Flow/ecology relationships and scenarios for the Lower Barwon Wetlands environmental entitlement: Final Report

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This report can be referred to as:

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1 INTRODUCTION

The Lower Barwon Wetlands are components of the Lake Connewarre Complex which forms the estuary of the Barwon River. The estuary lies in the depressed Moorlap block (Moorlap Lowland) and is confined by the uplifted Bellarine Block to the east. An interpreted fault on the western boundary of the uplifted block forms the eastern boundary of Reedy Lake and separates it from Lake Connewarre. The Bellarine Block dips to the south, locating the Lake Connewarre Complex in an area of subsidence (Dahlhaus et al. 2007).

The Lower Barwon Wetlands comprise Reedy Lake, Hospital Swamps, Salt Swamp and Lake Murtnaghurt. The wetlands are connected to various degrees to the Barwon River and/or Lake Connewarre, which lies centrally in the complex (see Figure 1).

This report presents the environmental flow objectives and documents the water regime recommendation for Reedy Lake and Hospital Swamps. This report is the final product of the project and it supersedes previous final reports arising out of this project.

1.1 Reedy Lake

Reedy Lake is located to the north-east of the lower Barwon River and is connected to Lake Connewarre on the southern side. The lake is a shallow sub-circular basin of 550 ha bordered by a higher terrestrial landscape on the west, north and eastern sides. The wetland has a small local catchment of 27 km^2 but is flooded almost entirely from the Barwon River.

The Barwon River channel flows from north-west to south-east on the southern margins of Reedy Lake, and discharges to the tidal, open water environment of Lake Connewarre. The river is separated from Reedy Lake by a natural levee.

Prior to European settlement, Reedy Lake was an ephemeral wetland that received minor inflows from a small local catchment and major flows from peaks in the Barwon River. The river was originally estuarine upstream of the lake and the lake would have received a combination of saline and freshwater inflows, depending on the contribution of high tides and high river flows.

Originally the spill of water from the river to Reedy Lake was controlled by the natural levee of the river bank. Water spilled to the wetland several times a year in response to winter and spring freshes. The wetland was normally continuously flooded in winter and spring and then dried out over summer and autumn. Inflows regularly exceeded the lake's capacity and discharged to Lake Connewarre to the south. The sill between the wetland and Lake Connewarre allowed saline estuarine water to enter the wetland during high tides.

The hydraulics of the system have been altered since settlement, significantly changing the water regime of the wetland. In 1898 a weir (the lower breakwater) was constructed where the Barwon River discharges to Lake Connewarre to raise the river level upstream and prevent the incursion of saline estuary water. The weir raised the level adjacent to Reedy Lake and presumably promoted inflow events. In 1906 the lake was described as drying out only in 'very prolonged dry weather' (PROV VPRS 5357/2365).

In the 1950s the State Rivers and Water Supply Commission (SRWSC) replaced the lower breakwater with a floating gate structure at a lower level to manage the higher rainfall that was occurring at the time and the higher flows that were expected to result from the Corangamite drainage scheme (Webster 1959 cited in Dahlhaus et al. 2007). Before the modifications, the Barwon River was 0.3 m higher so that water could easily be diverted into the Lake. The new structure ponds the river water 0.3 m lower than the lake offtake (Dahlhaus et al. 2007). A channel was cut between the Barwon River regulator in 1953 to aid inflows. Initially water entering the lake rapidly drained to the estuary. In order to maintain water levels in the lake during the 1967-1968 drought, the bank at the outlet was raised. These arrangements increased the wetland's volume, depth, area and permanence.

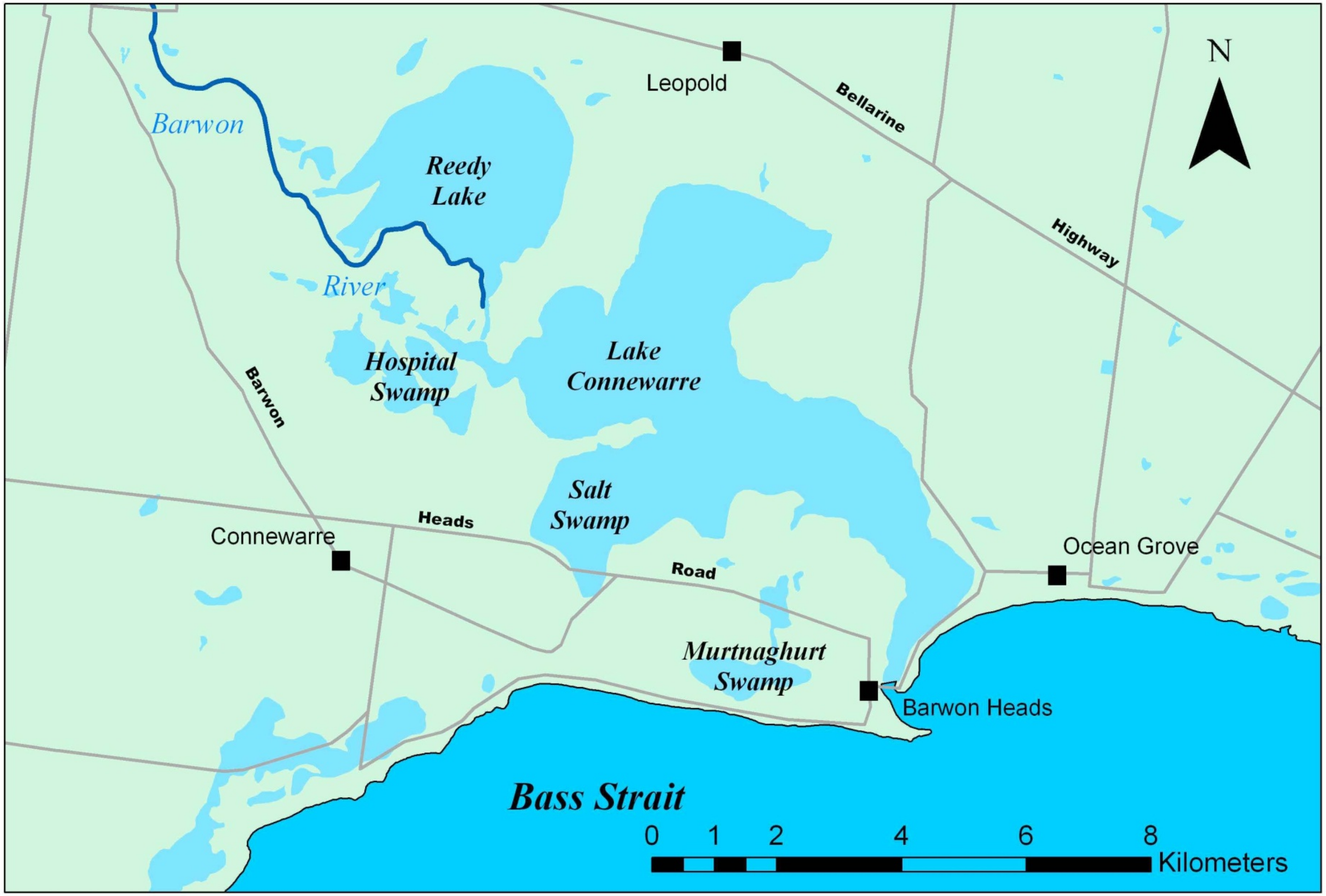


Figure 1: The Lower Barwon Wetlands

Around 1970, the outlet was regulated by raising the sill and installing flap gate regulators. The regulators prevented saline estuary water from entering the wetland.

The new lower breakwater structure highlighted competing interests in Reedy Lake during the dry years of the 1960s, particularly 1960, 1961 and the drought period of 1967-1968. Irrigators required a higher Reedy Lake water level to provide water for irrigation while graziers sought a low summer level to allow dairy cattle grazing. Field and Game sought to retain water in Reedy Lake in summer over a minimum of two thirds of the wetland area to provide habitat for waterfowl. The inlet structure was sabotaged on several occasions including in 1967 when the lake was dry and farmers sought to fill the lake.

The management objectives for Reedy Lake changed after 1961 when the Wildlife Reserves Investigation Committee recommended the area as one of the new State Wildlife Reserves. There was concern that waterbird numbers had been declining over the previous 50 years and that the lowering of the river level by the new lower breakwater had adversely impacted Reedy Lake. The lake came under the management of the Division of Fisheries and Wildlife. However, much of the on-ground management work, including fencing, revegetation and signage, was undertaken by the Field and Game Association.

Until the 1990s Barwon River flows were supplemented by brackish (around 4,500 EC) water discharged to the Moorabool from a dewatered quarry. This maintained the weir pool upstream of the lower breakwater and increased the frequency of spill events from river to Reedy Lake.

In 1995/1996, the lake was drained to eradicate the carp population that had developed and facilitate works on the drainage flow path. The flow path from the lake to the Barwon River below the Lower Breakwater was excavated to a depth of approximately 0.1 m AHD, allowing the wetland to be drained when lake levels permit. The regulator on the outlet channel may have been installed at this time.

In 1997 the regulator from the Barwon River was upgraded by closing two of the box culverts and replacing the flap gate on the third with a penstock regulator and fish screen.

In 2006 the lake was dried out and the channel from the inlet structure to the lake bed was excavated to 0.1 m AHD and cleared of vegetation. Accumulated sediment and vegetation was also cleared from the outlet channel, to a depth of 0.1 m AHD.

1.2 Hospital Swamps

Hospital Swamps are located to the south of the outlet of the Barwon River to Lake Connewarre. The wetland comprises five basins which receive water from both the Barwon River and from local runoff. The wetland is isolated from the estuary by a bund. Water is diverted from the Barwon River via a regulated channel through Sparrowvale Farm, which has an invert of 0.3 m AHD. Other unregulated channels become active at Barwon River levees greater than 1.4 m AHD.

The wetland overflows to Lake Connewarre at a level of 0.5 m AHD. The wetland can be drained using a regulated pipe with an invert of 0.2 m AHD. The regulator is opened when the Barwon River level exceeds 0.7 m AHD. Barwon levels greater than 0.9 m AHD allow Hospital Swamps levels to reach 0.5 m AHD, the normal full level.

The hydrology of Hospital Swamps was modified in 1983 by the installation of regulators and a water supply channel from the Barwon River. Prior to these works, the Swamp would only hold water temporarily after heavy winter rain or when flooded by the Barwon River, due to drainage many years ago. In the early 1980s the swamp held water for most of the year. (Yugovic 1985).

1.3 Literature Review

The lower Barwon River estuary and wetlands has been the subject of scientific observation, investigation and research since the mid-19th Century. Much has been written and published on the geology, geomorphology, hydrology, flora and fauna since that time. In 2007 a team of researchers from the University of Ballarat and Deakin University were engaged to review as much of this literature as possible for the Lake Connewarre Complex Values Project. The team reviewed around 250 documents across the areas of environmental history, geology, geomorphology, sedimentation, hydrogeology, flora, fauna, water quality and environmental flows, and wetland characterisation and planning (Dahlhaus et al. 2007). This literature review draws heavily on that 2007 document. In addition, Lloyd Environmental et al (2006) also reviewed the hydrology and ecology of lower Barwon River and its wetlands in order to develop river based environmental flow recommendations, including for Reedy Lake and Hospitals Swamps.

This project used the report from Water Technology (2011) as an input document. Despite some uncertainties and inadequacies, this work was reviewed and determined to be adequate as a component of the information used in these assessments. This report relied upon a previous hydrological assessment conducted and reported in Lloyd et al 2006, and the actual historical record at the site as a basis of the hydrology of the site. The recommended water regime for the ecology-flow relationships was mainly based on the hydrological requirements of the key ecological processes necessary to maintain the ecological character of the site, as represented by the 1983 condition, and not the hydraulic modelling. The hydraulic model (in Water Technology 2011) was used to test 4 water regime scenarios to assist in the choice of the most appropriate regime. The uncertainties and inadequacies of the hydraulic model have not affected the recommended water regimes and refining these uncertainties can be achieved through adaptive management, following implementation of the recommended water regimes.

1.4 Conceptual Models

The role of flow or water regime in providing for the habitat and other ecological requirements for the key environmental assets and driving other ecological, geomorphological and salinity processes (which indirectly provide for some habitat and life history needs) are defined in the EEFAM by the use of conceptual models.

The conceptual models describe the role of the estuary water regime in the growth, dispersal, survival or other process of the group in question. They will allow the identification of the key objectives for the ecological, geomorphological and salinity functions of the estuary.

Conceptual models draw on scientific information to describe the processes that govern ecosystem function and health. Conceptual models are “a generalised description or representation of the structure and function of a complex system”. They are constructed from a series of hypotheses that:

- represent the key assets which ecological objectives have been developed;
- identify processes and ecosystem function which are driven by water regime or flows; and,
- inform stakeholders about these functions and relationships and assist in supporting management actions.

