threatened by human acitivities such as four-wheel driving. Use of four-wheel drive vehicles on beaches can also harm interstitial inverterbrates in beach sand, which are a source of food for shorebirds (Stephen Smith 2010, pers. comm.).

Other activities which can have impacts on food sources for fauna include bait gathering on rocky ocean shores and use of hauling nets which can affect the benthic invertebrate flora and fauna of the Ramsar site (Steve Smith 2010, pers. comm,).

Vehicle access to the Ramsar site can result in higher fire frequency as a result of arson, and in the introduction of invasive weeds and potentially harmful pathogens such as *Phytophthera cinnamomi*, a fungus causing root rot in eucalypts (Stephen Smith 2010, pers. comm.).

Access to the Ramsar site and recreational use of the site is managed under the provisions of the *Myall Lakes National Park, Little Broughton Island and Stormpetrel Nature Reserves Plan of Management* (NPWS 2002).

8.5 Climate change

In general, climate change is expected to have a wide range of impacts on species and ecosystems, including changes in species distributions and abundances, ecosystem processes, interactions between species and various threats to biodiversity (Dunlop and Brown 2008). Four threats that will be affected by climate change and will be particularly hard to manage due to strong biophysical and social dimensions are:

- the arrival of new (native and exotic) species in a region
- altered fire regimes
- land use change
- altered hydrology.

Differences between species and the complexities of natural ecosystems will lead to uncertainties about the exact nature of change in biodiversity; key uncertainties concern the dynamics and processes of ecological changes and the role that habitat variability across the landscape plays in mediating changes (Dunlop and Brown 2008).

The projected changes in climate and their expected biophysical responses have been modelled for the Hunter region of NSW, which includes the Myall lakes (DECC 2008; DECCW 2010c). The expected regional climatic changes are:

- Temperatures are almost certain to rise.
- Rainfall is likely to decrease in winter and increase in summer.
- Increased evaporation is likely in all seasons.
- The impact of El Niño – Southern Oscillation is likely to become more extreme.

The expected impacts on land in the Hunter region of NSW resulting from climatic changes include:

- Rising sea level is almost certain to increase coastal recession.
- Coastal dune erosion and soil decline are likely to continue.
- Saltwater from sea level rise is very likely to affect subsoils on coastal plains.
- Increased sheet, rill and gully erosion due to higher rainfall is likely to induce sediment inundation in coastal floodplains.

The expected impacts on ecosystems in the Hunter region of NSW are:

- Sea level rise is likely to threaten some estuarine communities.
- Some fish species are likely to decline.
- Climate change is likely to reduce shorebird habitat and reduce shorebird numbers.
- Sea level rise is likely to alter ecosystems on shores and coastal lowlands.
- Specialised or localised communities are likely to be substantially altered.
- Altered fire regimes are likely to cause changes in wetter ecosystems.

- Climate change is likely to increase stress on fragmented and degraded ecosystems and on threatened species.

In order to address the threats to biodiversity from the expected impacts of climate change, *Priorities for Biodiversity Adaptation to Climate Change* has been developed (DECCW 2010d). Those priorities will focus on:

1. enhancing our understanding of the likely responses of biodiversity to climate change and re-adjusting management programs where necessary
2. protecting a diverse range of habitats through building a comprehensive, adequate and representative public reserve system in NSW, with a focus on underrepresented bioregions
3. increasing opportunities for species to move across the landscape by working with partners and the community to protect habitat and create the necessary connections across landscapes
4. assessing adaptation options for ecosystems most at risk from climate change in NSW.

9 Knowledge gaps

The knowledge gaps for Myall Lakes Ramsar site are presented in Table 18.

Table 18 Knowledge gaps and recommendations

Component or process	Identified knowledge gap	Recommended actions	Priority
Submerged aquatic vegetation	Inter-annual variation in distribution of submerged aquatic vegetation	Survey of distribution of submerged aquatic vegetation in consecutive years	High
Vegetation communities	Distribution of vegetation communities not mapped Distribution of invasive weeds in catchment	Use of remote sensing images of vegetation types and distribution with ground truthing to produce a vegetation map. Map locations of invasive weeds in catchment	High
Gyttja	Accurate map of gyttja distribution	Map gyttja distribution in lakes	Medium
Wetland dependent birds	Lack of data for diversity and abundance of waterbirds and shorebirds Knowledge of waterbird nesting, roosting and feeding habitats Habitats used by shorebirds e.g. for feeding Impacts of human disturbance on waterbirds and shorebirds	Annual survey of waterbirds and shorebirds Habitat assessment for waterbirds and shorebirds Monitor visitor use on waterbird nesting and breeding	Medium
Mammals, reptiles, and amphibians	Limited data about species, distribution and abundance about mammals, reptiles and amphibians	Fauna survey, especially for frogs, bats, and small marsupials	Medium
Fish	Fish species list not complete; fish abundance not known	Fish survey	Medium
Invertebrates	Limited knowledge of invertebrate species and abundance	Survey of invertebrates	Medium
Threatened species	No information about status of threatened species	Targeted surveys of species at greater risk	High
Groundwater input	No quantified data to estimate groundwater contribution to the lakes	Monitoring of groundwater levels	High
Wetland extent	No data for distribution, extent, timing of temporary wetlands	Remote sensing or aerial photos of wetland extent over time	Medium
Nutrients	Dynamics of nutrients in lakes not well understood Relationship between nutrient levels and phytoplankton growth unclear No data on nutrient levels for lower Myall River.	Targeted studies Sampling the lower Myall River	Medium
Salinity	Limited data for lower Myall River	Establish monitoring sites in the lower Myall River	Low
Recreational use and visitation	Limited knowledge of recreational carrying capacity	Assess the impacts of recreation, especially four-wheel driving and boating	High
Aboriginal sites	Location of Aboriginal sites, especially along the lake shore	Comprehensive archaeological survey of Ramsar site	Low

10 Monitoring

Monitoring of the critical ecological components and processes is essential for managing Myall Lakes Ramsar site. Monitoring requirements for the site are intended to:

- ensure that the threats to the site can be managed so they do not have a significant impact on the site's ecological character
- measure the critical components and processes against their LACs
- address key knowledge gaps identified for the site
- give feedback on management actions.

The recommended monitoring programs are presented in Table 19.

Table 19 Monitoring programs for Myall Lakes Ramsar site

Critical component, process or service	Indicators	Monitoring program	Priority
Submerged aquatic vegetation	Extent of macrophytes	Surveys of extent of submerged aquatic vegetation in summer and winter in consecutive years	High
Gyttja	Extent of gyttja	Surveys of extent of gyttja every three years	Medium
Habitat for birds	Bird roosting, breeding and feeding sites; abundance of birds	Bird surveys	Medium
Varying water levels	Variation in water level evident within natural range	Continuous water height logging	High
	Depth	Bathymetric surveys	Low
Salinity regime	Salinity	Continuous salinity logging at Bombah Point and in lower Myall River	High
Water quality	Chlorophyll-a, oligotrophic clear water – turbidity	Monitoring of chlorophyll-a and oligotrophic clear water in summer	High
Mosaic of freshwater to brackish wetlands	Presence of wetlands; presence of dominant vegetation types	Vegetation mapping	High
Biodiversity	Extent and condition of surrounding vegetation and presence of terrestrial biota	Vegetation mapping	High
	Abundance of fish	Fish surveys (5-yearly)	Medium
	Animal pests	Monitoring of animal pests in site	High
	Weeds in catchment	Monitoring of weeds in catchment, especially aquatic weeds	High
Nationally threatened species and ecological communities	Presence of threatened species and ecological communities	Threatened species surveys	High
Recreational amenity	Algal blooms	Monitoring of water quality	High
	Number of visitors	Visitor census	Medium

11 Changes since 1999

Myall Lakes Ramsar site was listed in 1999. This ECD was compiled in 2011 based on the best available information which includes data obtained since the time of listing. There is no evidence to suggest that the ecological character of this site has changed adversely since listing.

The Ramsar site was listed originally under the following criteria:

- Criterion 1a: A representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region.
- Criterion 1c: Wetland plays a substantial hydrological or ecological role in the functioning of a coastal system.
- Criterion 2a: Supports threatened plants and animals and a high biodiversity.
- Criterion 3b: Regularly supports substantial numbers of waterbirds.

Myall Lakes Ramsar site is now listed using the following three updated criteria under the Ramsar Convention:

- Criterion 1: A representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- Criterion 2: Wetland supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- Criterion 3: Wetland supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The updated criterion for waterbirds (Criterion 5) requires a wetland 'to regularly support 20,000 or more waterbirds'. Under the annual eastern Australia waterbird surveys, annual counts of waterbirds in the Myall lakes have ranged from 464 in 1999 to 4811 in 2002, with a mean of 1384 over 1999–2009 (John Porter 2010, pers. comm.). Other observations indicate that large gatherings (more than 1000 individuals) of a species sometimes occur; however, there is insufficient data to establish that the Myall lakes regularly support a population of 20,000 or more waterbirds. Therefore the Ramsar site is not considered to meet Criterion 5 at this time.

Several species listed as threatened under the EPBC Act or in the IUCN Red List are now known from the site but were not recorded from the site at the time of listing: Freycinet's frog (*Litoria freycineti*) (IUCN Red List), green-thighed frog (*Litoria brevipalmata*) (IUCN Red List) and stuttering frog (*Mixophyes balbus*) (EPBC Act).

The site is under greater protection now due to the adoption in 2002 of the plan of management for Myall Lakes National Park and for Little Broughton Island and Storm Petrel nature reserves, and the gazettal of the Port Stephens – Great Lakes Marine Park in 2005.

Fame Cove, which was part of Myall Lakes National Park in 1999, was gazetted as Gir-um-bit National Park on 1 July 2007. It is still part of the Ramsar site.

The Dark Point dune sheet, comprised of sand dunes up to 50 metres high and covering about 250 hectares of the Ramsar site, is estimated to have moved between 38 and 54 metres since 1999 (GBAC 2010). Whilst the dune sheet is moving towards Mungo Brush Road, the principal access road to the coastal parts of Myall Lakes National Park, its movement is a natural process and is being monitored.

12 Important communication, education and public awareness messages

Under the Ramsar Convention a program of communication, education, participation and awareness (CEPA) was established to help raise awareness of wetland values and functions. At the Conference of Contracting Parties in Korea in 2008, a resolution was made to continue the CEPA program in its third iteration for the subsequent two triennia (2009–15).

The vision of the Ramsar Convention's CEPA program is: 'People taking action for the wise use of wetlands'. To achieve that vision, three guiding principles have been developed:

1. The CEPA program offers tools to help people understand the values of wetlands so that they are motivated to become advocates for wetland conservation and wise use, and may act to become involved in relevant policy formulation, planning and management.
2. The CEPA program fosters the production of effective tools and expertise to engage major stakeholders' participation in the wise use of wetlands and to convey appropriate messages in order to promote the wise use principle throughout society.
3. The Ramsar Convention believes that CEPA activities should form a central part of implementing the Convention by each Contracting Party. Investment in CEPA will increase the number of informed advocates, participants and networks involved in wetland issues and build an informed decision-making and public constituency.