A schematic diagram is usually developed clearly specifying the relationship between flow components and responses that are expected to provide the habitat and ecological requirements of the assets. The conceptual models may also be flow charts or other graphics showing the features required. Some of the conceptual models used in this report are prepared using symbols from the IAN symbol libraries from the University of Maryland's Center for Environmental Science (see http://ian.umces.edu/).

1.5 Water Regime Objectives and Recommendations

The literature review identified several asset groups which underpin the key environmental values of the Lower Barwon Wetlands. Conceptual models were developed to support our understanding of the role of water regime and river flows to ecosystem function and to assist with the development of ecological objectives for these systems and ultimately an environmental water regime for Reedy Lake and Hospital Swamps. These asset groups are: Geomorphology; Vegetation; Waterbirds and Fish.

2 BACKGROUND

2.1 Regional setting

The Barwon River catchment covers 8,590 km2 and drains parts of the major provincial cities of Geelong and Ballarat, some of the most intensively farmed land in Victoria, and areas of pristine native forests set aside in National Parks. Urban contaminants, nutrient and sediment load, water quality decline, pest plant and animal invasion and have been recognised as threats to the river's ecological systems.

The lower Barwon River wetlands and estuary consists broadly of Lake Connewarre, Reedy Lake, and Hospital and Salt Swamps, Murtnaghurt Lagoon, the estuary and river mouth. Many parts of the complex are included in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.

The Barwon estuary is a permanently open estuary extending for 19 km (Mondon et al. 2003) from the river mouth at Barwon Heads. Prior to European settlement, the tidal water penetrated upstream to Buckleys Falls, above Geelong. In 1840 and 1898 the upper and lower breakwaters were built to limit the upstream intrusion of salt water (Rosengren 1973). The river mouth is 24.5 km below the upper breakwater, and the entire estuary exhibits widely fluctuating salinity levels during the year.

Lake Connewarre is the dominant feature of the estuary complex, holding around 42% of water, although the average depth was estimated in 1988 to be less than 50 cm (Sherwood et al. 1988). In drought conditions Lake Connewarre has been shown to be hypersaline over several months, but after heavy rains river discharge flushes the estuary with fresh water. These conditions impose a challenging physiological environment on the fauna and flora of the estuary and suggest that a persistent biota has evolved to be highly adapted to the variability of the system.

2.2 Environmental history

The environmental history of the lower Barwon River estuary and associated wetlands has been documented by Dr Erica Nathan (in Dahlhaus et al. 2007) who demarcated six periods of significant environmental change, briefly summarised below:

Period 1: 6,000 B.P. Aboriginal land management.

Aboriginal people have colonised the landscapes since the formation of the wetlands and estuary, as shown by the presence of oyster middens and artefacts (Gill and Lane 1985). The earliest ethnohistorical records from the 1830s identify people of the Wathawurrung language group occupying the lower Barwon landscapes. The few historical records and scientific studies suggest that at the time of contact, the indigenous population was sustained by light harvesting of the lakes' natural resources and mosaic burning of the surrounding country.

Period 2: 1840 – mid-1850s. Early pastoral - upper breakwater.

Pastoral runs were established from the late 1830s, with four situated around the lower Barwon River and estuary, viz: Thompson, Drysdale, Tait & Fenwick (Spreadborough and Anderson 1983). The pastoral runs supported thousands of sheep grazing with minimal tree clearance, and small areas were cultivated for food crops. In general, open grassy woodlands of sheoak, wattle and gum merged with samphire and polygonum at the lake margins, although more detailed vegetation descriptions are provided in Dahlhaus et al. (2007, pp:4-6).

The first breakwater was constructed in late 1840 to provide a freshwater supply for Geelong. However, in 1852 a flood brought mining sludge from the goldfields around Ballarat triggering a survey in 1855 to investigate alternative water supplies for Geelong. This survey contains the first detailed account of the physiographic condition of the lower Barwon River (Appendix 1).

Period 3: Mid-1850s – 1890. Agricultural subdivision, gold mining waste begins, extensive riverfront industries, two major flood events, dredging, and commercial shooting of wildfowl.

From 1840 to 1854 Geelong's population trebled, largely in response to the gold rush. Land subdivision divided the pastoral runs into smaller allotments and the lakes and wetlands were retained as water reserves. Pollution from gold mining wastes was brought down the Leigh and Moorabool rivers and combined with the rise in industrial pollution from the many river-side meatworks, tanneries, fellmongeries, wool scourers, flour mills, woollen mills, paper mills, rope factory and cement works. Low fish numbers were attributed to the pollution in 1875, although tens of thousands of ducks per year were being taken from the lakes in commercial shooting around the same time.

Major floods were recorded in September 1870 and September 1880. The latter was considered up to 3 metres higher than the 1852 event and caused damage to the riverside industries. Following the flood, dredging of the river channel was attempted in 1882, but was abandoned after 9 months. A petition to parliament the following year (1883) called for the removal of the breakwater; the removal of a sand bank at mouth of the Barwon River entering Reedy Lake; cutting a channel through the sand bank at Howard’s Point, Lake Connewarre; cutting a canal through the sand bank at Barwon Heads near the entrance; and making the river navigable from Geelong to Barwon Heads for small vessels.

Period 4: 1890 – 1950. Agricultural decline, tourism, Harbour Trust management (lower breakwater), gold mining waste ends, Geelong sewerage schemes, river ‘improvement’ works.

This period saw a decline in agricultural production due to a decade of rural depression, with horticulture and cropping replaced by grazing. Tourism emerged as an important industry, with Ocean Grove and Barwon Heads developing as sea-side resorts and recreational boating and fishing became popular activities on Lake Connewarre.

This period also marks the beginning of more deliberate water management for the lakes. The Barwon River estuary and foreshore was managed by the Geelong Harbour Commissioners from 1905-6 until the mid-1930s, and included Reedy Lake, Connewarre Farmers’ Common, Connewarre Lakes, Large Salt Swamp, Large Salt Lake and Murtnaghurt. The lower breakwater was built in 1898, probably in response to the low rainfall period which prompted Geelong once again to draw supplies from the Barwon River. The Harbour Commissioners made use of the lower breakwater in their aim to generate income from productive land by converting Connewarre Farmers’ Common (c. 2000 acres [800 ha]) and the old racecourse reserve at Marshalltown into Sparrowvale Farm, and by "reclaiming" Reedy Lake as grazing land.

Mining sludge reached a peak around the turn of the century when the Sludge Abatement Board reports included dramatic photographs and accounts of the sediment deposition along the Leigh River. However, by the commencement of the Great War in 1914, gold mining had virtually ceased, removing the sediment source. Sewerage construction for Geelong commenced in 1911, although the management of stormwater and industrial waste remained a problem throughout the 1920s.

During the 1930s the Geelong Harbour Commissioners were superseded by the Geelong’s Waterworks and Sewerage Trust as river managers. Together with the State Rivers and Water Supply Commission (SRWSC), they engaged in a series of river "improvements" which included desnagging, removal of trees, bank protection, checking erosion, groynes, chutes, diversion and weed removal (Strom and Forbes 1954).

Period 5 - 1950 – 1980. Growth of Geelong and Bellarine Peninsula, SRWSC lower breakwater works, early conservation management, cement quarry discharge, erosion of lower Barwon, recreational lobby, and high rainfall of early 1950s.

Following World War 2, Geelong was developed as an industrial centre, supported by post-war immigration. Geelong's population doubled in the twenty years after the end of the war, with subdivisions reaching a peak in the 1960s. Under the management of the State Fisheries and Wildlife, land adjoining the lower Barwon River, estuary and wetlands was purchased during the 1970s as a means of buffering residential pressure. Blocks with floodplain and wetland portions around Reedy Lake and Hospital Swamps were targeted, with purchases continuing into the 1980s.

A decade of high rainfall in the 1950s resulted in the construction of the Woady Yaloak Diversion Scheme transferring water from the Woady Yaloak Catchment to the Barwon River. This prompted the replacement of the lower breakwater with a SRWSC-designed and managed structure of 'floating gates' aimed at lowering the breakwater to cope with the extra volume of water. However, the following decade included droughts (1960-61 & 1967) which resulted in conflicting interests in the management of the breakwater for irrigation and conservation. The result was alterations or additions to the breakwater structure, including a flap-gate to prevent water outflow and a series of channelling works at Reedy Lake, aimed at maintaining water levels over summer.

The floods of 1951 and 1952 were severe, although not as voluminous as those of 1852 and 1880 (Strom and Forbes 1954). Construction of large capacity water supply reservoirs for the Barwon River (West Barwon, 1965) and Moorabool River (Lal Lal, 1972) was undertaken in this period.

In 1961 lake Connewarre was recommended as a State Wildlife Reserve based on the decline in waterbird numbers and the decline in habitat since settlement. Projects were designed to meet various conservation and recreation needs in different parts of the estuary and wetlands complex. The morphology of Reedy Lake, Hospital Swamps and Salt Swamp were modified from 1963 to 1967, mostly to retain water. The local Field and Game Association undertook considerable works including fixing next boxes, planting trees, erecting fences and signs, and constructing water management structures (channels and gates). Despite the conservation status, grazing continued throughout the 1970s, with over 300 cattle and 100 lambs grazing Reedy Lake in some years.

Period 6: 1980 – present. Ramsar wetland listing, Parks Victoria management, Hospital Swamps project, cessation of grazing and irrigation licences, estuarine studies, residential pressure.

Grazing and irrigation licences were terminated during this period and the complex was listed as a wetland of international importance under the Convention of Wetlands (Ramsar convention). It now forms a part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site under the management of Parks Victoria. One important development was the Hospital Swamps Project in the early 1980s, which implemented a scheme to divert excess water from the Barwon River to the Hospital Swamps. Urban expansion continued throughout this period and the increasing population has altered both the environmental and recreational uses of the Lake Connewarre Complex. Much of the history of these changes is covered in the other sections of this report.

2.3 Geology, Geomorphology and Hydrogeology

Aspects of the geology of the lower Barwon River, estuary and associated wetlands have been documented by a number of studies including: Daintree (1862) who geologically mapped the region; Coulson (1933; 1935; 1938) who investigated the lake sediments and interpreted a regional geological evolution; Spencer Jones (1970; Spencer-Jones et al. 1973) who undertook regional mapping in the area; Ladd (1971) who geologically mapped the area; Rosengren (1973; 2009) who described the geological evolution of the lakes; Cecil et al. (1988) who undertook a detailed sedimentological study of the Lake Connewarre complex; Bird (1964; 1993; 2000) who summarised the estuary evolution; Stokes (2002) who studied the sediment movement in the estuary; Muller (2003) who undertook a rockfall assessment at The Bluff at Barwon Heads; and Mockunas (2006) who investigated the hydrogeology of Reedy Lake.

A simplified geological map based on the paper by Rosengren (1973) and taken from Bird (1993) illustrates the main features of the site (Figure 2).

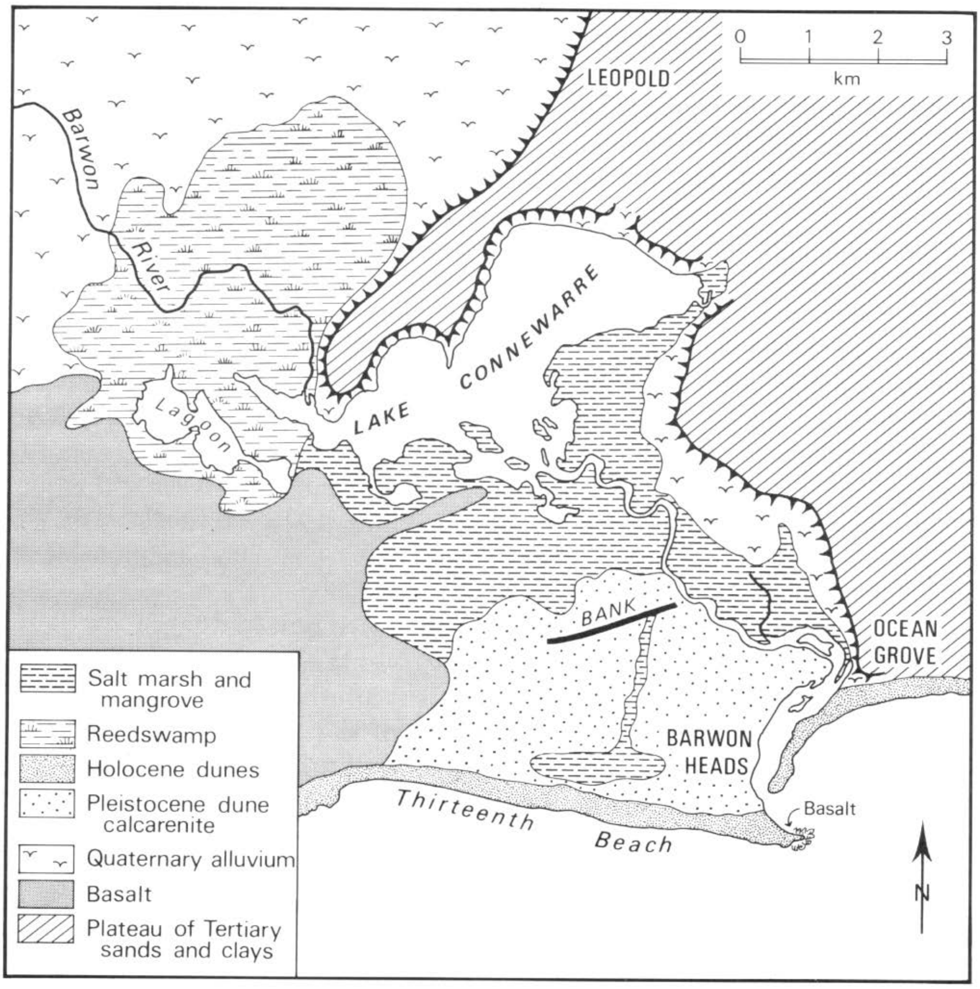


Figure 2: Simplified geology of the Lake Connewarre Complex (Bird 1993).

In summarising the literature cited above, the main events in the geological history of the site are as follows:

- In the Late Jurassic to Early Cretaceous the final break up of Gondwana initiates the Otway Basin, which fills rapidly with terrestrial sediments derived from the erosion of large volcanoes to the north or east. These sediments are compressed into the sedimentary rocks of the Otway Group which underlie the entire Bellarine Peninsula.
- Uplift across southern Victoria at the end of the Early Cretaceous restricts further deposition. As the seaway opens between Antarctica and Australia, subsidence along the north-easterly–trending faults flanking the uplifted blocks forms the Torquay and Port Phillip Basins. The basins are separated by a submerged ridge along the axis of the Bellarine Peninsula.
- Numerous sea-level fluctuations during the Palaeogene and Neogene result in a variety of sediments being deposited in the basins, including alluvial, marginal-marine and shallow-marine. During this time, the Eastern View Formation/Werribee Formation, the Older Volcanics and the Fyansford Formation are deposited.
- An extensive marine transgression in the early Miocene inundates the Bellarine Peninsula, and the coastline migrates significantly to the north. Uplift of the Bellarine Block probably commenced in the late Miocene when the tectonic stress field for Victoria changed to its present state of strong E-W to SE-NW compression.
- As a result of the uplift, an embayment develops between Torquay and Ocean Grove that narrows to a wide channel towards Corio Bay. Inundated by a shallow sea, the floor of the embayment comprises the clays of the Miocene Fyansford Formation.
- The sea retreats in the late Pliocene leaving a series of east-west trending barriers or strandlines. The barriers are principally composed of dense shell beds and minor sand beds in the embayment. On the slopes of the Bellarine Block, the sands of the Moorabool Viaduct Formation are deposited by the retreating sea.
- Volcanic activity in the late Pliocene or early Pleistocene in the form of eruptions at Mount Duneed results in lava sheet flows and the deposition of basalt. As the lava flows eastwards towards the area now occupied by the lower Barwon estuary complex, it separates into three lobes. The drainage of the ancient Barwon River system is strongly disrupted by the volcanism, and the river is temporarily blocked above Lake Connewarre. Lagoonal environments develop behind the lava flows to form the precursors to Reedy Lake, Hospital Swamps, Lake Connewarre and Salt Swamp. The lakes are subsequently connected by their present channels when the river finally erodes through the basalt barriers.
- Sedimentation in the Quaternary is influenced by sea-level changes in response to glaciation. Approximately 125,000 years ago the sea levels were around 7.5 metres higher than present, and the Bellarine block is believed to have been an island in a shallow sea. As the sea levels dropped in response to the following ice age, a barrier develops between the Bellarine Peninsula and Cape Shank. The remnants of this barrier now form the headland at the mouth of the Barwon River, known as The Bluff.
- Sea levels continue to recede, dropping to at least 150 metres below present levels by 20,000 years ago. During this time the climate was arid and cold, with evidence of frequent high wind events. At that time, the present-day Barwon estuary complex was situated well inland, with the shoreline west and south of Tasmania. As the ice-age ends, sea levels rise at a rapid rate, averaging just over 1 metre per century. By 6000 years ago the sea levels were approximately 2 metres higher than present and have fallen to their present level since around 3000 years before present. In the past century the sea levels are believed to have risen slightly.

The geomorphic setting places the lower Barwon River, estuary and associated wetlands in part of the Moolap Lowland (Marsden et al. 1988; Rosengren 2009), a depression that abuts the Bellarine high to the east (Figure 3). The surface of the Moolap Lowland is approximately 7 metres above sea level forming a low-elevation sedimentary plain on which the Barwon estuary complex is a system of alluvial, lacustrine and estuarine landforms.

Adjacent to the Moolap Lowland, the Bellarine high forms a topographic dome with a maximum elevation of 130 metres at Mount Bellarine (Figure 3). The high is the result of relatively recent (and continuing) uplift of a fault-bounded block. It slopes gently toward the sea on its south eastern and eastern sides and toward the Lake Connewarre complex on the west, steepening considerably adjacent to the estuary complex. On the north, the slope toward Corio Bay is relatively steep and reflects recent uplift along the Curlewis Monocline, which parallels the coast.

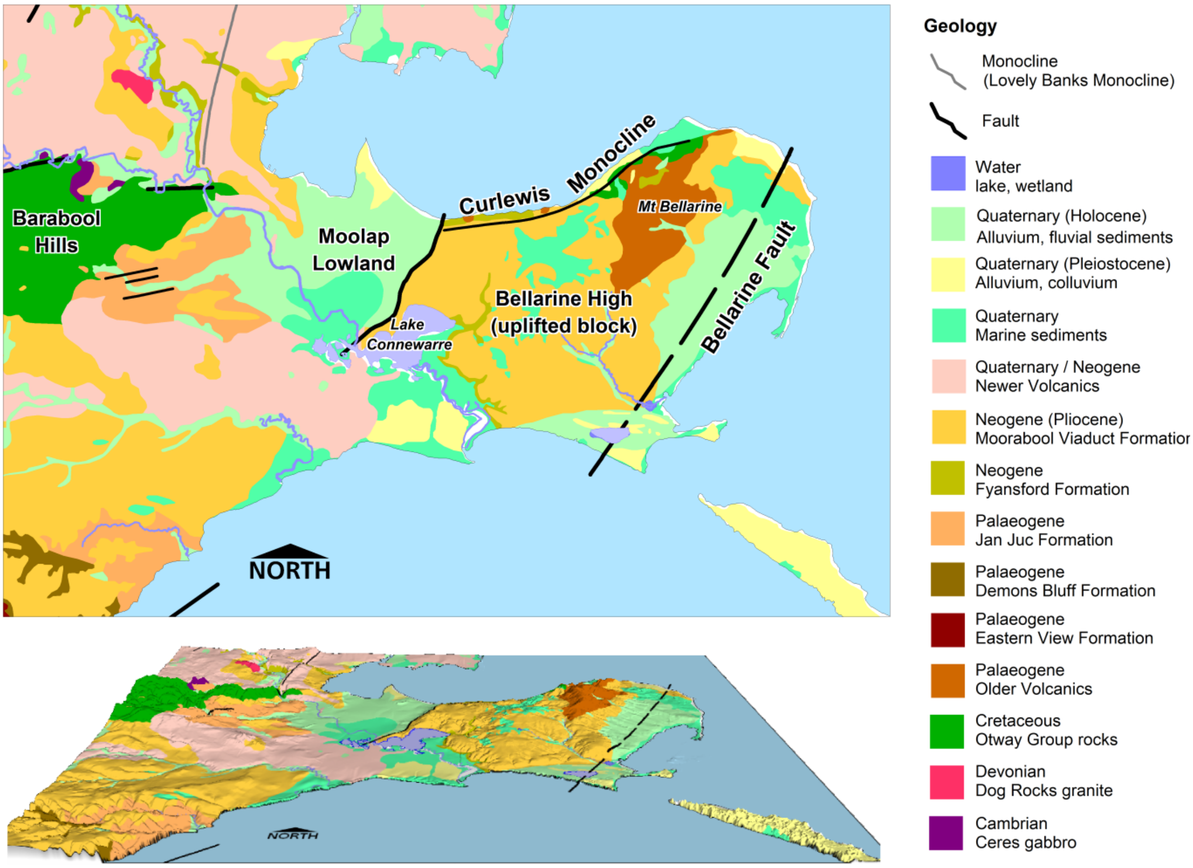


Figure 3: Geology and regional landform.

Within the Moolap Lowland, Rosengren (2009) delineates the Connewarre Lowland as the area occupied by the lower Barwon River, estuary and associated wetlands. Landforms associated with the Connewarre Lowland are listed in Table 1.

Environment	Landform
fluvial	channel
	levees
	floodplain
lacustrine	basin
	delta
	shore (beach and dunes)
estuarine	channels (1st, 2nd & 3rd order)
	marsh/swamp land
	flood-tidal delta

Table 1: Landforms of the Connewarre Lowland [summarised from Rosengren (1973; 2009); Cecil et al. (1988); Stokes (2002)].

Rosengren (2009) recognises four sets of dune ridges in the area of Salt Swamp and Murtnaghurt Lagoon: Ridge set 1 - comprising 12 arcuate parallel calcareous sand ridges north and west of Murtnaghurt Lagoon interpreted as the remnants of a receding Holocene shoreline; Ridge set 2 - east and parallel to the Murtnaghurt (palaeo)channel and largely obscured by the urban development at Barwon Heads, interpreted as coastal barriers similar to the present day Ocean Grove barrier spit; Ridge set 3 - very low relief parallel curving ridges around the margins of Salt Swamp, interpreted as receding shorelines of Lake Connewarre; and Ridge set 4 - the coastal dunes from Barwon Heads to Black Rock.

2.3.1 Characteristics of the geologically recent sediments

Geologically, the sediments underlying the lower Barwon River, estuary and associated wetlands are Holocene epoch and are probably <5000 years old (Rosengren 2009). Three sedimentary units are recognised that differ in age and, in part, in gross environment of deposition (Dahlhaus et al. 2007).

The oldest are marine sands, muds and shell beds that were deposited when the marine connection to the estuary and wetlands complex was much stronger than now, probably during the mid-Holocene sea-level maximum. Gill & Lane (1985) reported a radiocarbon age of 3620 years before present (BP) from an oyster shell from Campbell Point, Lake Connewarre, which they regarded as the approximate age of cessation of marine deposition in the lake. The fossils in this unit are identical in Lake Connewarre and at Reedy Lake, and indicate marine conditions in both in the mid-Holocene (Gill and Lane 1985).

The second unit represents the establishment of the complex of fluvial, lacustrine and estuarine environments, and consists of mud and sand.

The most recent sedimentary unit has been introduced since European settlement and is similar to the second unit in being silts, clays and sands deposited in fluvial, lacustrine and estuarine environments. Except for a thin, brown oxic layer at the surface, sediment from within Lake Connewarre is grey-black and strongly oxygen-depleted (Sherwood et al. 1988; Longmore et al. 2004). This uppermost sedimentary unit represents a marked increase in the rate of sediment supply to the estuary complex, particularly in the latter part of the 19th century and the beginning of the 20th century (Coulson 1935; Gill and Lane 1985). Small-scale sampling programmes by Billows (1998) and Bloink (2001) showed that surface sediment in the lower Barwon system contains a greater proportion of mud in areas of mangrove forests than adjacent unvegetated tidal flats, which are dominated by very fine- to medium-grained sand.

Units 2 and 3 have generally undergone intense mixing by organisms (*bioturbation* by plant roots and animal burrowing (Fabris et al. 2006) and are difficult to distinguish.

The sources of the sediments have been studied by Cecil et al. (1988), Longmore et al. (2004) and Fabris et al. (2006). Whereas the former studies were inconclusive, the latter study analysed the sediments in Lake Connewarre for a wide range of geochemical indicators and applied statistical analyses to estimate the sediment source (for the uppermost sedimentary unit). Fabris et al. (2006) concluded that over 50% of the sediment comes from the Moorabool River catchment, under 25% from the Barwon River catchment, about 15% from the Leigh River catchment and 5% from the immediate environs of Lake Connewarre. The majority input from the Moorabool River is explained by the steep gradient of the river valley, even in its lower reaches, which allows the sediment to travel to the lakes before it has the opportunity to settle in the river bed.

2.3.2 Sedimentary processes

A summary of the present-day sedimentary processes have been documented by Dahlhaus et al. (2007) based on the previous studies in the Barwon estuary complex. Three main processes are recognised: deposition, erosion and transport.

Sediment deposition has been studied by Coulson (1935) who undertook an extensive drilling program to examine the sediment distribution and thickness; Rosengren (1973) who examined and documented the sedimentary processes; Cecil et al. (1988) who drilled and logged the sediment distribution and profile to examine the impact of environmental history and proposed changes to the water regime; and Stokes (2002) who undertook a comprehensive study of the estuarine sedimentary dynamics. All studies demonstrate that the sediment deposition varies across the lower Barwon River, associated wetlands and estuary, with the local energy of the water and the distance from the river channel being the main factors.