The Ramsar Convention encourages CEPA to be used effectively at all levels, from local to international, to promote the value of wetlands.

A comprehensive CEPA program for an individual Ramsar site is beyond the scope of an ECD, but key communication messages and CEPA actions, such as a community education program, can be used as a component of a management plan.

Myall Lakes Ramsar site is important for a number of reasons other than those under which it was listed in 1999.

- It is a significant tourist destination for Australian and international visitors, as it offers a variety of water-based activities (boating, water-skiing, kayaking, fishing, swimming), a wide range of camping experiences, resort accommodation and other land-based recreation.
- It contains significant Aboriginal cultural and historic settlement heritage sites.
- The extensive wetlands, forested areas and coastal shores, including islands, provide important roosting, nesting and foraging sites for both migratory and resident birds, including 22 species listed under migratory bird agreements (JAMBA, CAMBA and ROKAMBA).
- It supports the unique and ecologically important gyttja.
- It supports five wetland dependent threatened animals, four other threatened animals, three threatened plants and one threatened ecological community under the EPBC Act. It also supports 11 threatened plants and 46 threatened animals under the TSC Act.
- The variety of habitats support a diverse range of flora and fauna that is significant in terms of biodiversity on a larger scale, including 948 plant, 298 bird, 46 mammal, 44 fish, 37 reptile and 29 amphibian species.
- It is part of a larger connected corridor of native vegetation on the mid-north coast of NSW from Port Stephens north to Wallis Lake along the coast, and north-west to near Gloucester.
- Extensive macrophyte beds within the lakes system provide important fish habitats and food for waterbirds.
- Forty-four species of fish are found in the Myall lakes and at least nine are of economic or recreational importance.

Myall Lakes Ramsar site is conserved within the boundaries of Myall Lakes National Park, and some of the Ramsar site is also protected within the Port Stephens – Great Lakes Marine Park. However, only about one-third of the Myall lakes catchment is protected within national park, while the other two-thirds of the catchment allow for a range of land uses, including timber production forests, agriculture and urban settlement.

Key communication messages concerning threats that impact on the Myall Lakes Ramsar site's ecological character include the following.

- Catchment land uses can alter nutrient and sediment loads in the waterways, thereby changing the hydrological regime, resulting in impacts on macrophytes, gyttja, fauna and their habitats, and leading to blue–green algae blooms.
- Weeds and pests can affect populations of flora and fauna and their habitats.
- Climate change may impact on the Ramsar site's values as a result of sea level rise, temperature change, change in precipitation patterns and increased atmospheric carbon dioxide.
- Inappropriate human activities, including recreation and use of fire, can impact on fauna populations and their habitats.

Key communication messages to be promoted by managers of the Ramsar site include:

- the important ecological values of Myall Lakes Ramsar site, including the wetlands, macrophytes and gyttja, its biodiversity including threatened species, and its connectivity with other vegetated areas
- the importance of monitoring water quality for nutrient and sediment loads entering from the catchment
- the importance of monitoring and managing the impact of recreation and promoting appropriate recreation
- the importance of monitoring the impact of commercial fishing
- the need to monitor the impact of climate change and develop strategies to minimise its effect on the Ramsar site
- the importance of controlling the impact of weeds, particularly bitou bush, slash pine and aquatic weeds
- the need to monitor and manage fire regimes
- the importance of the Ramsar site's Aboriginal cultural and historic settlement heritage values
- the need to develop a comprehensive species list based on flora and fauna survey to better understand the site's values.

Appendix 1 Bird records

There have been no systematic surveys of birds within the Ramsar site. As a consequence, data on the presence of bird species come mainly from reported sightings stored in the Atlas of NSW Wildlife. Most sightings that are reported to the Wildlife Atlas tend to be for rare or threatened species and common species tend to get overlooked. For example, the superb blue wren and blue-faced honeyeater are both common in the Ramsar site but are not in the Wildlife Atlas.

Family name	Scientific name	Common name	No. of sightings	Status
Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped thornbill	8	
	Acanthiza lineata	Striated thornbill	63	
	Acanthiza nana	Yellow thornbill	75	
	Acanthiza pusilla	Brown thornbill	109	
	Acanthiza reguloides	Buff-rumped thornbill	10	
	Calamanthus pyrrhopygius	Chestnut-rumped heathwren	1	
	Gerygone levigaster	Mangrove gerygone	6	
	Gerygone mouki	Brown gerygone	38	
	Gerygone olivacea	White-throated gerygone	42	
	Sericornis citreogularis	Yellow-throated scrubwren	10	
	Sericornis frontalis	White-browed scrubwren	90	
	Sericornis magnirostris	Large-billed scrubwren	10	
	Smicrornis brevirostris	Weebill	2	Vag.
Accipitridae	*Accipiter cirrocephalus*	Collared sparrowhawk	11	
	Accipiter fasciatus	Brown goshawk	13	
	Accipiter novaehollandiae	Grey goshawk	3	
	Aquila audax	Wedge-tailed eagle	20	
	Aviceda subcristata	Pacific baza	6	
	Circus approximans	Swamp harrier	20	
	Elanus axillaris	Black-shouldered kite	27	
	Elanus scriptus	Letter-winged kite	1	Vag.
	Haliaeetus leucogaster	White-bellied sea-eagle	116	C
	Haliastur indus	Brahminy kite	8	
	Haliastur sphenurus	Whistling kite	120	
	Hieraaetus morphnoides	Little eagle	7	
	Lophoictinia isura	Square-tailed Kite	1	
	Pandion haliaetus	Osprey	8	
Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar	35	
Alcedinidae	*Alcedo azurea*	Azure kingfisher	32	
Anatidae	*Anas castanea*	Chestnut teal	53	
	Anas gracilis	Grey teal	51	
	*Anas platyrhynchos**	Mallard*	2	
	Anas superciliosa	Pacific black duck	83	
	Aythya australis	Hardhead	30	
	Biziura lobata	Musk duck	11	
	Chenonetta jubata	Australian wood duck	34	
	Cygnus atratus	Black swan	65	
	Oxyura australis	Blue-billed duck	1	
Anhingidae	*Anhinga melanogaster*	Darter	20	

Family name	Scientific name	Common name	No. of sightings	Status
Apodidae	*Apus pacificus*	Fork-tailed swift	7	J, C, R
	Hirundapus caudacutus	White-throated needletail	68	C
Ardeidae	*Ardea alba*	Great egret	72	J, C
	Ardea ibis	Cattle egret	9	J, C
	Ardea intermedia	Intermediate egret	10	
	Ardea pacifica	White-necked heron	42	
	Botaurus poiciloptilus	Australasian bittern	11	E, IUCN
	Butorides striatus	Striated heron	24	
	Egretta garzetta	Little egret	26	
	Egretta novaehollandiae	White-faced heron	127	
	Egretta sacra	Eastern reef egret	18	C
	Ixobrychus flavicollis	Black bittern	5	
	Ixobrychus minutus	Little bittern	3	
	Nycticorax caledonicus	Nankeen night heron	46	
Artamidae	*Artamus cyanopterus*	Dusky woodswallow	45	
	Artamus leucorynchus	White-breasted woodswallow	50	
	Artamus personatus	Masked woodswallow	1	
	Artamus superciliosus	White-browed woodswallow	5	
	Cracticus nigrogularis	Pied butcherbird	30	
	Cracticus torquatus	Grey butcherbird	108	
	Gymnorhina tibicen	Australian magpie	150	
	Strepera graculina	Pied currawong	133	
Burhinidae	*Burhinus grallarius*	Bush stone-curlew	2	
Cacatuidae	*Cacatua galerita*	Sulphur-crested cockatoo	5	
	Callocephalon fimbriatum	Gang-gang cockatoo	1	Vag.
	Calyptorhynchus funereus	Yellow-tailed Black-cockatoo	40	
	Calyptorhynchus lathami	Glossy black-cockatoo	5	
	Eolophus roseicapillus	Galah	29	
Campephagidae	*Coracina maxima*	Ground cuckoo-shrike	6	
	Coracina novaehollandiae	Black-faced cuckoo-shrike	119	
	Coracina papuensis	White-bellied cuckoo-shrike	11	
	Coracina tenuirostris	Cicadabird	14	
	Lalage tricolor	White-winged triller	3	
Caprimulgidae	*Eurostopodus mystacalis*	White-throated nightjar	16	
Centropodidae	*Centropus phasianinus*	Pheasant coucal	58	
Charadriidae	*Charadrius bicinctus*	Double-banded plover	7	
	Charadrius leschenaultii	Greater sand-plover	4	J, C, R
	Charadrius mongolus	Lesser sand-plover	18	J, C, R
	Charadrius ruficapillus	Red-capped plover	51	
	Charadrius veredus	Oriental plover	1	
	Pluvialis dominica	Lesser golden plover	14	J, C
	Vanellus miles	Masked lapwing	105	
	Vanellus tricolor	Banded lapwing	1	
Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked stork	18	
Climacteridae	*Climacteris erythrops*	Red-browed treecreeper	3	
	Climacteris picumnus	Brown treecreeper	7	
	Cormobates leucophaeus	White-throated treecreeper	101	

Family name	Scientific name	Common name	No. of sightings	Status
Columbidae	*Chalcophaps indica*	Emerald dove	4	
	Columba leucomela	White-headed pigeon	7	
	*Columba livia**	Rock dove*	10	
	Geopelia humeralis	Bar-shouldered dove	50	
	Geopelia placida	Peaceful dove	16	
	Leucosarcia melanoleuca	Wonga pigeon	18	
	Lopholaimus antarcticus	Topknot pigeon	4	
	Macropygia amboinensis	Brown cuckoo-dove	17	
	Ocyphaps lophotes	Crested pigeon	22	
	Phaps chalcoptera	Common bronzewing	9	
	Phaps elegans	Brush bronzewing	6	
	Ptilinopus magnificus	Wompoo fruit-dove	2	
	*Streptopelia chinensis**	Spotted turtle-dove*	20	
Coraciidae	*Eurystomus orientalis*	Dollarbird	43	
Corcoracidae	*Corcorax melanorhamphos*	White-winged chough	38	
Corvidae	*Corvus coronoides*	Australian raven	115	
	Corvus orru	Torresian crow	14	
	Corvus tasmanicus	Forest raven	22	
Cuculidae	*Cacomantis flabelliformis*	Fan-tailed cuckoo	64	
	Cacomantis variolosus	Brush cuckoo	25	
	Chalcites basalis	Horsfield's bronze-cuckoo	4	
	Chalcites lucidus	Shining bronze-cuckoo	17	
	Cuculus pallidus	Pallid cuckoo	16	
	Eudynamys orientalis	Pacific koel	64	
	Scythrops novaehollandiae	Channel-billed cuckoo	22	
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoe bird	43	
Dicruridae	*Dicrurus bracteatus*	Spangled drongo	14	
	Grallina cyanoleuca	Magpie-lark	115	
	Monarcha melanopsis	Black-faced monarch	25	
	Monarcha trivirgatus	Spectacled monarch	2	
	Myiagra cyanoleuca	Satin flycatcher	5	
	Myiagra inquieta	Restless flycatcher	12	
	Myiagra rubecula	Leaden flycatcher	37	
	Rhipidura albiscapa	Grey fantail	160	
	Rhipidura leucophrys	Willie wagtail	133	
	Rhipidura rufifrons	Rufous fantail	40	
Diomedeidae	*Diomedea exulans*	Wandering albatross	3	V
	Thalassarche melanophris	Black-browed albatross	6	V; IUCN
Estrildidae	*Neochmia temporalis*	Red-browed finch	102	
	Stagonopleura guttata	Diamond firetail	1	Vag.
	Taeniopygia bichenovii	Double-barred finch	15	
Eupetidae	*Cinclosoma punctatum*	Spotted quail-thrush	2	
	Psophodes olivaceus	Eastern whipbird	94	
Falconidae	*Falco berigora*	Brown falcon	14	
	Falco cenchroides	Nankeen kestrel	52	
	Falco longipennis	Australian hobby	1	Vag.
	Falco peregrinus	Peregrine falcon	12	