The main active depositional landforms recognised are the levees along the river channel, a tidal delta where Lake Connewarre meets the lower Barwon estuary channel, the sandy beaches along the eastern shore of Lake Connewarre and the saltmarsh and mangrove swamps bordering the estuary in the vicinity of Ocean Grove and Barwon Heads. Of these, the tidal delta (Figure 4) is perhaps the most contentious. The deposition of the shells and shell fragments, sand and silt has been variously interpreted as a tidal (Rosengren 1973); a result of river channel constriction (Cecil et al. 1988); a static tidal delta (Sherwood et al. 1988); and an active tidal delta (Stokes 2002). Stokes' study concluded that the delta has advanced 1.5 kilometres into Lake Connewarre since 1863, through deposition during flood tides.

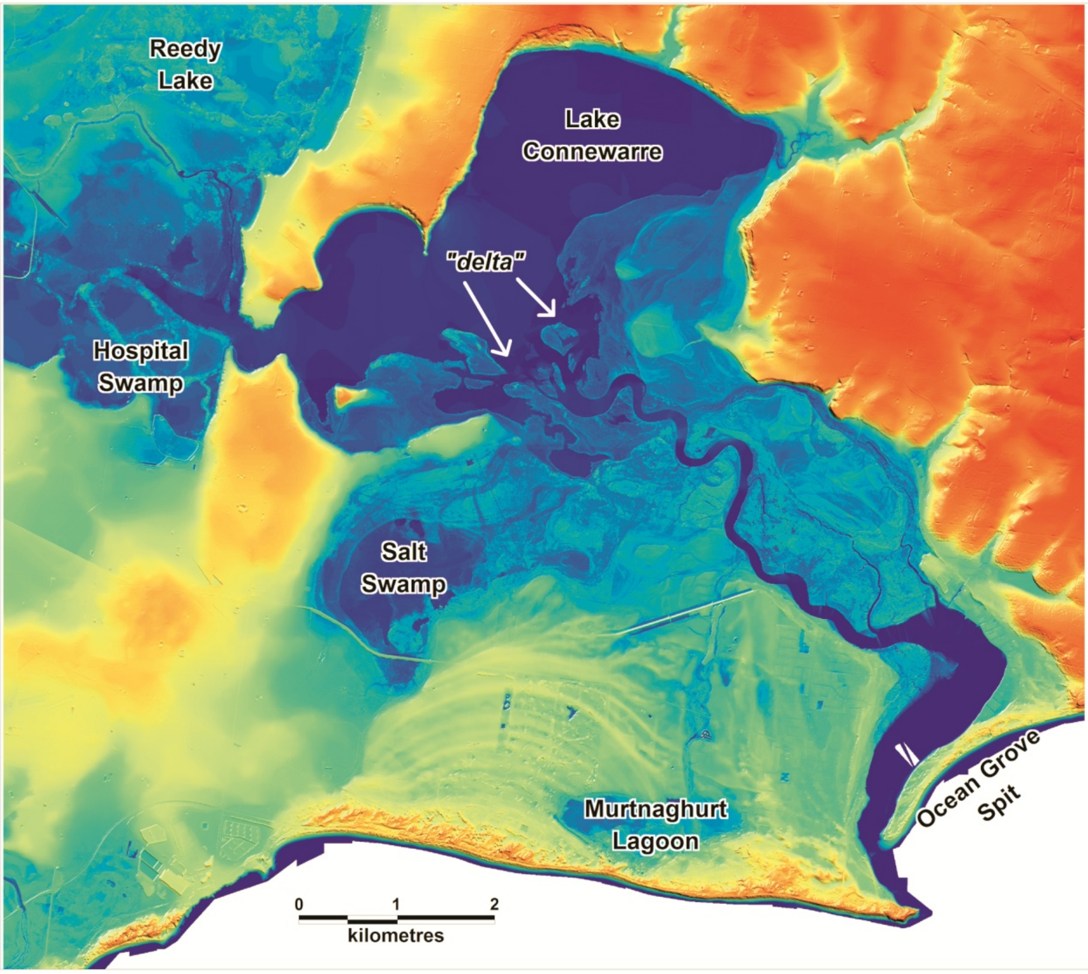


Figure 4: High-resolution DEM showing the Lake Connewarre 'delta'. (histogram equalisation colour stretch, illuminated from the north east)

As recognised by Rosengren (1973) and Stokes (2002), vegetation such as marsh plants, reeds and mangroves, have a significant influence in sediment deposition and composition. The increase in mangroves in the lower Barwon River since 1947 is thought to have also changed the rate of sediment accumulation (Stokes 2002).

Erosion of sediments is responsible for the dynamic fluvial and tidal channels and some shoreline erosion associated with storm events. As commonly observed in fluvial geomorphic processes, channels migrate laterally over time, as observed by Stokes (2002). Her research also concluded that the erosion associated with tidal influences is greater for a flood tide than an ebb tide. Turbidity in Lake Connewarre is observed during and following high wind events, when waves erode sediments from the floor and move them as suspended sediment load (Sherwood et al. 1988). Shoreline erosion due to wave action is also greatest on the eastern margin of the lake because of the strength of the south-westerly winds (Cecil et al. 1988).

Cecil et al. (1988) concluded that sediment transport throughout the complex occurs dominantly as suspended loads of fine-grained silts, although some bedload is recognised in the estuary where tidal influences dominate. Fluvial bedload (i.e. that carried by the Barwon River) is likely to higher during flood periods, although moderated by the two barrages across the river channel. Sediment by-passes Reedy Lake due to the channel configuration, and most of the suspended load is carried out to sea.

2.3.3 Predictions of sediment response to flows

At a time before climate change was recognised as an urgent issue, the study by Cecil et al. (1988) was commissioned to examine how changes to the flow regimes of the Barwon River would affect the sedimentation within the lower Barwon River, estuary and associated wetlands. Their study made the following prediction for four scenarios:

1. With no change in river flows, deposition of a predominantly suspended sediment load would continue, and the lake basins would gradually fill. No timescale is given but they state that it would occur “over a much greater timespan” than described for the present lake system.
2. With a reduction in the flood peak as usually experienced in winter-spring, the delivery of coarse sediment would decline. There would be reduced flushing of the lake complex with increased opportunity for suspended sediment to settle out, and sediment would aggrade more rapidly.
3. With higher baseflows, the proportion of coarse sediment in the sediment load would rise. The channel across the lake complex from the upper Barwon to the lower Barwon would become well defined with the development of levees. As a consequence, Lake Connewarre would become detached and would develop into an aggrading brackish marsh. The general rate of sedimentation would be much more rapid than at present.
4. With significantly lower baseflows, sedimentation would be slower than now. The incidence and rate of erosion within the system would rise with the loss of bank vegetation as the reduced freshwater input results in more saline conditions.

Two more recent studies have investigated the potential impacts of climate change scenarios: one examining the sediment movement at the coast for the reconstruction of the Barwon Heads Bridge (Maunsell 2006); and the other reporting on hydrodynamic modelling of the tidal channel to investigate the effects on Lake Connewarre (Womersley and Andersen 2009). The first report concluded that under the future climate change scenarios the Ocean Grove Spit should remain relatively stable, and that neither bank (eastern or western) of the Barwon River is likely to be significantly eroded. The second study - hydrodynamic modelling of the estuary - examined two scenarios: the predicted higher sea levels due to climate change; and dredging of the tidal channel to increase flushing in the lake. While the modelling of the climate change scenario showed significant changes in water quality (and therefore long-term biological and ecological character), sediment movement was not mentioned. The modelling of the dredging scenario however, found that the intensity of erosion and deposition would be altered as the tidal channel moved to establish a new equilibrium (Womersley and Andersen 2009).

2.3.4 Hydrogeology

Studies on the groundwater hydrology of the lower Barwon River, estuary and associated wetlands have only recently commenced and the groundwater processes are therefore still poorly understood (Dahlhaus et al. 2007). In particular the nature of the interactions between the three hydrological systems: the fluvial system (river, lakes, wetlands), groundwater systems, and estuarine and marine systems have not yet been established, with only low-level research undertaken in selected locations around Reedy Lake and Hospital Swamps (Dahlhaus 2011). The first investigation / observation bores were constructed in 2006 in response to a recommendation resulting from a study of the vegetation patterns(Ecological Associates 2006). Since then, an additional 9 bores were installed in 2009 by the University of Ballarat (UB) as part of an Honours research project.

Another 3 were constructed adjacent to land salinity monitoring sites established by the Corangamite CMA.

The bores have been monitored quarterly since their installation and data loggers have been fitted to the original five bores, as well as the Reedy Lake inlet and outlet channels. All data is available on the UB Spatial web-GIS and interoperative groundwater bore database (www.ubspatial.com.au). Although a rigorous analysis of the data is yet to be undertaken (but is intended as a part of this project), the preliminary results reveal that the hydrologic responses in the groundwater to fluctuations in the surface water is not straightforward (Figure 5) (Dahlhaus 2011).

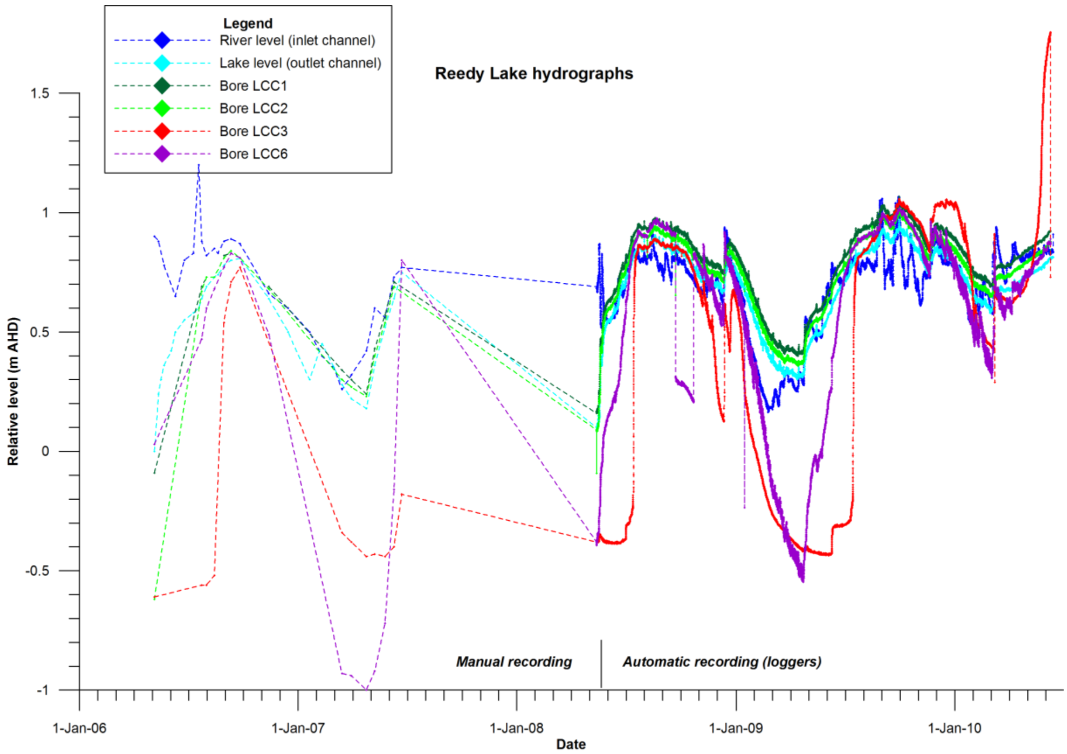


Figure 5: Response of Reedy Lake bores to river levels (raw data).

Where it has been monitored, groundwater salinity varies considerably across the lower Barwon River and estuary complex. Upstream of the lower barrage and close to the river, salinities are lowest and reflect those of the river water (electrical conductivity (EC) of 3.3 - 7.2mS/cm). Downstream of the barrage the groundwater salinities are slightly higher than that of seawater (EC 60 - 77mS/cm). In the (Reedy) lake sediments, groundwater EC varies from 15 - 25mS/cm, whereas at the northern and western edges of the lake it is consistently a little higher. In the basalt aquifer at the western end of Hospital Swamps, the EC is generally 13mS/cm, whereas it is 25mS/cm or higher at the eastern end.

The preliminary interpretation of these data show that the marine (estuarine) influence and the fluvial (fresh) water influence on the groundwater is both significant and complex. It is highlighted as one of the most critical information gaps in understanding the ecological health of the complex.

2.4 Recent Water Management Regime

2.4.1 Reedy Lake

The Barwon River channel flows from north-west to south-east on the southern margins of Reedy Lake, and discharges to the tidal, open water environment of Lake Connewarre. The river is separated from Reedy Lake by a natural levee.