Family name	Scientific name	Common name	No. of sightings	Status
Fregatidae	*Fregata ariel*	Lesser frigatebird	2	J, C, R
Fringillidae	*Carduelis carduelis**	European goldfinch*	1	
Haematopodidae	*Haematopus fuliginosus*	Sooty oystercatcher	16	
	Haematopus longirostris	Pied oystercatcher	33	
Halcyonidae	*Dacelo novaeguineae*	Laughing kookaburra	164	
	Todiramphus macleayii	Forest kingfisher	1	
	Todiramphus sanctus	Sacred kingfisher	102	
Hirundinidae	*Cheramoeca leucosternus*	White-backed swallow	1	Vag.
	Hirundo neoxena	Welcome swallow	174	
	Petrochelidon ariel	Fairy martin	19	
	Petrochelidon nigricans	Tree martin	35	
Hydrobatidae	*Oceanites oceanicus*	Wilson's storm-petrel	1	J
	Pelagodroma marina	White-faced storm-petrel	25	
Laridae	*Catharacta skua*	Great skua	1	
	Larus dominicanus	Kelp gull	4	
	Larus novaehollandiae	Silver gull	322	
	Procelsterna cerulea	Grey ternlet	1	Vag.
	Stercorarius parasiticus	Arctic jaeger	7	
	Stercorarius pomarinus	Pomarine jaeger	4	
	Sterna albifrons	Little tern	28	J, C, R
	Sterna bergii	Crested tern	110	J
	Sterna caspia	Caspian tern	13	C
	Sterna fuscata	Sooty tern	2	
	Sterna hirundo	Common tern	#	J, C, R
	Sterna striata	White-fronted tern	1	
Maluridae	*Malurus cyaneus*	Superb fairy-wren	131	
	Malurus lamberti	Variegated fairy-wren	100	
	Stipiturus malachurus	Southern emu-wren	24	
Megapodiidae	*Alectura lathami*	Australian brush-turkey	9	
	Acanthorhynchus tenuirostris	Eastern spinebill	110	
	Anthochaera carunculata	Red wattlebird	60	
	Anthochaera chrysoptera	Little wattlebird	112	
	Entomyzon cyanotis	Blue-faced honeyeater	31	
	Epthianura albifrons	White-fronted Chat	17	
	Gliciphila melanops	Tawny-crowned honeyeater	3	
	Grantiella picta	Painted honeyeater	1	IUCN
	Lichenostomus chrysops	Yellow-faced honeyeater	162	
	Lichenostomus fuscus	Fuscous honeyeater	1	
	Lichenostomus leucotis	White-eared honeyeater	2	
	Lichenostomus penicillatus	White-plumed honeyeater	1	
	Lichmera indistincta	Brown honeyeater	13	
	Manorina melanocephala	Noisy miner	117	
	Manorina melanophrys	Bell miner	2	
	Meliphaga lewinii	Lewin's honeyeater	114	
	Melithreptus brevirostris	Brown-headed honeyeater	9	
	Melithreptus lunatus	White-naped honeyeater	30	
	Myzomela sanguinolenta	Scarlet honeyeater	72	

Family name	Scientific name	Common name	No. of sightings	Status
	Philemon citreogularis	Little friarbird	2	
	Philemon corniculatus	Noisy friarbird	127	
	Phylidonyris nigra	White-cheeked honeyeater	130	
	Phylidonyris novaehollandiae	New Holland honeyeater	17	
	Phylidonyris pyrrhoptera	Crescent honeyeater	1	Vag.
	Plectorhyncha lanceolata	Striped honeyeater	5	
	Xanthomyza phrygia	Regent honeyeater	1	IUCN
Menuridae	*Menura novaehollandiae*	Superb lyrebird	23	
Meropidae	*Merops ornatus*	Rainbow bee-eater	4	
Motacillidae	*Anthus australis*	Australian pipit	66	
Muscicapidae	*Zoothera sp.*	Unidentified ground thrush	1	
Nectariniidae	*Nectarinia jugularis*	Olive-backed sunbird	4	
Neosittidae	*Daphoenositta chrysoptera*	Varied sittella	28	
Oriolidae	*Oriolus sagittatus*	Olive-backed oriole	62	
	Sphecotheres vieilloti	Australasian figbird	23	
Orthonychidae	*Orthonyx temminckii*	Logrunner	3	
Pachycephalidae	*Colluricincla harmonica*	Grey shrike-thrush	122	
	Falcunculus frontatus	Eastern shrike-tit	21	
	Pachycephala pectoralis	Golden whistler	99	
	Pachycephala rufiventris	Rufous whistler	85	
Paradisaeidae	*Ptiloris paradiseus*	Paradise riflebird	2	
Pardalotidae	*Pardalotus punctatus*	Spotted pardalote	54	
	Pardalotus striatus	Striated pardalote	15	
Passeridae	*Passer domesticus**	House sparrow*	31	
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican	112	
Petroicidae	*Eopsaltria australis*	Eastern yellow robin	99	
	Melanodryas cucullata	Hooded robin	3	
	Microeca fascinans	Jacky winter	50	
	Petroica boodang	Scarlet robin	2	
	Petroica rosea	Rose robin	12	
Phaethontidae	*Phaethon lepturus*	White-tailed tropicbird	1	J, C
	Phaethon rubricauda	Red-tailed tropicbird	2	Vag.
Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant	113	
	Phalacrocorax melanoleucos	Little pied cormorant	116	
	Phalacrocorax sulcirostris	Little black cormorant	86	
	Phalacrocorax varius	Pied cormorant	84	
Phasianidae	*Coturnix pectoralis*	Stubble quail	2	
	Coturnix ypsilophora	Brown quail	14	
Pittidae	*Pitta versicolor*	Noisy pitta	1	
Podargidae	*Podargus strigoides*	Tawny frogmouth	36	
Podicipedidae	*Podiceps cristatus*	Great crested grebe	5	
	Poliocephalus poliocephalus	Hoary-headed grebe	11	
	Tachybaptus novaehollandiae	Australasian grebe	18	
Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned babbler (eastern subspecies)	1	
Procellariidae	*Daption capense*	Cape petrel	2	
	Macronectes giganteus	Southern giant petrel	7	E
	Pachyptila turtur	Fairy prion	2	

Family name	Scientific name	Common name	No. of sightings	Status
	Pterodroma inexpectata	Mottled petrel	2	
	Pterodroma leucoptera leucoptera	Gould's petrel	60	E; IUCN
	Puffinus bulleri	Buller's shearwater	2	IUCN
	Puffinus carneipes	Flesh-footed shearwater	6	J, R
	Puffinus gavia	Fluttering shearwater	6	
	Puffinus griseus	Sooty shearwater	19	J, C
	Puffinus huttoni	Hutton's shearwater	1	IUCN
	Puffinus pacificus	Wedge-tailed shearwater	65	J
	Puffinus tenuirostris	Short-tailed shearwater	41	J, R
Psittacidae	*Alisterus scapularis*	Australian king-parrot	43	
	Glossopsitta pusilla	Little lorikeet	34	
	Glossopsitta concinna	Musk lorikeet	#	
	Lathamus discolor	Swift parrot	2	IUCN
	Neophema pulchella	Turquoise parrot	7	
	Platycercus adscitus eximius	Eastern rosella	120	
	Platycercus elegans	Crimson rosella	14	
	Psephotus haematonotus	Red-rumped parrot	17	
	Trichoglossus chlorolepidotus	Scaly-breasted lorikeet	48	
	Trichoglossus haematodus	Rainbow lorikeet	19	
Ptilonorhynchidae	*Ailuroedus crassirostris*	Green catbird	17	
	Ptilonorhynchus violaceus	Satin bowerbird	42	
	Sericulus chrysocephalus	Regent bowerbird	17	
Rallidae	*Aythya australis*	Hardhead	#	
	Fulica atra	Eurasian coot	31	
	Gallinula tenebrosa	Dusky moorhen	40	
	Gallirallus philippensis	Buff-banded rail	10	
	Porphyrio porphyrio	Purple swamphen	47	
	Porzana fluminea	Australian spotted crake	2	
	Porzana pusilla	Baillon's crake	1	Vag.
	Rallus pectoralis	Lewin's rail	2	
Recurvirostridae	*Himantopus himantopus*	Black-winged stilt	3	
	Recurvirostra novaehollandiae	Red-necked avocet	3	
Scolopacidae	*Arenaria interpres*	Ruddy turnstone	6	J, C, R
	Calidris acuminata	Sharp-tailed sandpiper	17	J, C
	Calidris alba	Sanderling	2	
	Calidris canutus	Red knot	2	J, C, R
	Calidris ferruginea	Curlew sandpiper	7	J, C, R
	Calidris melanotos	Pectoral sandpiper	3	J, R
	Calidris ruficollis	Red-necked stint	12	J, C, R
	Gallinago hardwickii	Latham's snipe	11	J, C, R
	Heteroscelus brevipes	Grey-tailed tattler	12	J
	Limosa lapponica	Bar-tailed godwit	40	J, C, R
	Numenius madagascariensis	Eastern curlew	44	J, C, R
	Numenius phaeopus	Whimbrel	18	J, C, R
	Tringa nebularia	Common greenshank	6	J, C, R
	Tringa stagnatilis	Marsh sandpiper	1	J, C, R
	Xenus cinereus	Terek sandpiper	5	J, C, R

Family name	Scientific name	Common name	No. of sightings	Status
Spheniscidae	*Eudyptula minor*	Little penguin	35	
Strigidae	*Ninox boobook*	Southern boobook	27	
	Ninox connivens	Barking owl		
	Ninox strenua	Powerful owl	15	
Sturnidae	*Sturnus vulgaris**	Common starling*	38	
Sulidae	*Morus serrator*	Australasian gannet	50	
	Sula dactylatra	Masked booby	1	J, R
	Sula leucogaster	Brown booby	1	J, C, R
Sylviidae	*Acrocephalus stentoreus*	Clamorous reed-warbler	7	
	Cincloramphus mathewsi	Rufous songlark	5	Vag.
	Cisticola exilis	Golden-headed cisticola	23	
	Megalurus gramineus	Little grassbird	1	Vag.
	Megalurus timoriensis	Tawny grassbird	2	
Threskiornithidae	*Platalea flavipes*	Yellow-billed spoonbill	11	
	Platalea regia	Royal spoonbill	41	
	Plegadis falcinellus	Glossy ibis	2	C
	Threskiornis molucca	Australian white Ibis	85	
	Threskiornis spinicollis	Straw-necked Ibis	17	
Turnicidae	*Turnix varia*	Painted button-quail	5	
Tytonidae	*Tyto alba*	Barn owl	7	
	Tyto capensis	Grass owl	2	
	Tyto novaehollandiae	Masked owl	21	
	Tyto tenebricosa	Sooty owl	7	
Zosteropidae	*Zosterops lateralis*	Silvereye	137	

Source: Atlas of NSW Wildlife (report generated July 2007)

Status:
J = JAMBA, C = CAMBA, R = ROKAMBA
IUCN = IUCN Red List
E = Endangered, V = vulnerable in Australia under EPBC Act
# Observed by David Turner, NPWS, during 1990–2000 (David Turner 2011, pers. comm.)
* introduced species
Vag. = vagrant sighting

Appendix 2 Amphibians, mammals and reptiles

There have been no systematic surveys of fauna within the Ramsar site and this is a major knowledge gap. As a consequence, data on the presence of fauna such as mammals and reptiles come mainly from reported sightings stored in the Atlas of NSW Wildlife. For most groups, the sightings that are reported to the atlas tend to be for rare or threatened species and common species tend to get overlooked. For example, the tiger snake and blue-tongued lizard are both found in the Ramsar site but are not included in the atlas.

Family	Scientific name	Common name	Status
Amphibians			
Myobatrachidae	*Adelotus brevis*	Tusked frog	
Myobatrachidae	*Crinia signifera*	Common eastern froglet	
Myobatrachidae	*Crinia tinnula*	Wallum froglet	
Myobatrachidae	*Limnodynastes dumerili*	Bullfrog	
Myobatrachidae	*Limnodynastes ornatus*	Ornate burrowing frog	
Myobatrachidae	*Limnodynastes peronii*	Striped marsh frog	
Myobatrachidae	*Limnodynastes tasmanie*	Spotted marsh frog	
Hylidae	*Litoria aurea*	Green and golden bell frog	V; IUCN
Hylidae	*Litoria brevipalmata*	Green-thighed frog	IUCN
Hylidae	*Litoria caerulea*	Green Tree frog	
Hylidae	*Litoria chloris*	Red-eyed tree frog	
Hylidae	*Litoria dentata*	Keferstein's tree frog	
Hylidae	*Litoria fallax*	Eastern dwarf tree frog	
Hylidae	*Litoria freycineti*	Freycinet's frog	IUCN
Hylidae	*Litoria jervisiensis*	Jervis Bay tree frog	
Hylidae	*Litoria latopalmata*	Broad-palmed frog	
Hylidae	*Litoria lesueuri*	Lesueur's frog	
Hylidae	*Litoria nasuta*	Rocket frog	
Hylidae	*Litoria pearsoniana*	Pearson's green tree frog	
Hylidae	*Litoria pearsoniana/ph*	Leaf green tree frog species complex	
Hylidae	*Litoria peronii*	Peron's tree frog	
Hylidae	*Litoria phyllochroa*	Green Stream frog	
Hylidae	*Litoria tyleri*	Tyler's tree frog	
Myobatrachidae	*Mixophyes balbus*	Stuttering frog	V
Myobatrachidae	*Mixophyes fasciolatus*	Great barred frog	
Myobatrachidae	*Paracrinia haswelli*	Haswell's froglet	
Myobatrachidae	*Pseudophryne bibronii*	Bibron's toadlet	
Myobatrachidae	*Pseudophryne coriacea*	Red-backed toadlet	
Myobatrachidae	*Uperoleia laevigata*	Smooth toadlet	

Family	Scientific name	Common name	Status
Mammals			
Acrobatidae	*Acrobates pygmaeus*	Feathertail glider	
Potoroidae	*Aepyprymnus rufescens*	Rufous bettong	
Dasyuridae	*Antechinus sp.*	Unidentified antechinus	
Dasyuridae	*Antechinus stuartii*	Brown antechinus	
Dasyuridae	*Antechinus swainsonii*	Dusky antechinus	
Dasyuridae	*Antechinus/Sminthopsis*	Unidentified 'marsupial mouse'	
Otariidae	*Arctocephalus pusillus*	Australian fur-seal	
Canidae	*Canis lupus*	Dingo, domestic dog	
Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat	
Vespertilionidae	*Chalinolobus morio*	Chocolate wattled bat	
Dasyuridae	*Dasyurus maculatus*	Spotted-tailed quoll	E
Equidae	*Equus caballus*	Horse	I
Felidae	*Felis catus*	Cat	I
Delphinidae	*Globicephala macrorhyn*	Short-finned pilot whale	
Muridae	*Hydromys chrysogaster*	Water-rat	
Peramelidae	*Isoodon macrourus*	Northern brown bandicoot	
Kogiidae	*Kogia breviceps*	Pygmy sperm whale	
Leporidae	*Lepus capensis*	Brown hare	I
Macropodidae	*Macropod sp.*	Unidentified macropod	
Macropodidae	*Macropus giganteus*	Eastern grey kangaroo	
Macropodidae	*Macropus parma*	Parma wallaby	
Macropodidae	*Macropus rufogriseus*	Red-necked wallaby	
Macropodidae	*Macropus sp.*	Kangaroo	
Vespertilionidae	*Miniopterus australis*	Little bentwing-bat	
Vespertilionidae	*Miniopterus schreibers*	Eastern bentwing-bat	
Molossidae	*Mormopterus norfolkens*	Eastern freetail-bat	
Muridae	*Mus musculus*	House mouse	I
Vespertilionidae	*Nyctophilus geoffroyi*	Lesser long-eared bat	
Vespertilionidae	*Nyctophilus gouldi*	Gould's long-eared bat	
Ornithorhynchida	*Ornithorhynchus anatin*	Platypus	
Leporidae	*Oryctolagus cuniculus*	Rabbit	I
Peramelidae	*Perameles nasuta*	Long-nosed bandicoot	
Pseudocheiridae	*Petauroides volans*	Greater glider	
Petauridae	*Petaurus australis*	Yellow-bellied glider	
Petauridae	*Petaurus breviceps*	Sugar glider	
Petauridae	*Petaurus norfolcensis*	Squirrel glider	
Dasyuridae	*Phascogale tapoatafa*	Brush-tailed phascogale	
Phascolarctidae	*Phascolarctos cinereus*	Koala	
Pseudocheiridae	*Pseudocheirus peregrin*	Common ringtail possum	

Family	Scientific name	Common name	Status
Muridae	*Pseudomys gracilicauda*	Eastern chestnut mouse	
Muridae	*Pseudomys novaeholland*	New Holland mouse	
Pteropodidae	*Pteropus poliocephalus*	Grey-headed flying-fox	V; IUCN
Pteropodidae	*Pteropus scapulatus*	Little red flying-fox	
Muridae	*Rattus fuscipes*	Bush rat	
Muridae	*Rattus lutreolus*	Swamp rat	
Muridae	*Rattus rattus*	Black rat	I
Muridae	*Rattus sp.*	Rat	
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern horseshoe bat	
Vespertilionidae	*Scotorepens orion*	Eastern broad-nosed bat	
Dasyuridae	*Sminthopsis murina*	Common dunnart	
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked echidna	
Molossidae	*Tadarida australis*	White-striped freetail-bat	
Macropodidae	*Thylogale thetis*	Red-necked pademelon	
Phalangeridae	*Trichosurus caninus*	Mountain brushtail possum	
Phalangeridae	*Trichosurus sp.*	Brushtail possum	
Phalangeridae	*Trichosurus vulpecula*	Common brushtail possum	
Vespertilionidae	*Vespadelus pumilus*	Eastern forest bat	
Vespertilionidae	*Vespadelus regulus*	Southern forest bat	
Vespertilionidae	*Vespadelus vulturnus*	Little forest bat	
Canidae	*Vulpes vulpes*	Fox	I
Macropodidae	*Wallabia bicolor*	Swamp wallaby	
Balaenopteridae	*Whale sp.*	Unidentified whale	
Reptiles			
Elapidae	*Acanthophis antarcticu*	Southern death adder	
Agamidae	*Amphibolurus muricatus*	Jacky lashtail	
Scincidae	*Anomalopus swansoni*	Punctate worm-skink	
Elapidae	*Cacophis krefftii*	Dwarf crowned snake	
Scincidae	*Calyptotis ruficauda*	Red-tailed calyptotis	
Elapidae	*Cryptophis nigrescens*	Eastern small-eyed snake	
Scincidae	*Ctenotus robustus*	Robust ctenotus	
Scincidae	*Ctenotus taeniolatus*	Copper-tailed ctenotus	
Scincidae	*Cyclodomorphus michael*		
Elapidae	*Demansia psammophis*	Yellow-faced whipsnake	
Scincidae	*Egernia major*	Land mullet	
Scincidae	*Egernia mcpheei*	Eastern crevice skink	
Scincidae	*Eulamprus murrayi*	Blue-speckled forest-skink	
Scincidae	*Eulamprus quoyii*	Eastern water-skink	
Elapidae	*Hemiaspis signata*	Marsh snake	
Scincidae	*Hemiergis peronii*	Lowlands earless skink	

Family	Scientific name	Common name	Status
Elapidae	*Hoplocephalus stephens*	Stephens' banded snake	
Agamidae	*Hypsilurus spinipes*	Southern forest dragon	
Scincidae	*Lampropholis amicula*	Friendly sunskink	
Scincidae	*Lampropholis delicata*	Dark-flecked garden sunskink	
Scincidae	*Lampropholis guichenot*	Pale-flecked garden sunskink	
Scincidae	*Lampropholis sp.*	Unidentified grass skink	
Pygopodidae	*Lialis burtonis*	Burton's snake-lizard	
Boidae	*Morelia spilota*	Diamond python	
Boidae	*Morelia spilota spilot*	Diamond python	
Gekkonidae	*Oedura lesueurii*	Lesueur's velvet gecko	
Agamidae	*Physignathus lesueurii*	Eastern water dragon	
Elapidae	*Pseudechis porphyriacu*	Red-bellied black snake	
Elapidae	*Pseudonaja textilis*	Eastern brown snake	
Pygopodidae	*Pygopus lepidopodus*	Southern scaly-foot	
Typhlopidae	*Ramphotyphlops nigresc*	Blackish blind snake	
Scincidae	*Saiphos equalis*	Yellow-bellied three-toed skink	
Gekkonidae	*Saltuarius swaini*	Southern leaf-tailed gecko	
Scincidae	*Saproscincus rosei*	Orange-tailed shadeskink	
Elapidae	*Tropidechis carinatus*	Rough-scaled snake	
Varanidae	*Varanus varius*	Lace monitor	
Elapidae	*Vermicella annulata*	Eastern bandy-bandy	