Prior to European settlement, Reedy Lake was an ephemeral wetland that received minor inflows from a small local catchment and major flows from peaks in the Barwon River. The river was originally estuarine upstream of the lake and the lake would have received a combination of saline and freshwater inflows, depending on the contribution of high tides and high river flows.

Originally the spill of water from the river to Reedy Lake was controlled by the natural levee of the river bank. Water spilled onto the wetland several times a year in response to winter and spring freshes. It is believed that the wetland was mostly flooded in winter and spring and then dried out over summer and autumn. Inflows regularly exceeded the lake's capacity and discharged to Lake Connewarre to the south. The sill between the wetland and Lake Connewarre allowed saline estuarine water to enter the wetland during high tides.

The hydraulics of the system have been altered since settlement, significantly changing the water regime of the wetland. In 1898, a weir (the lower breakwater) was constructed where the Barwon River discharges to Lake Connewarre to raise the river level upstream and prevent the incursion of saline estuary water. The weir raised the level adjacent to Reedy Lake and presumably promoted inflow events. In 1906, the lake was described as drying out only in 'very prolonged dry weather' (PROV VPRS 5357/2365).

In the 1950s, the lower breakwater was replaced by the State Rivers and Water Supply Commission (SRWSC) with a floating gate structure at a lower level to manage the higher rainfall that was occurring at the time and the higher flows that were expected to result from the Corangamite Drainage Scheme (Webster 1959 cited in Dahlhaus et al. 2007). Before the modifications, the Barwon River was 0.3 m higher so that water could easily be diverted into the lake. The new structure held river water 0.3 m below the lake (Dahlhaus et al. 2007). A channel was cut between the Barwon River regulator in 1953 to aid inflows. Initially water entering the lake rapidly drained into the estuary. In order to maintain water levels in the lake during the 1967-1968 drought, the bank at the outlet was raised to 0.7 to 0.8 m AHD. These arrangements increased the wetland's volume, depth, area, and permanence. Around 1970 the outlet was regulated by raising the sill (to 0.2 m, Ian MacLachlan July 2006) and installing flap gate regulators. The regulators prevented saline estuary water from entering the wetland.

The new lower breakwater structure highlighted competing interests in Reedy Lake during the dry years of the 1960s, particularly 1960, 1961, and the drought period of 1967-1968. Irrigators required a higher Reedy Lake water level to provide water for irrigation while graziers sought a low summer level to allow dairy cattle grazing. Field and Game sought to retain water in Reedy Lake in summer over a minimum of two thirds of the wetland area to provide habitat for waterfowl. The inlet structure was sabotaged on several occasions, including in 1967 when the lake was dry and farmers sought to fill the lake.

The typical water regime in the 1960s has been described as flooding in the central lake 3 to 4 times per year, with water retained between floods and mostly dry by February (i.e. prior to duck hunting season) (pers com Ian McLachlan July 2006).

The management objectives for Reedy Lake had changed after 1961 when the Wildlife Reserves Investigation Committee recommended the area as one of the new State Wildlife Reserves. There was concern that waterbird numbers had been declining over the previous

50 years and that the lowering of the river level by the new lower breakwater had adversely impacted Reedy Lake. The lake came under the management of the Division of Fisheries and Wildlife. However, much of the on-ground management work, including fencing, revegetation and signage, was undertaken by the Field and Game Association.

In 1973 a report was prepared on the effects of grazing in Reedy Lake. Because of the fluctuating water level the grazing pressure was very cyclic, with most grazing occurring from mid-November to April. To gain the benefit of what was an annual licence, stocking was particularly heavy when feed was available. In 1973, the Hinchcliffe Licence, involved grazing 289 cattle on 700 ha of the lake, and the Anderson Licence, involved grazing 38 cattle and 100 lambs on 9 ha of the lake were introduced. Other licences were not described in the report.

An extract from the report describes the impacts on vegetation.

As the lake recedes grazing occurs mainly on spike rush, water couch and water tolerant species along the shallows, and pasture species on higher ground. In the autumn and dryer seasons as grazing becomes scarce, Lignum, cumbungi, round stemmed bulrush and phragmites are eaten as the water recedes further. This can be damaging.

The only benefit derived from grazing is the reduction of plant material if it becomes over dense and restricts the use of areas by waterbirds. Grazing may then be beneficial from time to time with a specified number of animals.

Grazing and irrigation licences were terminated before 1983 (Ian MacLachlan, Geelong Field and Game pers. comm. 2006).

Until the 1990s, Barwon River flows were supplemented by brackish (around 4,500 EC) water discharged to the Moorabool River from a dewatered quarry. This maintained the weir pool upstream of the lower breakwater and increased the frequency of spill events from the river to Reedy Lake. In 1995 Field and Game drained the lake by cutting a new outlet. In 1995/96 the lake was dried for the first time since the 1970s. There were estimated 5,000 to 10,000 carp in 300 mm of water

In 1995/96, the lake was drained to eradicate the carp population that had developed and facilitate works on the drainage flow path. The flow path from the lake to the Barwon River below the Lower Breakwater was excavated to a depth of approximately 0.1 m AHD, allowing the wetland to be drained when lake levels permit. The regulator on the outlet channel may have been installed at this time.

In 1997, the regulator from the Barwon River was upgraded by closing two of the box culverts and replacing the flap gate on the third with a penstock regulator and fish screen.

In 2006, the lake was dried out and the channel from the inlet structure to the lake bed was excavated to 0.1 m AHD and cleared of vegetation. Accumulated sediment and vegetation was also cleared from the outlet channel, to a depth of 0.1 m AHD.

A major management objective has been to dry Reedy Lake out once every 6 to 7 years to enable Carp control.

In summary, based on a review of the previous work and further advice from Field and Game Association (McLachlan pers. comm.) the water regime in the most recent past is described as the following:

- Full in winter/spring (0.7m AHD)
- Drying to average 0.4m by late summer
- Refilling in response to autumn breaks, usually April/May

Other recent water management information includes:

- Post 1995 there have been two drying cycles when Reedy Lake has been dried out completely in summers of and 1995/96 and 2006 (in 2003 it was also drawdown by 80% effectively dry);
- Post 1995, the years in-between drying cycle years, the lake has returned to the traditional pattern with the following exceptions:
    - Water levels maintained higher in summer – average of 0.5m AHD
    - In the summer of 2010/2011, flooding has kept the lake full up to the present (0.85m on 4th Jan 2011 after peaking earlier at about 1.15m or 1.25m)
- The lake can be drained to 0.2m (then has to evaporate to dry out completely)
- At 1.7m AHD, the river floods into Reedy Lake along flood paths (due to shallow depressions in the landscape)
- The outlet channel controls drying:
    - 2 banks of drop boards (each 1.2m wide) – base at 0.1m - top is 0.9m.
    - They are typically opened in November.
    - If they are not opened by November, the lake will not dry by April when filling begins again.
    - The king tide is up to 0.4m and can flood up to the outlet channel.
- The draft water entitlement (normal modis operandi) says all water above 0.7m can be diverted into the lake.

2.4.2 Hospital Swamps

This wetland comprises five basins which receive water from both the Barwon River and from local runoff. The wetland is isolated from the estuary by a bund. Water is diverted from the Barwon River via a regulated channel through Sparrowvale Farm, which has an invert of 0.3 m AHD. Other unregulated channels become active at Barwon River levees greater than 1.4 m AHD.

The bed of the wetland lies at 0.0 m AHD. The inlet regulator is opened when the Barwon River level exceeds 0.7 m AHD. Barwon levels greater than 0.9 m AHD allow Hospital Swamps levels to reach 0.5 m AHD, the normal full level. The wetland overflows to Lake Connewarre at a level of 0.5 m AHD. The wetland can be drained using a regulated pipe with an invert of 0.2 m AHD.

The hydrology of Hospital Swamps was modified in 1983 by the installation of regulators and a water supply channel from the Barwon River. Prior to these works, the swamp would only hold water temporarily after heavy winter rain or when flooded by the Barwon River, due to drainage many years ago. In the early 1980s the swamp held water for most of the year. (Yugovic 1985).

The water management cycle for Hospital Swamps which has operated over the last 25 years (with no changes in vegetation over that time), is, in summary, the following:

- Fills in spring.
- Drops to 0.3m AHD in Jan.
- Usually dry by end of summer.

Other recent water management information includes:

- 5 pools are present in the swamp (open water);
    - 3 at 0.5m.
    - 2 at 0.2m.
- Note: above 0.5m water flows into private land from Hospital Swamps.

3 ECOSYSTEM PROCESSES

The literature review identified several asset groups which underpin the key environmental values of the Lower Barwon Wetlands. Information on these assets and associated processes are documented to support our understanding of the role of water regime and river flows to ecosystem function and to assist with the development of ecological objectives for these systems and ultimately an environmental water regime for Reedy Lake and Hospital Swamps.

These asset groups are:

- Geomorphology
- Vegetation
- Waterbirds
- Fish

3.1 Site and Temporal Context

The information on the site, from data, reports and personal accounts of the various users of the sites, has provided an excellent site and temporal context in which to frame our understanding on the flora and fauna diversity and populations in Reedy Lake and Hospital Swamps. The ecological character of Reedy Lake has changed during the period 1970 to the present. Some of the key drivers of change in Reedy Lake are known at a qualitative level and the outcome of these changes, with respect to vegetation cover for example, have been quantified. Changes of other aspects (such as fish ecology and geomorphology) are largely unknown.

Some of these changes have arisen as a consequence of changes to management practice including the removal of cattle grazing and the regulation of water flow into and out of the wetland, as well as changes arising from the invasion of the Barwon River system by carp (Figure 6). Carp were first recorded in the lower Barwon River in 1979, and Reedy Lake was subsequently dried in 1995/96 and 2006 to reduce carp populations in the lake. Grazing by cattle in Reedy Lake was curtailed and finally stopped during the 1970’s.

Together these changes have affected the extent of reed cover and submerged macrophyte cover within the wetland. Many of these changes may have had implications for the diversity in general and the abundance of individual species within Reedy Lake. During this same period the ecological character of Hospital Swamps does not appear to have undergone such marked changes. The wetting and drying pattern has remained relatively consistent and the extent of open water and reed cover has not apparently undergoing marked change.

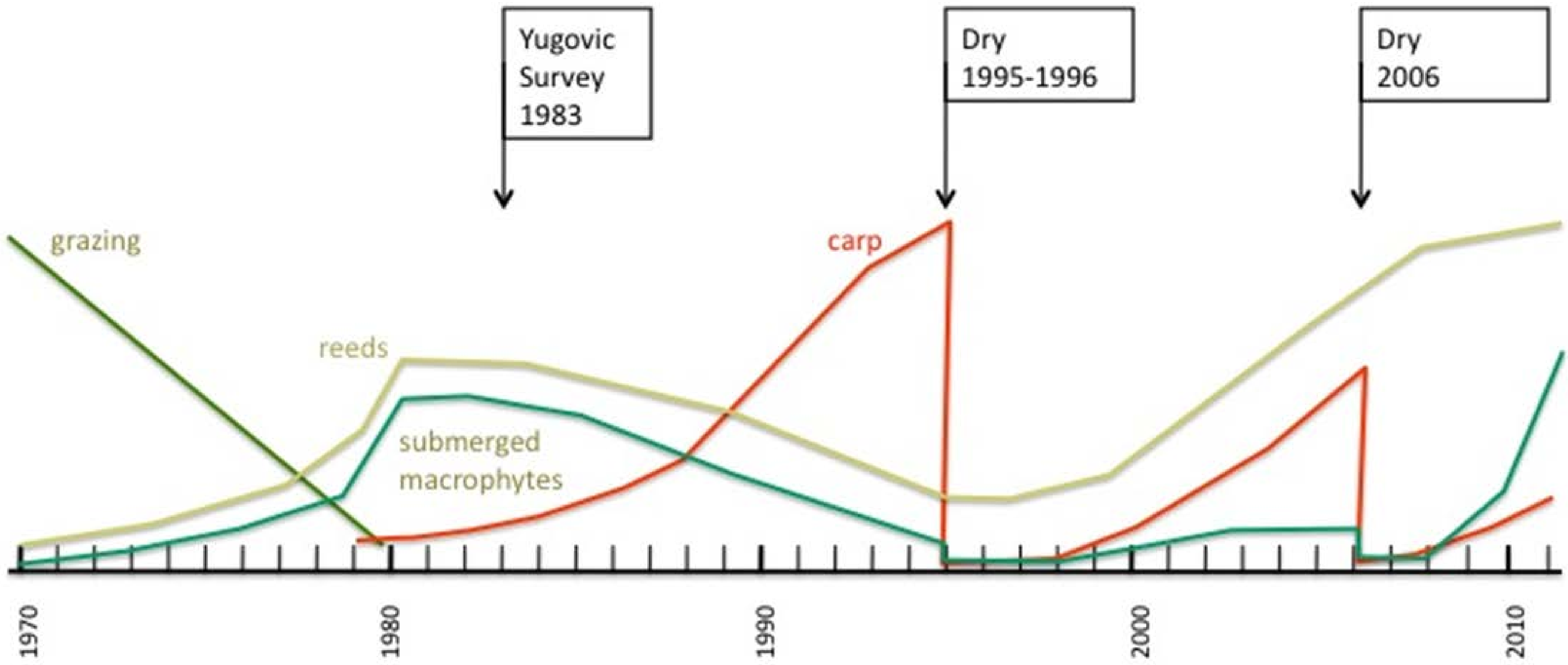


Figure 6: An overview of changes in reed and macrophyte cover, and relative carp populations in Reedy Lake since 1970. Carp were first recorded in the lower Barwon River in 1979, and Reedy Lake was subsequently dried in 1995/96 and 2006 to reduce carp populations in the lake. Grazing by cattle in Reedy Lake was curtailed and finally stopped during the 1970's.

3.2 Geomorphological Processes

Geomorphological processes are mainly concerned with wetland sediment budgets (Figure 7).

The sediment budget comprises:

1. Sources
    a. External (river load).
    b. Internal (wind-induced re-suspension and bank erosion) – minor contribution.
2. Transport
    a. Dominantly supplied during flood flows that overtop banks and structures (moderate frequency and magnitude).
    b. The majority of the annual river load passes to Lake Connewarre and beyond.
    c. Flood height relative to flood magnitude is partly controlled by roughness and constriction of estuary – sedimentation and constriction of the estuary will increase flooding frequency of Reedy Lake and Hospital Swamps.
3. Deposition
    a. Modern deposition rates are low (est. <1 mm/year in Reedy Lake and Hospital Swamps).

The suspended sediment concentration (and thus photic depth) of water in wetlands depends on:

1. Hydrology – flood events cause a period of high turbidity.
2. Wind – resuspension of bed sediment, and erosion of shorelines.
3. Water level – high water levels (with wind) result in more erosion than low levels.
4. Water level rate of fall – sudden drawdown can cause bank collapse.
5. Vegetation cover and type – dense macrophytes baffle wind and current effects.

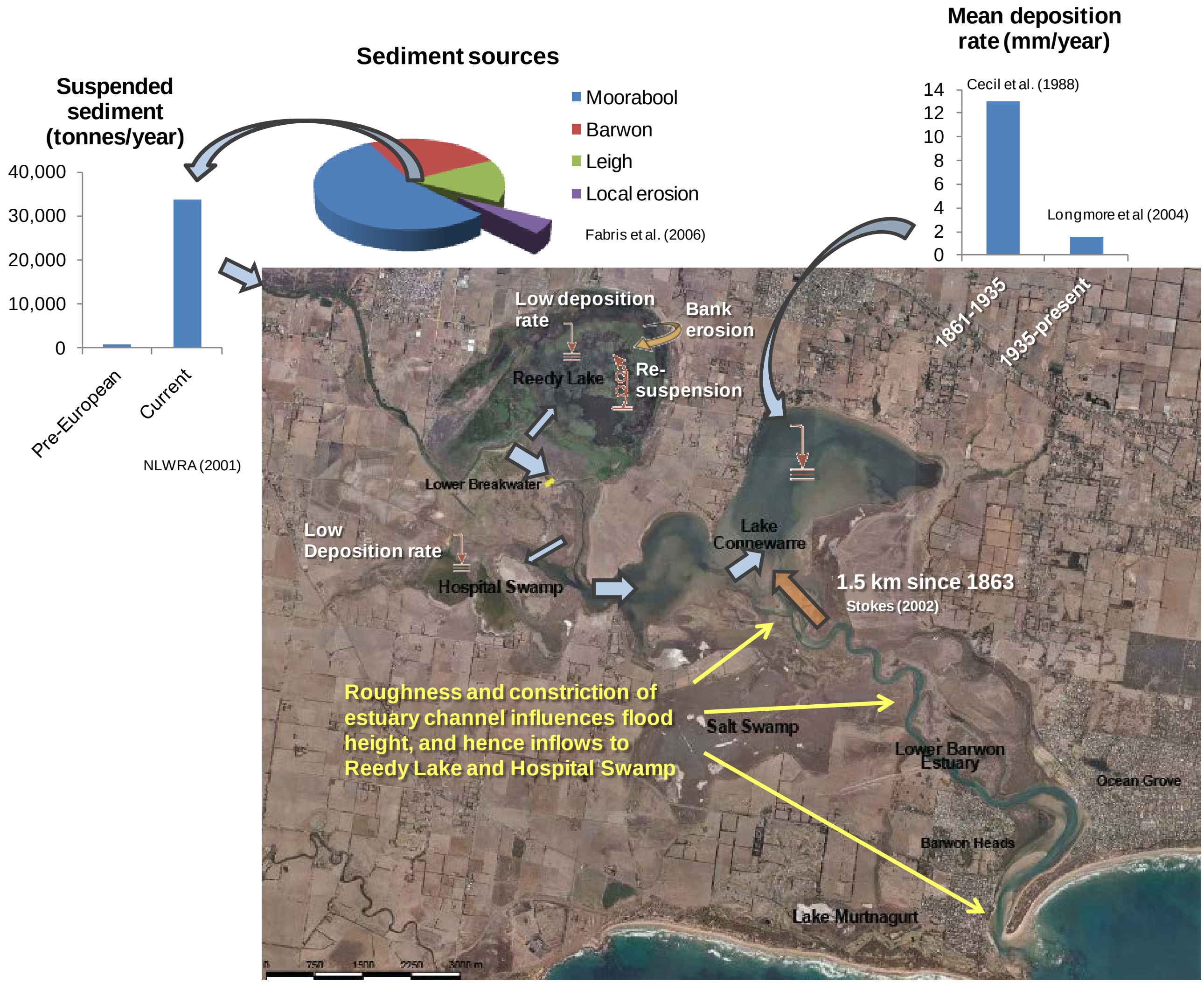


Figure 7: Conceptual model of the main geomorphological processes over the management time-scale.

Reedy Lake and Hospital Swamps are within the Moorlap Lowland. Being about seven metres above sea level, the area is dominantly under fluvial influence. However, the Barwon River is tidal up to the lower breakwater, located in the vicinity of these two wetlands, and storm surges would occasionally influence inundation of Hospital Swamps. The fluvial sediments in the area are thought to be less than 5,000 years old.

The wetland sediments are fine-grained, being dominantly clay-, silt- and fine sand-sized. The presence of vegetation has a significant impact on the sedimentation process, locally increasing deposition rates and being associated with finer material. Significant sediment deposition is episodic, occurring only when turbid river water enters the wetlands during high flow events. The bed sediments can be re-suspended, causing turbid water conditions, episodically in association with periods of high wind velocity. The events also generate waves, which can erode exposed shorelines. Bed sediments are also subject to the ongoing process of mixing by organisms (bioturbation by plant roots and animal burrowing).

In its current configuration, Reedy Lake and Hospital Swamps receive only a small percentage of the Barwon River sediment load, with most of it being transferred to Lake Connewarre. Also, the sediment load in the Barwon River is currently much lower than it was in the period from the mid-1800s to the mid-1930s, when mining and land clearing caused accelerated erosion.

Reedy Lake and Hospital Swamps are slowly accumulating, shallow, relatively flat-bottomed wetlands, containing open water and areas of dense macrophyte cover. The geomorphological values of the wetlands arise from (i) the chemical, physical and ecological processes that are associated with these characteristics, and in turn, (ii) the communities of plants and animals that respond to these processes.

In Reedy Lake and Hospital Swamps, the geomorphological processes of relevance to the ecology are subtle, and are only partly manageable. The water regime established for the benefit of ecosystem health will affect the geomorphological process, because without water the wetlands are geomorphologically inactive. A water regime that encourages macrophyte growth within the wetlands and growth of fringing vegetation around the shorelines will lower the intensity of sediment re-suspension and shoreline erosion, but will encourage bioturbation. A water regime that discourages carp will reduce the rates of bioturbation. These processes cannot be viewed as either positive or negative from a geomorphological perspective – the only value they have arises from their association with ecological process.

The geomorphological objectives suggested here are based on the assumption that ecosystem health relies on periods of relative geomorphological stability, interrupted by episodic disturbance.

3.2.1 Objectives

Given the above considerations, flow related geomorphological objectives were identified and a list of key hydrological objectives was outlined for Reedy Lake and Hospital Swamps (Table 2). The objectives are not specific, because in this case (due to low rates and intensities of geomorphological processes) the specifics of the hydrological regime should be governed primarily by ecological requirements.

Table 2: Geomorphology-based ecological objectives and hydrological requirements for Reedy Lake and Hospital Swamps.

Hydrological Component	Timing / frequency	Geomorphological Objective	Ecological Signficance
Rate of fall during recession of water levels	Applies to all events	Follow the natural rate of fall in river level, or lower, in order to minimise the chance of shoreline bank slumping	Allow suitable stable environment for vegetation communities to establish an plants grow
Bankfull	September to October / annually on average	Delivery of fine sediment to the wetlands and generation of a high turbidity disturbance event	Nutrient and organic carbon necessarily for wetland and floodplain productivity. Disturbance events resets ecosystem, priming it response on drawdown
Dry, part or all of wetlands	Summer months / partial drying annually; full drying in accordance with ecological objectives	Crack and oxidize sediments to release nutrients upon subsequent inundation	Stimulates growth of algae and productivity of macro- and micro-invertebrates

3.3 Vegetation

3.3.1 Reedy Lake

Reedy Lake has been recognised as an area of wetland vegetation since settlement. In 1906 the site was described as being covered by rushes and water lilies during and after flooding, but drying up as water disappears (PROV VPRS 5357/2365).

There is little information to describe the wetland vegetation until the early 1970s.

Lake salinities declined after the installation of flap gates on the outlet around 1970, which excluded saline estuary water from the lake. Submerged aquatic plants increased in response so that by 1979 the lake supported approximately 25% open water, 25% submerged aquatics and 50% reeds. Despite the arrival of carp around 1979, the lake vegetation retained this general structure until 1990 (Ian MacLachlan, Geelong Field and Game pers. comm. 2006).

The Yugovic (1985) vegetation survey described Reedy Lake as having a particularly rich flora. At this time, the lake featured open water in the central, deep part of the lake (elevation less than 0.0 m AHD) and at the eastern, northern and western perimeter of the lake, for lakebed elevations between 0.4 and 0.5 m AHD. Large stands and smaller patches of *Phragmites, Typha, Eleocharis sphacelata* and *Schoenoplectus validus* occupied the lake bed where the elevation lies between 0.0 and 0.4 m AHD. The aquatic habitat in and around the reed beds supported abundant semi-emergent aquatic macrophytes including *Myriophyllum* spp., *Potamogeton* spp., *Ruppia maritima* and *Vallisneria gigantea*.

The shallow plain to the south of Reedy Lake and Lake Connewarre, which forms the outlet flow path, was occupied by Lignum and grassland / herbfield species. Notably, the south-western part of the lake and the southern bank, where the elevation lies between 0.3 and 0.5 m AHD, featured several large patches of *Eleocharis acuta*. The vegetation of this area has since changed.

The outer perimeter of the lake, at the base of the scarp, where the elevation lies between 0.5 and 1 m AHD supported salt-tolerant herbland species such as *Sarcocornia quinqueflora, Bolboschoenus caldwelli* (incorrectly identified by Yugovic as *Scheonoplectus pungens),* Lignum and *Distischlis distichophylla*.

Phragmites and *Typha* are present at high elevations (greater than 0.8 m AHD) on the natural levee between the Barwon River and the lake. These areas were flooded much less frequently than the other areas occupied by this vegetation, but presumably provided access to fresh groundwater recharging from the river.

Between 1990 and 1993 there was a rapid change in vegetation with the growth of open water and the loss of reeds. However, this trend reversed over the following seven years and reeds increased dramatically in extent (Ian MacLachlan pers comm. Geelong Field and Game 2006). The potential for dense stands of reeds to reduce habitat for waterfowl remains a concern for Field and Game.

3.3.2 Hospital Swamps

Hospital Swamps is located to the south of the outlet of the Barwon River to Lake Connewarre. The wetland comprises five basins which receive water from both the Barwon River and from local runoff. The wetland is isolated from the estuary by a bund. The limit of wetland vegetation is defined by *Muehlenbeckia florulenta* shrubland which occurs in association with *Distichlis distochophylla* and *Juncus kraussii*. This association lies at an elevation of more than 1 m AHD and is rarely flooded. It is likely to occur in soils that are seasonally waterlogged. Flooding would be tolerated, but is not a requirement to sustain this vegetation.