Status:

E = Endangered under EPBC Act
V = vulnerable under EPBC Act
IUCN = IUCN Red List
I = introduced

Appendix 3 Fish collected from the Myall lakes

Scientific name	Common name	Number	Legal status
Acanthaluteres spilomelanurus	Bridled leatherjacket	70	
Acanthopagrus australis	Yellowfin bream*	100	
Achoerodus viridis	Eastern blue groper	1	
Afurcagobius tamarensis	Tamar river goby	39	
Ambassis jacksoniensis	Glassfish	203	
Arenigobius frenatus	Half-bridled goby	11	
Atherinomorus vaigiensis	Ogilbys hardyhead	1	
Atherinosoma microstoma	Small mouthed hardyhead	4	
Bathygobius krefftii	Kreffts goby	10	
Centropogon australis	Eastern fortescue	26	
Cnidoglanis macrocephalus	Estuary catfish	3	
Dicotylichthys punctulatus	Three-bar porcupine fish	4	
Favonigobius exquisitus	Exquisite sand-goby	14	
Favonigobius lateralis	Long finned goby	17	
Galaxias maculatus	Common jollytail	1	
Gerres subfasciatus	Silver biddy	8	
Girella tricuspidata	Luderick*	233	
Gobiomorphus australis	Striped gudgeon	7	
Gobiopterus semivestita	Glass goby	2	
Hyporhamphus regularis	River garfish	17	
Hypseleotris compressa	Empire gudgeon	27	
Hypseleotris sp.	Gudgeon	1	
Liza argentea	Flat-tail mullet*	21	
Meuschenia freycineti	Six-spined leatherjacket	5	
Meuschenia trachylepis	Variable (yellow tailed) leatherjacket	3	
Mugil cephalus	Striped mullet*	44	
Myxus elongatus	Sand mullet*	1	
Notesthes robusta	Bullrout	1	
Parupeneus signatus	Black-spot goatfish	1	
Pelates sexlineatus	Eastern striped trumpeter	76	
Philypnodon grandiceps	Flathead gudgeon	132	
Philypnodon spp.	Dwarf flathead gudgeon	91	
Platycephalus fuscus	Dusky flathead*	4	
Pseudogobius olorum	Swan river goby	84	
Pseudomugil signifer	Southern blue-eye	146	
Pseudorhombus jenynsii	Small-toothed flounder	2	
Redigobius macrostoma	Large-mouth goby	146	
Rhabdosargus sarba	Tarwhine*	145	
Sillago ciliata	Sand whiting*	14	
Synaptura nigra	Black sole*	1	
Taenioides spp.	Eel goby	1	
Tetractenos hamiltoni	Common toadfish	3	
Urocampus carinirostris	Hairy pipefish	2	P
Vanacampus margaritifer	Mother of Pearl pipefish	3	P

Source: Trudy Walford 2006, pers. comm. (unpublished data provided DPI NSW (Fisheries))

* Fish of significance for commercial and recreational fishing.
P – Protected under the FM Act

Appendix 4 Fish observed in marine waters off Broughton Island (within Ramsar site) and Fingal Head (outside Ramsar site)

Family	Scientific name	Common name	Legal status
Aplodactylidae	*Aplodactylus lophodon*	Rock cale	
Aulopidae	*Aulopus purpurissatus*	Sergeant baker	
Berycidae	*Centroberyx lineatus*	Swallowtail	
Brachaeluridae	*Brachaelurus waddi*	Blind shark	
Carangidae	*Pseudocaranx dentex*	Silver trevally	
	Trachurus novaezelandiae	Yellowtail scad	
Chaetodontidae	*Chelmonops truncatus*	Eastern talma	
Cheilodactylidae	*Cheilodactylus fuscus*	Red morwong	
	Cheilodactylus vestitus	Magpie morwong	
	Nemadactylus douglasii	Grey morwong	
Dasyatidae	*Dasyatis brevicaudata*	Smooth stingray	
Diodontidae	*Dicotylichthys punctulatus*	Three-bar porcupine fish	
Dinolestidae	*Dinolestes lewini*	Long-finned pike	
Enoplosidae	*Enoplosus armatus*	Old wife	
Heterodontidae	*Heterodontus galeatus*	Crested horn shark	
	Heterodontus portusjacksoni	Port Jackson shark	
Kyphosidae	*Girella elevata*	Rock blackfish	
	Girella tricuspidata	Luderick	
Labridae	*Achoerodus viridis*	Eastern blue groper	
	Coris picta	Comb wrasse	
	Notolabrus gymnogenis	Crimson banded wrasse	
	Ophthalmolepis lineolatus	Maori wrasse	
Monacanthidae	*Aluterus monoceros*		
	Eubalichthys bucephalus	Black reef leatherjacket	
	Eubalichthys mosaicus	Mosaic leatherjacket	
	Meuschenia flavolineata	Yellow-striped leatherjacket	
	Meuschenia freycineti	Six-spined leatherjacket	
	Meuschenia scaber	Velvet leatherjacket	
	Meuschenia trachylepis	Yellow-finned leatherjacket	
	Nelusetta ayraudi	Ocean jacket	
Moridae	*Lotella rhacina*	Beardie	
Mullidae	*Parupeneus spilurus*	Black-spot goatfish	
	Upeneichthys lineatus	Blue-lined goatfish	
Muraenidae	*Gymnothorax prasinus*	Green moray	
	Gymnothorax prionodon	Sawtooth moray	
Myliobatidae	*Myliobatis australis*	Southern eagle ray	
Odacidae	*Odax cyanomelas*	Herring cale	
Odontaspididae	*Carcharias taurus*	Grey nurse shark	P
Orectolobidae	*Orectolobus maculatus*	Spotted wobbegong	
	Orectolobus ornatus	Banded wobbegong	
Ostraciidae	*Anoplocapros inermis*	Eastern smooth boxfish	
Pentacerotidae	*Pentaceropsis recurvirostris*	Longsnout boarfish	
Platycephalidae	*Platycephalus caeruleopunctatus*	Bluespotted flathead	
Plesiopidae	*Trachinops taeniatus*	Eastern hulafish	

Pomacentridae	*Chromis hypsilepis*	One-spot puller	
	Mecaenichthys immaculatus	Immaculate damsel	
	Parma microlepis	White-ear scalyfin	
	Parma unifasciata	Girdled scalyfin	
Rhinobatidae	*Aptychotrema rostrata*	Eastern shovelnose ray	
	Trygonorrhina fasciata	Southern fiddler ray	
Scorpaenidae	*Scorpaena cardinalis*	Red rock cod	
Scorpididae	*Atypichthys strigatus*	Mado	
	Scorpis lineolata	Sweep	
Scyliorhinidae	*Asymbolus analis*	Grey spotted catshark	
Serranidae	*Acanthistius ocellatus*	Eastern wirrah	
	Hypoplectrodes maccullochi	Half-banded sea perch	
	Hypoplectrodes nigroruber	Black-banded sea perch	
Sparidae	*Acanthopagrus australis*	Yellowfin bream	
	Pagrus auratus	Snapper	
	Rhabdosargus sarba	Tarwhine	
Tetraodontidae	*Canthigaster callisterna*	Clown toby	
Triakidae	*Mustelus antarcticus*	Gummy shark	

Source: Malcolm et al. (2007)
P – protected under the FM Act

Appendix 5 Flora

Family name	Scientific name	Common name	Legal status
Acanthaceae	*Brunoniella australis*	Blue trumpet	
	Brunoniella pumilio	Dwarf blue trumpet	
	Pseuderanthemum variabile	Pastel flower	
Adiantaceae	*Adiantum aethiopicum*	Common maidenhair	
	Adiantum formosum	Giant maidenhair	
	Adiantum hispidulum	Rough maidenhair	
	Cheilanthes sieberi subsp. *sieberi*		
	Pellaea paradoxa		
Aizoaceae	*Carpobrotus glaucescens*	Pigface, iceplant	
	Macarthuria neo-cambrica		
	Tetragonia tetragonioides	New Zealand spinach	
Alangiaceae	*Alangium villosum* subsp. *Polyosmoides*	Muskwood	
Alismataceae	*Sagittaria platyphylla*	Sagittaria	I
Anthericaceae	*Caesia parviflora*	Pale grass-lily	
	Caesia parviflora var. *parviflora*		
	Thysanotus tuberosus	Common fringe-lily	
	Tricoryne elatior	Yellow autumn-lily	
Apiaceae	*Actinotus helianthi*	Flannel flower	
	Centella asiatica	Pennywort	
	Hydrocotyle acutiloba		
	Hydrocotyle bonariensis		
	Hydrocotyle geraniifolia	Forest pennywort	
	Hydrocotyle pedicellosa		
	Hydrocotyle peduncularis		
	Hydrocotyle spp.		
	Platysace lanceolata		
	Platysace linearifolia		
	Trachymene incisa		
Apocynaceae	*Parsonsia induplicata*	Thin-leaved silkpod	
	Parsonsia straminea	Common silkpod	
Araceae	*Gymnostachys anceps*	Settler's flax	
	Typhonium eliosurum		
Araliaceae	*Polyscias elegans*	Celery wood	
	Polyscias sambucifolia	Elderberry panax	
Arecaceae	*Livistona australis*	Cabbage palm	
Asclepiadaceae	*Gomphocarpus fruticosus*	Narrow-leaved cotton bush	I
	Marsdenia rostrata	Common milk vine	
	Tylophora paniculata	Thin-leaved tylophora	
Asteraceae	*Ageratina adenophora*	Crofton weed	I
	Bidens pilosa	Cobbler's pegs	I
	Brachyscome decipiens	Field daisy	
	Cassinia uncata	Sticky cassinia	
	Chrysanthemoides monilifera		I
	Chrysanthemoides monilifera subsp. *rotundata*	Bitou bush	I
	Cirsium vulgare	Spear thistle	I