Elevations between the Lignum and the normal full level of the wetland (0.5 m AHD) support salt tolerant sedges and herbs. *Bolboschoenus caldwellii* was observed growing over *Sarcocornia quinqueflora* and *Selliera radicans*. Other species likely to be present include *Mimulus repens, Bolboschoenus caldwellii, Triglochin striata* and *Distichlis distichophylla.* The vegetation in this area most likely reflects a zone of permanent waterlogging where saline groundwater discharges to the surface, but soil salinities are reduced seasonally by flooding.

The normal full level of the wetland is marked by emergent macrophytes, particularly *Phragmites australis* and *Bolboschoenus caldwellii. Schoenopletctus validus* is also likely to be present. This association occurs at the fringe of the wetland and of islands within the wetland that emerge above 0.5 m AHD.

Between elevations of 0.5 and 0.1 m AHD (the base of the wetland) the vegetation comprises a marshland assemblage. This area is regularly inundated to a largely stable maximum depth of 0.5 m AHD and supports a range of submerged and semi-emergent herbs and shrubs. Common species observed during the site inspection include *Sarcocornia quinqueflora, Ruppia maritima, Distichlis distichophylla, Mimulus repens* and *Cotula coronopifolia.* Other species likely to be present include *Potamogeton* sp., *Crassula helmsii, Rumex bidens, Triglochin procerum, Triglochin striata, Bolboschoenus caldwellii* and *Lilaeopsis polyantha.* This assemblage reflects the brackish conditions of the wetland, which are likely to be least saline when freshwater enters from the Barwon River, but becomes progressively more saline as water levels fall and groundwater discharge increases. Species such as *Triglochin procerum, Ruppia* and *Lilaeopsis* will tolerate permanent inundation or seasonal flooding. Species such as *Sacrocornia, Distichlis, Mimulus, Rumex* and *Triglochin striata* are favoured by seasonal inundation but will tolerate permanent waterlogging. The presence of the latter species suggests that drawdown of the wetland in late spring is important to this vegetation structure. Low water levels in November and December provide an opportunity for these low-growing species to flower and set seed before excessive temperatures, high salinities or insufficient moisture in January and February inhibit further growth.

3.3.1 Vegetation Conceptual Models

The ecology and ecosystem processes for the variety of vegetation communities are outlined in sections 4.1 to 4.9. These sections list the key drivers for each community and shows how these might change under different water and salinity regimes. Water and salinity regimes are linked at this site as drier wetlands tend to be saltier and wetter sites tend to be fresher. These communities are linked together as part of Reedy Lake (Figure 8) and Hospital Swamps (Figure 9).

a) Lignum Shrubland

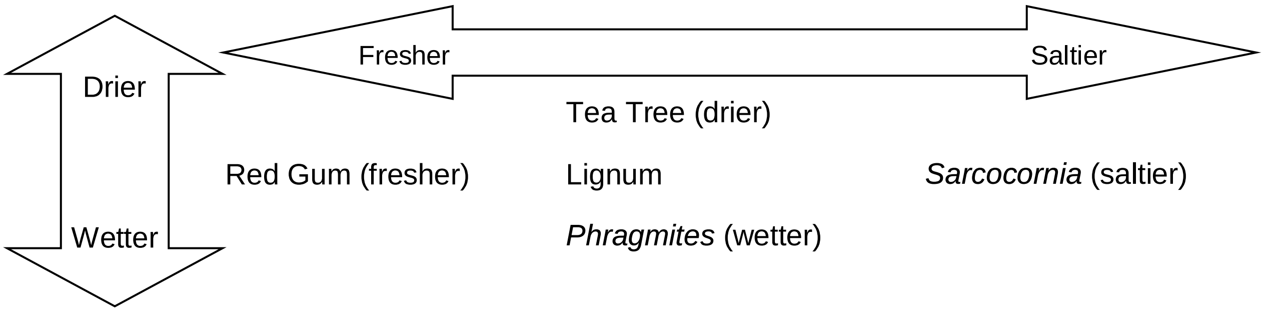
Reedy and Hospital

Lignum Shrubland occurs in areas subject to seasonal waterlogging in moderately saline soils. In Reedy Lagoon Lignum is found mainly to the west of the main basin on very low rises. The lower-lying ground between the mounds is vegetated by Sarcocornia / Salt Grass which experiences higher soil salinities and shallow flooding from pooled rainfall or very high lake levels. Lignum Shrubland can be flooded, but only on rare occasions when Reedy Lake is surcharged, such as when the Barwon River breaks its banks and overland flow enters the wetland from the west.

Lignum Shrubland occupies the highest elevation of any intact plant community in Reedy Lagoon and Hospital Swamps. Higher elevations have been cleared and are vegetated by pasture grasses. Historical information suggests that pasture has replaced Tea Tree shrublands which were extensive in the area. Remnants of Tea Tree are present as shallow fringe on the landward edge of Lignum around Lake Connewarre.

Soil salinisation is contributed by evaporation concentration of salts through the soil profile. The water table is deep enough (estimated 0.5 m depth) to allow some flushing by rainfall and intermittent flooding, which moderates soil salt concentrations.

These areas are currently subject to waterlogging or shallow flooding by overbank flooding events which occur approximately three times each year (Water Technology 2011).



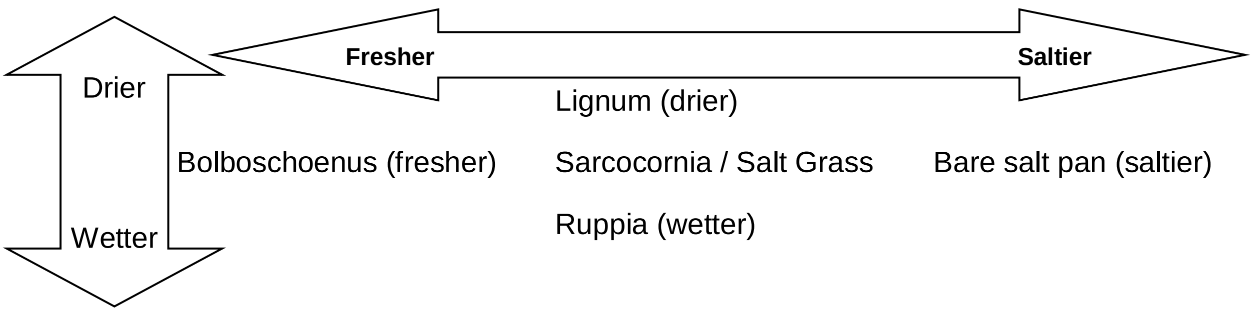
b) Sarcocornia / Salt Grass

Reedy

Sarcocornia / Salt Grass is found in Reedy Lagoon in areas with high soils salinities that are subject to shallow inundation for part of the year. This community occurs at the fringes of the lake, just above the lake full supply level. The gently sloping areas surrounding the lake are underlain by saline groundwater which evaporates from the capillary zone, particularly in summer. These soils are not effectively flushed by flooding, which is infrequent above the full supply level, or by rainfall, because the water table is so shallow and does not permit significant flushing.

This plant community is most extensive on the eastern shore of Reedy Lagoon, probably because the slope to the upthrust block of the Moorlap Fault creates a relatively steep groundwater gradient towards the wetland and maintains a shallow water table at all times, regardless of lake levels. The community is also present on the northern shore but the shallower groundwater gradient and drains and creeks bringing fresh water promote non-halophyte communities, particularly *Bolboschoenus caldwellii* sedgeland.

Sarcocornia and Salt Grass are both perennial, but their growth, and the diversity of the community, is promoted by flooding by fresh or brackish water. This community will also supports *Triglochin striata, Mimulus repens* and *Glyceria maxima*.

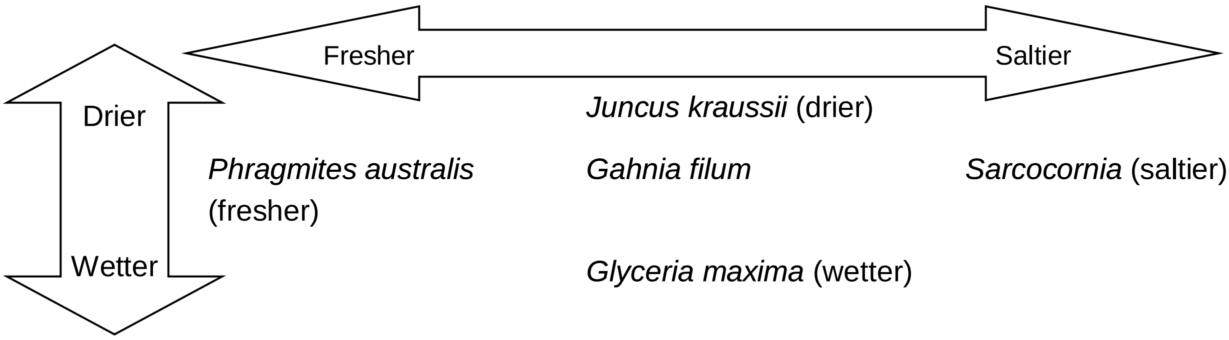


c) Gahnia filum Shrubland

Hospital

Gahnia Shrubland occurs in areas subject to seasonal freshwater inundation and prolonged waterlogging in Hospital Swamps. *Gahnia* is mainly found in the western area of the wetland, which is west of the causeway that extends north from Baenschs Lane. Water from a significant drain is pooled behind the causeway and creates freshwater flooding in winter and spring. The area dries down in most summers to dry or waterlogged soils.

The soils are moderately saline, and *Gahnia filum* relies on freshwater flooding in winter and spring to support its growth.

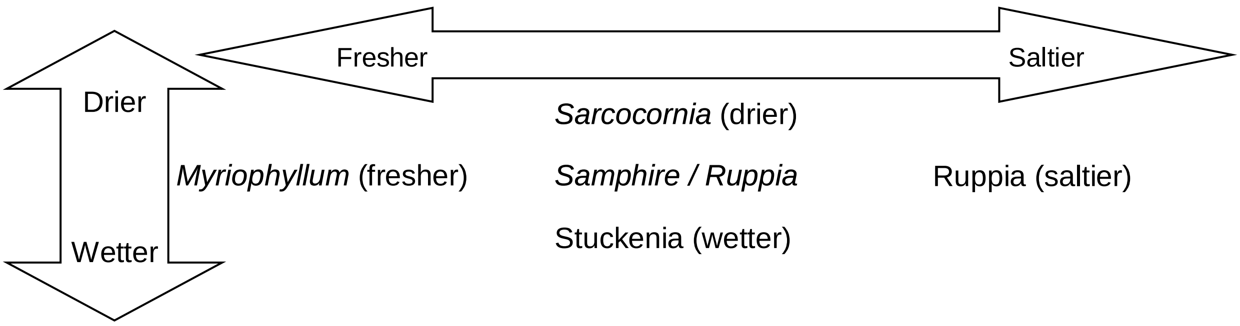


d) Samphire / Ruppia

Hospital

Samphire and Ruppia occur in shallow depressions between the main, deep basins of Hospital Swamps and Lake Connewarre. The basins are enclosed by higher ground supporting Phragmites and Lignum.

The basins are underlain by a shallow saline water table from which salts accumulate in the soil profile and on the surface in summer. There is little scope for salts to be exported as wetland levels rarely reach this level. Instead, the basins are inundated by rainfall or possibly by high groundwater levels, creating brackish or saline surface water in winter and spring. Flooding is typically shallow, less than 0.3 m deep.



e) Bolboschoenus

Reedy and Hospital

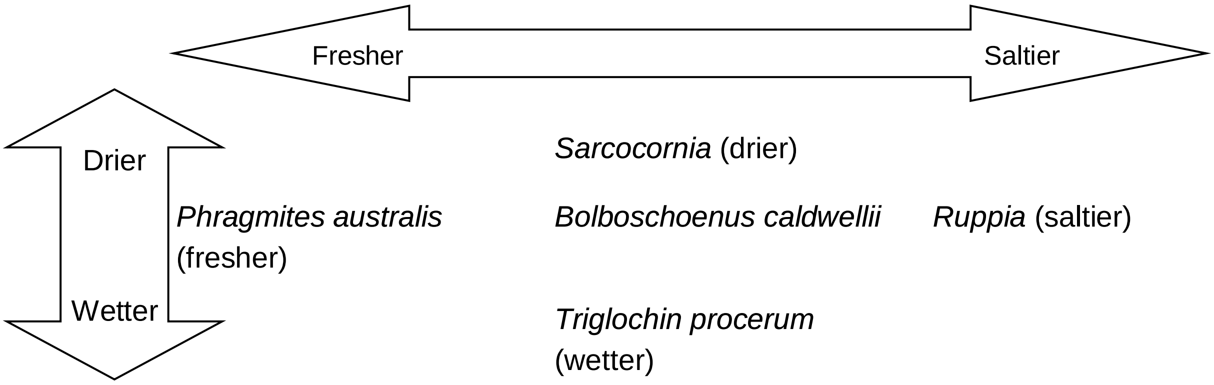
Bolboschoenus caldwellii sedgeland is an extensive plant community in Reedy Lagoon. It occurs as extensive beds in the south-west of the wetland, to the west of the inlet regulator. It also occurs on the north and southern edges of the wetland, near the full supply level.