Family name	Scientific name	Common name	Legal status
	Conyza sumatrensis	Tall fleabane	I
	Eclipta platyglossa		
	Enydra fluctuans		
	Euchiton sphaericus		
	Hypochaeris radicata	Catsear	I
	Lagenifera gracilis	Slender lagenophora	
	Ozothamnus diosmifolius	White dogwood	
	Senecio lautus subsp. *lanceolatus*		
	Senecio madagascariensis	Fireweed	I
	Senecio spathulatus	Coast groundsel	E
	Sigesbeckia orientalis subsp. *orientalis*	Indian weed	
	Vernonia cinerea		
Bignoniaceae	*Pandorea pandorana*	Wonga wonga vine	
Blechnaceae	*Blechnum cartilagineum*	Gristle fern	
	Blechnum indicum	Swamp water fern	
	Doodia aspera	Prickly rasp fern	
	Doodia caudata		
Burmanniaceae	*Burmannia disticha*		
Cactaceae	*Opuntia stricta*		I
Campanulaceae	*Wahlenbergia spp.*		
	Wahlenbergia stricta	Tall bluebell	
Casuarinaceae	*Allocasuarina littoralis*	Black she-oak	
	Allocasuarina torulosa	Forest oak	
	Casuarina glauca	Swamp oak	
Celastraceae	*Cassine australis* var. *australis*	Red olive-berry	
	Maytenus silvestris	Narrow-leaved Orangebark	
Centrolepidaceae	*Centrolepis fascicularis*		
Chenopodiaceae	*Einadia hastata*	Berry saltbush	
	Enchylaena tomentosa	Ruby saltbush	
Clusiaceae	*Hypericum gramineum*	Small St John's wort	
Colchicaceae	*Burchardia umbellata*	Milkmaids	
Commelinaceae	*Commelina cyanea*	Native wandering jew	
Convolvulaceae	*Dichondra repens*	Kidney weed	
	Polymeria calycina		
Cunoniaceae	*Callicoma serratifolia*	Black wattle	
	Schizomeria ovata	Crab-apple	
Cyperaceae	*Baumea acuta*		
	Baumea articulata	Jointed twig-rush	
	Baumea gunnii		
	Baumea juncea		
	Baumea nuda		
	Baumea rubiginosa		
	Baumea teretifolia		
	Carex appressa	Tall sedge	
	Carex gaudichaudiana		
	Carex longebrachiata	Bergalia tussock	
	Chorizandra cymbaria		

Family name	Scientific name	Common name	Legal status
	Chorizandra sphaerocephala		
	Cladium procerum		
	Cyperus fulvus		
	Cyperus polystachyos		
	Cyperus tetraphyllus		
	Cyperus trinervis		
	Fimbristylis dichotoma	Common fringe-sedge	
	Gahnia aspera	Rough saw-sedge	
	Gahnia clarkei	Tall saw-sedge	
	Gahnia melanocarpa	Black Fruit saw-sedge	
	Gahnia sieberiana	Red-fruit saw-sedge	
	Gymnoschoenus sphaerocephalus		
	Isolepis nodosa	Knobby club-rush	
	Lepidosperma elatius		
	Lepidosperma laterale		
	Lepidosperma quadrangulatum		
	Lepironia articulata		
	Schoenus apogon	Fluke bogrush	
	Schoenus brevifolius		
	Schoenus ericetorum		
Dennstaedtiaceae	*Histiopteris incisa*	Bat's wing fern	
	Pteridium esculentum	Bracken	
Dicksoniaceae	*Calochlaena dubia*	Common ground fern	
Dilleniaceae	*Adrastaea salicifolia*		
	Hibbertia aspera	Rough guinea flower	
	Hibbertia dentata	Twining guinea flower	
	Hibbertia empetrifolia subsp. *empetrifolia*		
	Hibbertia linearis		
	Hibbertia obtusifolia	Hoary guinea flower	
	Hibbertia scandens	Climbing guinea flower	
Dioscoreaceae	*Dioscorea transversa*	Native yam	
Droseraceae	*Drosera auriculata*		
	Drosera binata	Forked sundew	
	Drosera spatulata		
Dryopteridaceae	*Lastreopsis decomposita*	Trim shield fern	
Elaeocarpaceae	*Elaeocarpus reticulatus*	Blueberry ash	
Epacridaceae	*Astroloma pinifolium*	Pine heath	
	Epacris microphylla		
	Epacris obtusifolia	Blunt-leaf heath	
	Epacris pulchella		
	Leucopogon ericoides		
	Leucopogon juniperinus	Prickly beard-heath	
	Leucopogon lanceolatus var. *gracilis*		
	Leucopogon leptospermoides		
	Leucopogon parviflorus	Coastal beard-heath	
	Leucopogon virgatus		
	Monotoca elliptica	Tree broom-heath	

Family name	Scientific name	Common name	Legal status
	Monotoca scoparia		
	Sprengelia sprengelioides		
	Woollsia pungens		
Euphorbiaceae	*Breynia oblongifolia*	Coffee bush	
	Chamaesyce psammogeton	Sand spurge	E
	Cleistanthus cunninghamii		
	Croton verreauxii	Native cascarilla	
	Glochidion ferdinandi	Cheese tree	
	Omalanthus populifolius	Bleeding heart, native poplar	
	Phyllanthus gunnii		
	Phyllanthus hirtellus		
	Poranthera ericifolia		
	Poranthera microphylla		
	Pseudanthus orientalis		
	Ricinocarpos pinifolius	Wedding bush	
Eupomatiaceae	*Eupomatia laurina*	Bolwarra	
Fabaceae (Faboideae)	*Aotus ericoides*		
	Aotus subglauca		
	Bossiaea ensata		
	Bossiaea heterophylla	Variable bossiaea	
	Bossiaea rhombifolia subsp. *rhombifolia*		
	Chorizema parviflorum	Eastern flame pea	
	Daviesia ulicifolia	Gorse bitter pea	
	Desmodium brachypodum	Large tick-trefoil	
	Desmodium rhytidophyllum		
	Desmodium spp.		
	Desmodium varians	Slender tick-trefoil	
	Dillwynia glaberrima		
	Dillwynia retorta species complex		
	Dillwynia sericea		
	Glycine clandestina		
	Glycine microphylla		
	Glycine tomentella	Woolly glycine	
	Gompholobium glabratum	Dainty wedge pea	
	Gompholobium latifolium	Golden glory pea	
	Gompholobium virgatum	Leafy wedge pea	
	Gompholobium virgatum var. *virgatum*		
	Hardenbergia violacea	False sarsaparilla	
	Kennedia rubicunda	Red kennedy pea	
	Platylobium formosum subsp. *parviflorum*		
	Podolobium ilicifolium	Prickly shaggy pea	
	Pultenaea blakelyi		
	Pultenaea daphnoides		
	Pultenaea flexilis		
	Pultenaea linophylla		
	Pultenaea myrtoides		

Family name	Scientific name	Common name	Legal status
	Pultenaea retusa		
	Pultenaea villosa		
	Viminaria juncea	Native broom	
Fabaceae (Mimosoideae)	*Acacia barringtonensis*		
	Acacia binervata	Two-veined hickory	
	Acacia binervia	Coast myall	
	Acacia elongata	Swamp wattle	
	Acacia falcata		
	Acacia floribunda	White sally	
	Acacia irrorata	Green wattle	
	Acacia longifolia		
	Acacia longifolia subsp. *longifolia*	Sydney golden wattle	
	Acacia maidenii	Maiden's wattle	
	Acacia myrtifolia	Red-stemmed wattle	
	Acacia quadrilateralis		
	Acacia suaveolens	Sweet wattle	
	Acacia terminalis subsp. *longiaxialis*		
	Acacia ulicifolia	Prickly Moses	
Geraniaceae	*Geranium homeanum*		
	Geranium potentilloides		
Goodeniaceae	*Dampiera purpurea*		
	Goodenia bellidifolia		
	Goodenia fordiana		
	Goodenia heterophylla		
	Goodenia heterophylla subsp. *Eglandulosa*		
Haloragaceae	*Gonocarpus micranthus* subsp. *Micranthus*		
	Gonocarpus micranthus subsp. *Ramosissimus*		
	Gonocarpus tetragynus		
	Gonocarpus teucrioides	Raspwort	
Hypoxidaceae	*Hypoxis hygrometrica*	Golden weather-grass	
Iridaceae	*Patersonia sericea*	Silky purple-flag	
Juncaceae	*Juncus kraussii* subsp. *australiensis*	Sea rush	
	Juncus subsecundus		
	Juncus usitatus		
Juncaginaceae	*Triglochin procerum*	Water ribbons	
Lamiaceae	*Plectranthus graveolens*		
	Plectranthus parviflorus		
	Plectranthus suaveolens		
	Prostanthera densa	Villous mint-bush	V
	Prostanthera incana	Velvet mint-bush	
	Prostanthera incisa	Cut-leaved Mint-bush	
	Prostanthera scutellarioides		
	Westringia fruticosa	Coastal rosemary	
Lauraceae	*Cassytha glabella*		
	Cassytha pubescens		
	Cryptocarya microneura	Murrogun	
	Cryptocarya rigida	Forest maple	

Family name	**Scientific name**	**Common name**	**Legal status**
Lentibulariaceae	*Utricularia lateriflora*	Small bladderwort	
	Utricularia uliginosa	Asian bladderwort	
Lindsaeaceae	*Lindsaea linearis*	Screw fern	
Lobeliaceae	*Lobelia alata*	Angled lobelia	
	Lobelia trigonocaulis	Forest lobelia	
	Pratia purpurascens	Whiteroot	
Loganiaceae	*Mitrasacme paludosa*		
Lomandraceae	*Lomandra confertifolia* subsp. *pallida*		
	Lomandra confertifolia subsp. *rubiginosa*		
	Lomandra elongata		
	Lomandra filiformis	Wattle mat-rush	
	Lomandra filiformis subsp. *filiformis*		
	Lomandra glauca	Pale mat-rush	
	Lomandra hystrix		
	Lomandra longifolia	Spiny-headed mat-rush	
	Lomandra obliqua		
Loranthaceae	*Dendrophthoe vitellina*		
Luzuriagaceae	*Eustrephus latifolius*	Wombat berry	
	Geitonoplesium cymosum	Scrambling lily	
Lycopodiaceae	*Lycopodiella lateralis*		
Malvaceae	*Hibiscus diversifolius*	Swamp hibiscus	I
	Hibiscus heterophyllus subsp. *heterophyllus*	Native rosella	
	Sida rhombifolia	Paddy's lucerne	I
Meliaceae	*Synoum glandulosum* subsp. *glandulosum*	Scentless rosewood	
Menispermaceae	*Sarcopetalum harveyanum*	Pearl vine	
	Stephania japonica		
	Stephania japonica var. *discolor*	Snake vine	
Menyanthaceae	*Villarsia exaltata*	Yellow marsh Flower	
Monimiaceae	*Wilkiea huegeliana*	Veiny wilkiea	
Myrsinaceae	*Rapanea howittiana*	Brush muttonwood	
	Rapanea variabilis	Muttonwood	
Myrtaceae	*Angophora costata*	Sydney red/rusty gum	
	Backhousia myrtifolia	Grey myrtle	
	Baeckea imbricata		
	Callistemon acuminatus	Tapering-leaved Bottlebrush	
	Callistemon citrinus	Crimson bottlebrush	
	Callistemon linearifolius	Netted bottle brush	
	Callistemon pachyphyllus	Wallum bottlebrush	
	Callistemon salignus	Willow bottlebrush	
	Callistemon sieberi	River bottlebrush	
	Corymbia gummifera	Red bloodwood	
	Corymbia maculata	Spotted gum	
	Darwinia leptantha		
	Eucalyptus acmenoides	White mahogany	
	Eucalyptus agglomerata	Blue-leaved stringybark	

Family name	Scientific name	Common name	Legal status
	Eucalyptus carnea	Thick-leaved mahogany	
	Eucalyptus fergusonii subsp. *fergusonii*		
	Eucalyptus globoidea	White stringybark	
	Eucalyptus grandis	Flooded gum	
	Eucalyptus microcorys	Tallowwood	
	Eucalyptus paniculata	Grey ironbark	
	Eucalyptus paniculata subsp. *matutina*		
	Eucalyptus parramattensis subsp. *Decadens*	Earp's gum	V
	Eucalyptus pilularis	Blackbutt	
	Eucalyptus propinqua	Small-fruited grey gum	
	Eucalyptus punctata	Grey gum	
	Eucalyptus resinifera	Red mahogany	
	Eucalyptus robusta	Swamp mahogany	
	Eucalyptus saligna	Sydney blue gum	
	Eucalyptus siderophloia	Grey ironbark	
	Eucalyptus signata	Scribbly gum	
	Eucalyptus umbra	Broad-leaved white mahogany	
	Leptospermum continentale	Prickly teatree	
	Leptospermum laevigatum	Coast teatree	
	Leptospermum liversidgei		
	Leptospermum polygalifolium		
	Leptospermum polygalifolium subsp. polygalifolium		
	Leptospermum trinervium	Slender tea-tree	
	Lophostemon confertus	Brush box	
	Melaleuca groveana	Grove's paperbark	V
	Melaleuca nodosa		
	Melaleuca quinquenervia	Broad-leaved paperbark	
	Melaleuca sieberi		
	Rhodamnia rubescens	Scrub turpentine	
	Syncarpia glomulifera	Turpentine	
	Syzygium paniculatum	Magenta lilly pilly	E
Olacaceae	*Olax stricta*		
Oleaceae	*Notelaea longifolia forma intermedia*		
	Notelaea ovata		
	Notelaea venosa	Veined mock-olive	
Orchidaceae	*Acianthus spp.*		
	Corybas undulatus	Tailed helmet orchid	
	Cryptostylis erecta	Tartan tongue orchid	
	Cryptostylis subulata	Large tongue orchid	
	Cymbidium suave	Snake orchid	
	Diuris arenaria	Sand doubletail	E
	Diuris pedunculata	Small snake orchid	E
	Pterostylis alveata		
	Thelymitra nuda	Plain sun orchid	

Family name	Scientific name	Common name	Legal status
Oxalidaceae	*Oxalis corniculata*	Creeping oxalis	I
	Oxalis exilis		
	Oxalis perennans		
Passifloraceae	*Passiflora edulis*	Common passionfruit	I
	Passiflora herbertiana		
Phormiaceae	*Dianella caerulea*	Blue flax-lily	
	Dianella congesta		
	Dianella longifolia		
Phytolaccaceae	*Phytolacca octandra*	Inkweed	I
Pittosporaceae	*Billardiera scandens*	Appleberry	
	Bursaria spinosa	Native blackthorn	
	Hymenosporum flavum	Native frangipani	
	Pittosporum multiflorum	Orange thorn	
	Pittosporum revolutum	Rough fruit pittosporum	
Poaceae	*Aristida vagans*	Threeawn speargrass	
	Austrodanthonia tenuior		
	Axonopus fissifolius	Narrow-leafed carpet grass	I
	Capillipedium spicigerum	Scented-top grass	
	Cenchrus caliculatus	Hillside burrgrass	
	Cymbopogon refractus	Barbed wire grass	
	Deyeuxia parviseta		
	Digitaria breviglumis		
	Digitaria parviflora	Small-flowered finger grass	
	Echinopogon caespitosus var. *caespitosus*	Tufted hedgehog grass	
	Echinopogon ovatus	Forest hedgehog grass	
	Entolasia marginata	Bordered panic	
	Entolasia stricta	Wiry panic	
	Eragrostis brownii	Brown's lovegrass	
	Eragrostis elongata	Clustered lovegrass	
	Eragrostis sororia		
	Hemarthria uncinata	Matgrass	
	Hemarthria uncinata var. *uncinata*		
	Imperata cylindrica var. *major*	Blady grass	
	Ischaemum australe		
	Joycea pallida	Silvertop wallaby grass	
	Microlaena stipoides		
	Microlaena stipoides var. *stipoides*		
	Oplismenus aemulus		
	Oplismenus imbecillis		
	Panicum simile	Two-colour Panic	
	Paspalidium criniforme		
	Paspalidium distans		
	Paspalum dilatatum	Paspalum	I

Family name	Scientific name	Common name	Legal status
	Paspalum scrobiculatum	Scrobic	I
	Paspalum wettsteinii	Broad-leaved paspalum	
	Phragmites australis	Common reed	
	Poa labillardierei var. *labillardierei*	Tussock	
	Poa poiformis var. *poiformis*		
	Setaria sphacelata	South African pigeon grass	I
	Spinifex sericeus	Hairy spinifex	
	Sporobolus diander		
	Sporobolus virginicus		
	Themeda australis	Kangaroo grass	
	Themeda quadrivalvis	Grader grass	I
	Zoysia macrantha	Prickly couch	
Polygalaceae	*Comesperma defoliatum*		
	Comesperma ericinum		
	Comesperma spp.		
	Polygala japonica		
Primulaceae	*Samolus repens*	Creeping brookweed	
Proteaceae	*Banksia integrifolia*	Coast banksia	
	Banksia oblongifolia	Fern-leaved banksia	
	Banksia robur	Swamp banksia	
	Banksia serrata	Old-man banksia	
	Banksia spinulosa var. *collina*		
	Conospermum taxifolium		
	Grevillea guthrieana	Guthrie's grevillea	E
	Grevillea linearifolia		
	Hakea teretifolia	Needlebush	
	Lomatia silaifolia	Crinkle bush	
	Persoonia lanceolata	Lance leaf geebung	
	Persoonia laurina		
	Persoonia levis	Broad-leaved geebung	
Proteaceae	*Persoonia linearis*	Narrow-leaved geebung	
Ranunculaceae	*Clematis aristata*	Old man's beard	
	Clematis glycinoides	Headache vine	
	Ranunculus lappaceus	Common buttercup	
Restionaceae	*Baloskion pallens*		
	Baloskion tetraphyllum		
	Baloskion tetraphyllum subsp. meiostachyum		
	Eurychorda complanata		
	Hypolaena fastigiata		
	Leptocarpus tenax		
	Lepyrodia muelleri		
	Sporadanthus caudatus		
	Sporadanthus interruptus		
Rhamnaceae	*Alphitonia excelsa*	Red ash	

Family name	Scientific name	Common name	Legal status
Ripogonaceae	*Ripogonum fawcettianum*	Small supplejack	
Rosaceae	*Rubus moluccanus* var. *trilobus*	Molucca bramble	
	Rubus parvifolius	Native raspberry	
	Rubus rosifolius	Rose-leaf bramble	
Rubiaceae	*Asperula asthenes*	Trailing woodruff	V
	Durringtonia paludosa		
	Galium binifolium		
	Opercularia diphylla		
	Pomax umbellata		
	Psychotria loniceroides	Hairy psychotria	
Rutaceae	*Boronia falcifolia*		
	Boronia parviflora	Swamp boronia	
	Boronia pinnata		
	Boronia polygalifolia		
	Boronia spp.		
	Correa alba var. *alba*	White correa	
	Eriostemon australasius		
	Zieria laevigata		
	Zieria smithii	Sandfly zieria	
Santalaceae	*Exocarpos cupressiformis*	Native cherry	
	Leptomeria acida	Sour currant bush	
Sapindaceae	*Alectryon subcinereus*	Wild quince	
	Cupaniopsis anacardioides	Tuckeroo	
	Dodonaea triquetra	Large-leaf hop-bush	
	Guioa semiglauca		
	Jagera pseudorhus var. *pseudorhus forma pseudorhus*	Foambark tree	
Sapotaceae	*Pouteria australis*	Black apple	
Schizaeaceae	*Schizaea bifida*	Forked comb fern	
	Schizaea dichotoma	Branched comb fern	
Selaginellaceae	*Selaginella uliginosa*	Swamp selaginella	
Smilacaceae	*Smilax australis*	Lawyer vine, Wait-a-while, Barbwire vine	
Smilacaceae	*Smilax glyciphylla*	Sweet sarsaparilla	
Solanaceae	*Duboisia myoporoides*	Corkwood	
	Physalis peruviana	Cape gooseberry	I
	Solanum brownii	Violet nightshade	
	Solanum mauritianum	Wild tobacco bush	I
	Solanum opacum	Green-berry nightshade	
	Solanum pungetium	Eastern nightshade	
	Solanum stelligerum	Devil's needles	
Stackhousiaceae	*Stackhousia spp.*		
	Stackhousia viminea	Slender stackhousia	
Sterculiaceae	*Commersonia fraseri*	Brush kurrajong	
Stylidiaceae	*Stylidium graminifolium*	Grass triggerplant	
Thelypteridaceae	*Cyclosorus interruptus*		
Thymelaeaceae	*Pimelea linifolia*		
Tremandraceae	*Tetratheca juncea*	Black-eyed Susan	V

Family name	Scientific name	Common name	Legal status
Tremandraceae	*Tetratheca thymifolia*		
Ulmaceae	*Trema tomentosa* var. *viridis*	Native peach	
Uvulariaceae	*Tripladenia cunninghamii*		
Verbenaceae	*Clerodendrum tomentosum*	Hairy clerodendrum	
	Lantana camara	Lantana	I
	Verbena bonariensis	Purpletop	I
Violaceae	*Hybanthus enneaspermus*	Spade flower	
	Viola betonicifolia	Native violet	
	Viola hederacea	Ivy-leaved violet	
Vitaceae	*Cayratia clematidea*	Slender grape	
	Cissus antarctica	Water vine	
	Cissus hypoglauca	Giant water vine	
	Cissus opaca	Small-leaved water vine	
Xanthorrhoeaceae	*Xanthorrhoea fulva*		
	Xanthorrhoea johnsonii		
	Xanthorrhoea latifolia		
	Xanthorrhoea macronema		
Xyridaceae	*Xyris juncea*	Dwarf yellow-eye	
	Xyris operculata		
	Xyris ustulata		
Zamiaceae	*Macrozamia flexuosa*		
Zingiberaceae	*Alpinia arundelliana*		

Status under TSC Act: E = Endangered, V = vulnerable
I = introduced

Appendix 6 Threatened animals under TSC Act

Family	Scientific name	Common name	TSC Act status
Amphibians			
Myobatrachidae	*Crinia tinnula*	Wallum froglet	V
Hylidae	*Litoria aurea*	Green and golden bell frog	E
Hylidae	*Litoria brevipalmata*	Green-thighed frog	V
Myobatrachidae	*Mixophyes balbus*	Stuttering frog	E
Birds			
Ardeidae	*Botaurus poiciloptilus*	Australasian bittern	V
Cacatuidae	*Calyptorhynchus latham*	Glossy black cockatoo	V
Climacteridae	*Climacteris picumnus*	Brown treecreeper	V
Diomedeidae	*Diomedea exulans*	Wandering albatross	E
Ciconiidae	*Ephippiorhynchus asiat*	Black-necked stork	E
Meliphagidae	*Grantiella picta*	Painted honeyeater	V
Haematopodidae	*Haematopus fuliginosus*	Sooty oystercatcher	V
Haematopodidae	*Haematopus longirostri*	Pied oystercatcher	V
Ardeidae	*Ixobrychus flavicollis*	Black bittern	V
Psittacidae	*Lathamus discolor*	Swift parrot	E
Procellariidae	*Macronectes giganteus*	Southern giant petrel	E
Petroicidae	*Melanodryas cucullata*	Hooded robin	V
Psittacidae	*Neophema pulchella*	Turquoise parrot	V
Strigidae	*Ninox connivens*	Barking owl	V
Strigidae	*Ninox strenua*	Powerful owl	V
Accipitridae	*Pandion haliaetus*	Osprey	V
Phaethontidae	*Phaethon rubricauda*	Red-tailed tropicbird	V
Laridae	*Procelsterna cerulea*	Grey ternlet	V
Procellariidae	*Pterodroma leucoptera leucoptera*	Gould’s petrel	E
Columbidae	*Ptilinopus magnificus*	Wompoo fruit dove	V
Procellariidae	*Puffinus carneipes*	Flesh footed shearwater	V
Laridae	*Sterna albifrons*	Little tern	E
Diomedeidae	*Thalassarche melanophris*	Black browed albatross	V
Tytonidae	*Tyto capensis*	Grass owl	V
Tytonidae	*Tyto novaehollandiae*	Masked owl	V
Tytonidae	*Tyto tenebricosa*	Sooty owl	V
Meliphagidae	*Xanthomyza phrygia*	Regent honeyeater	E
Mammals			
Potoroidae	*Aepyprymnus rufescens*	Rufous bettong	V
Otariidae	*Arctocephalus pusillus*	Australian fur seal	V
Dasyuridae	*Dasyurus maculatus*	Spotted-tailed quoll	V
Macropodidae	*Macropus parma*	Parma wallaby	V

Family	Scientific name	Common name	TSC Act status
Vespertilionidae	*Miniopterus australis*	Little bentwing bat	V
Vespertilionidae	*Miniopterus schreibers*	Eastern bentwing bat	V
Molossidae	*Mormopterus norfolkens*	Eastern freetail bat	V
Petauridae	*Petaurus australis*	Yellow-bellied glider	V
Petauridae	*Petaurus norfolcensis*	Squirrel glider	V
Dasyuridae	*Phascogale tapoatafa*	Brush-tailed phascogale	V
Phascolarctidae	*Phascolarctos cinereus*	Koala	V
	Phascolarctos cinereus	Koala population, Hawks Nest and Tea Gardens	
Muridae	*Pseudomys gracilicauda*	Eastern chestnut mouse	V
Pteropodidae	*Pteropus poliocephalus*	Grey headed flying-fox	V
Reptiles			
Elapidae	*Hoplocephalus stephens*	Stephens' banded snake	V
Invertebrates			
Petaluridae	*Petalura gigantea*	Giant dragon fly	E

E = endangered under TSC Act
V = vulnerable under TSC Act
Source: Atlas of NSW Wildlife

Glossary

Assessment: the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Resolution VIII.6, 8th Conference of Parties to the Ramsar Convention)

Attributes: biological diversity and unique cultural and heritage features; these lead to uses or derivations of products, but they may also have intrinsic, unquantifiable importance (Annex A to Resolution VI.1, 6th Conference of Parties to the Ramsar Convention)

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

Benchmark: a pre-determined state, based on the values to be protected, to be achieved or maintained

Benefits: as they relate to Ramsar wetlands and to ecological character and change in that character, are the benefits that people receive from ecosystems (Resolution IX.1, 9th Conference of Parties)

Change in ecological character: the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Resolution IX.1, 9th Conference of Parties)

Charophytes: plants that grow completely submerged in the water of wetlands, rivers, streams, lakes, estuaries and swamps, i.e. in non-marine watery habitats

Components: physical, chemical and biological constituents (from large scale, such as habitat, to small scale, such as genes) (Ramsar Convention 2005)

Driver: direct or indirect human forces of change; examples include laws, institutional arrangements, river basin management, and water allocation etc. or natural aspects of a wetland ecosystem such as natural hydrology, climate, and geomorphology

Ecological character: the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time (Resolution IX.1 Annex A, 9th Conference of Parties)

Ecological condition: the health or quality of a site – a comparative assessment, analysis and value-based judgment

Ecosystem: a dynamic complex of living (including human) communities and the nonliving environment interacting as a functional unit which provides, inter alia, benefits to people

Ecosystem services: are benefits that people receive or obtain from an ecosystem; the types of ecosystem services are:

- provisioning (food, water)
- regulating (flood control)
- cultural (spiritual, recreational)
- supporting (nutrient cycling, ecological value) (Ramsar Convention 2005; DEWHA 2008)

Ecological character description: a report of the living and non-living components and how they interact, the natural variability of the wetland, and the limits of acceptable change (DEWHA 2008)

Eutrophic: having a high level of nutrients, typically compounds containing nitrogen or phosphorus

Functions: activities or actions that occur naturally in wetlands as a product of interactions between ecosystem structure and processes, and include flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stabilisation and erosion controls; storm protection; and stabilisation of local climatic conditions, particularly rainfall and temperature (Annex to Resolution VI.1, 6th Conference of Parties)

Mesotrophic: having moderate levels of nutrients, typically compounds containing nitrogen or phosphorus

Monitoring: systematically observing and measuring conditions in order to assess any changes

Oligotrophic: having very low levels of nutrients, typically compounds containing nitrogen or phosphorus

Processes: changes or reactions – physical, chemical or biological – that occur naturally (Ramsar Convention 2005)

Shorebirds: birds frequent the shores of coastal, estuarine and inland water bodies, including wetlands; also known as waders

Tidal prism: the change in the volume of water covering an area, such as a wetland, between a low tide and subsequent high tide

Values: the perceived benefits to society, either direct or indirect, that result from wetland functions; these values include human welfare, environmental quality and wildlife support (Annex A to Resolution VI.1, 6th Conference of Parties)

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)

Wise use: sustainable utilisation that is compatible with the maintenance of the natural properties of an ecosystem (Ramsar Convention 2005)

Abbreviations

ANZECC	Australia and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
CAMBA	China–Australia Migratory Bird Agreement
CEPA	communication, education and public awareness
DPI	Department of Primary Industries, NSW
ECD	ecological character description
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FM Act	*Fisheries Management Act 1974*
GIS	geographic information system
I&I	Industry and Investment NSW
IUCN	International Union for the Conservation of Nature
JAMBA	Japan–Australia Migratory Bird Agreement
LAC	limits of acceptable change
MHL	Manly Hydraulic Laboratory
NPW Act	*National Parks and Wildlife Act 1974*, NSW
NPWS	National Parks and Wildlife Service, NSW
NSW	New South Wales
OEH	Office of Environment and Heritage, NSW
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SAV	submerged aquatic vegetation
TSC Act	*Threatened Species Conservation Act 1995* (NSW)

Curriculum vitae of principal authors

Dr Peter Scanes, MSc and PhD in ecology, The University of Sydney

Peter has been employed as a research assistant at The University of Sydney and as a scientist at NSW Fisheries and OEH.

Since 1996 Peter has led the team responsible for OEH's coastal and estuarine waters science in NSW. The main focus for the research has been understanding catchment based threats to ecological integrity of estuaries, and developing a modelling platform to allow catchment managers to assess the consequences for estuaries of landuse change in catchments.

Kirsty Brennan, Advanced Diploma in Environmental Technology, Canada, 2004

Kirsty has worked for OEH in various research and project management roles including wildlife management and integrated ecosystem restoration. Her understanding of estuarine ecosystems is demonstrated in the comprehensive report, *Ecological Character Description: Towra Point Nature Reserve*, which led to the development and management of a biological corridor project in a highly developed landscape. Further to her report writing experience, Kirsty has field experience in setting up research experiments and compiling the results for on-ground management.

Brian Leahy, Bachelor of Science (Forestry) and Graduate Diploma of Environmental Studies

Brian has worked for the National Parks and Wildlife Service and OEH since 1987 in a variety of roles, including ranger, reserve manager and policy officer. His experience includes vegetation surveys, fire management, wilderness assessments, threatened fauna licensing, establishing new reserves, management of Aboriginal cultural heritage, and contributing to the nomination for the Greater Blue Mountains World Heritage Area. Recently Brian has been involved in preparing ECDs for Ramsar sites, including Towra Point Nature Reserve and the Myall lakes, and implementing policies relating to Ramsar sites in NSW.

Fiona Miller, Bachelor of Applied Science (Environmental Resource Management)

Fiona worked as a Fisheries Officer for NSW Fisheries from 1998 to 1999, and has been employed as a Ranger with the NSW National Parks and Wildlife Service since 1999. She has been the Ranger responsible for Myall Lakes National Park since 2001, with responsibility in the park for management of wetlands and biodiversity, pest and weed management, fire management, education and interpretation programs for visitors, and management of historic heritage and Aboriginal cultural heritage.

Dr Jane Jelbart, Master of Environmental Science and PhD, marine ecology.

Jane has over 11 years experience in ecological surveys and environmental impact assessment in estuarine, coastal and freshwater habitats. Jane has published 5 scientific papers on effects of seagrass fragmentation on fish and macroinvertebrate diversity, and has completed a Post Doctoral Fellowship investigating the impacts of pearl oyster farms on the Kimberley coastal region. She has also co-ordinated herpetofauna surveys, as well as waderbird and freshwater macroinvertebrates surveys. Jane has attained AUSRIVAS accreditation for evaluating the ecological condition of freshwater rivers using macroinvertebrates as indicators. She now works as a Senior Aquatic Ecologist at Umwelt Environmental Consultants.

Dr Li Wen, Master of Agricultural Ecology, Chinese Academy of Science, Beijing; PhD, freshwater ecology, University of Adelaide

Li has had considerable experience in researching catchments and aquatic ecosystems in China and Australia, in particular nutrient transportation, land degradation, eutrophication and cyanobacteria blooms. He has also had experience in ecosystem restoration, statistical ecological modelling, hydrodynamic and hydrological modelling, and GIS and spatial analysis.

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