Bolboschoenus caldwellii grows in areas subject to alternating dry and flooded conditions. Maximum flooding depths are typically 0.5 m but *Bolboschoenus* will grow in depths of more than 1 m. Above ground growth is seasonal, arising from a buried perennial corm in winter and persisting into late summer.

Bolboschoenus tolerates highly saline soils in summer and autumn while it is dormant, as long as the winter-spring growing season is sustained by fresh surface water. It therefore occurs at slightly lower elevations than the *Sarcocornia* that fringes Reedy Lagoon to the north and east.

Areas subject to a similar flooding regime, but in less saline soils, would support *Phragmites australis.*

In Hospital Swamps *Bolboschoenus* mainly occurs at the fringes of saline wetlands. Salinities are lower at the fringes because the water table is slightly deeper and some freshwater flushing occurs from the surrounding deeper freshwater basins.

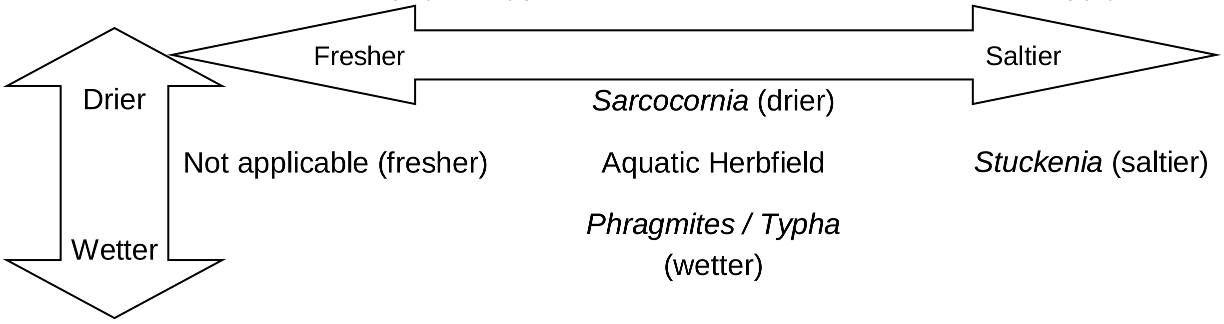


f) Aquatic Herbfield

Reedy

An aquatic herbfield community occurs at the shallow fringes of Reedy Lagoon between the full supply level and the typical summer low water level. A range of aquatic plants grows in response to winter flooding to 1 m including *Myriophyllum, Villarsia reniformis* and *Triglochin procerum*. These plants retreat to below-ground perennating tissues or propagules as water levels decline in spring and a range of seasonal herbs appear. These include *Mimulus repens, Lilaeopsis polyantha* and *Triglochin striata.*

This community depends on flooding by freshwater, which is provided by the main water body of Reedy Lagoon. Freshwater flooding moderates soil salinity over summer by flushing soil salts so fewer halophytes appear than at elevations above the full supply level.

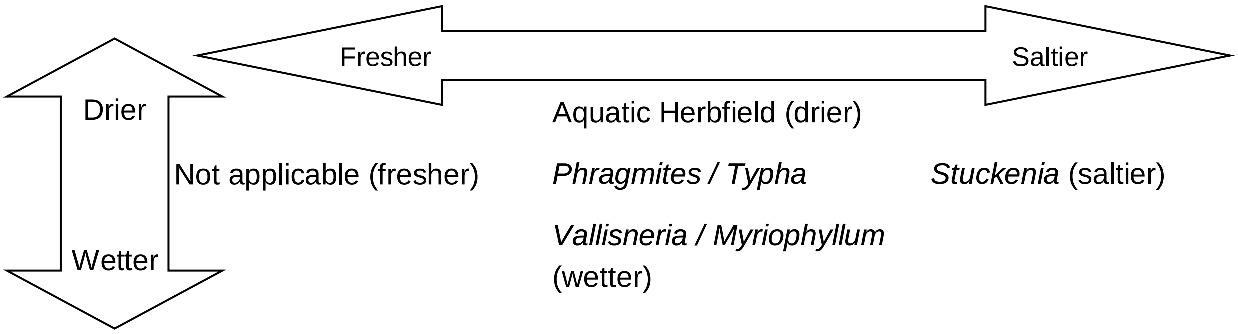


g) Typha sp. / Phragmites australis

Reedy and Hospital

Typha sp. and *Phragmites australis* form extensive beds in Reedy Lagoon. They are favoured by seasonally fluctuating water levels that vary between a depth of 1 to 1.5 m in winter shallow flooding in summer and autumn.

Both plants are tolerant of saline conditions which would develop at low lake levels when saline groundwater flux to the lake will be greater and the dilution capacity of the lake is reduced. However, the plants generally grow in fresh conditions provided by the water column, and its limited flushing capacity, during spring.



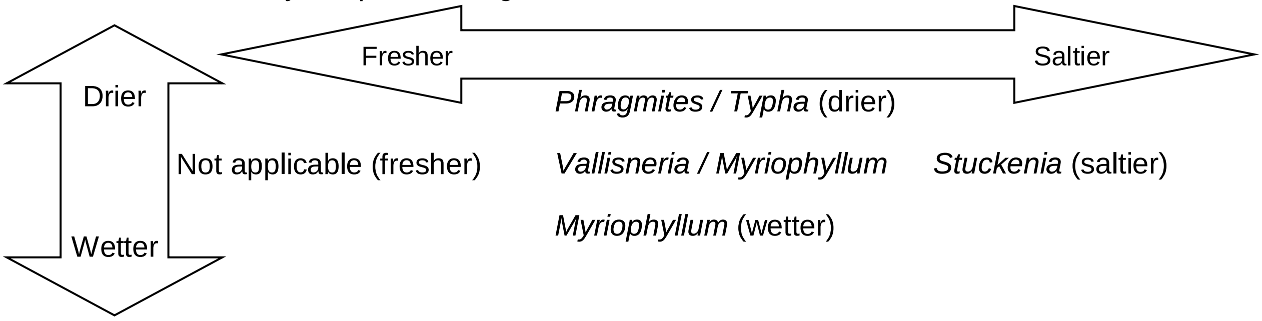
h) *Vallisneria / Myriophyllum*

Reedy

The deepest areas of Reedy Lagoon are flooded to over 1.5 m. These conditions are too deep for *Phragmites* and *Typha* but are suitable for the deep semi-emergent aquatic macrophytes *Vallisneria* and *Myriophyllum*.

The water column is predominantly fresh and would only become saline when lake levels are very low and the lake is drying out. These temporary saline conditions would be tolerated by the plants in perrenating below ground tissues, seeds or plant fragments.

The lake is underlain by saline groundwater, but this has little effect on surface water salinities while the lake is full. The full lake suppresses groundwater discharge and readily dilutes salts. *Vallisneria* and *Myriophyllum* have shallow roots and their growth would not be constrained by deeper saline groundwater.



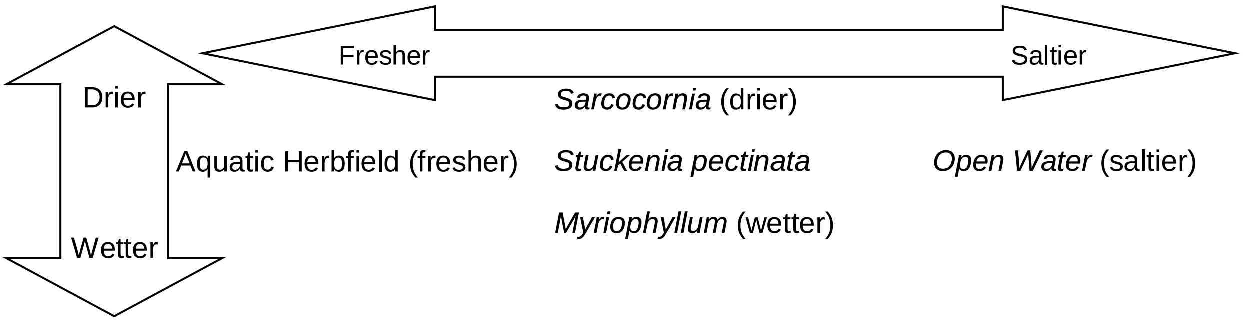
i) *Stuckenia*

Hospital

Stuckenia pectinata is a salt tolerant submerged aquatic macrophyte. It dominates the deep, seasonally inundated basins of Hospital Swamps where it occurs with *Chara* sp. Water depths in winter are typically 0.3 to 0.6 m and the basins dry out completely in summer.

Hospital Swamps briefly provides fresh conditions when it is filled in winter and stormwater inflows regularly flush the system. The wetland will become more saline in spring and summer as inflows decline and saline groundwater discharges to the surface water body. In summer and autumn, when the wetland is usually dry, saline groundwater discharges directly to the surface or accumulates salt in the soil profile through evaporative concentration.

These conditions favour *Stuckenia* and *Chara*, which tolerate the saline surface flooding and dry, saline conditions over summer when they survive as dormant propagules.



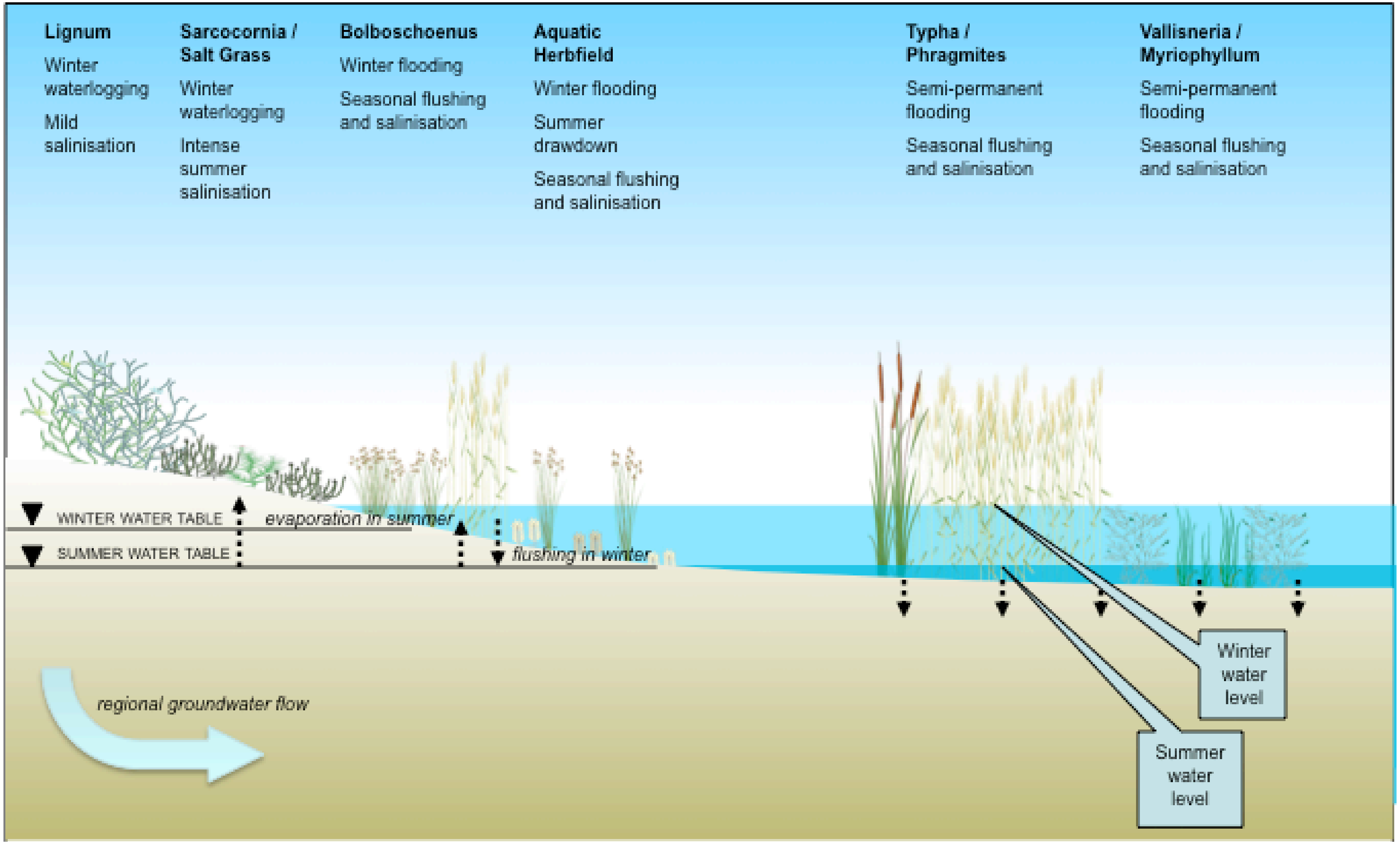


Figure 8: Conceptual model for vegetation species and processes in Reedy Lake.

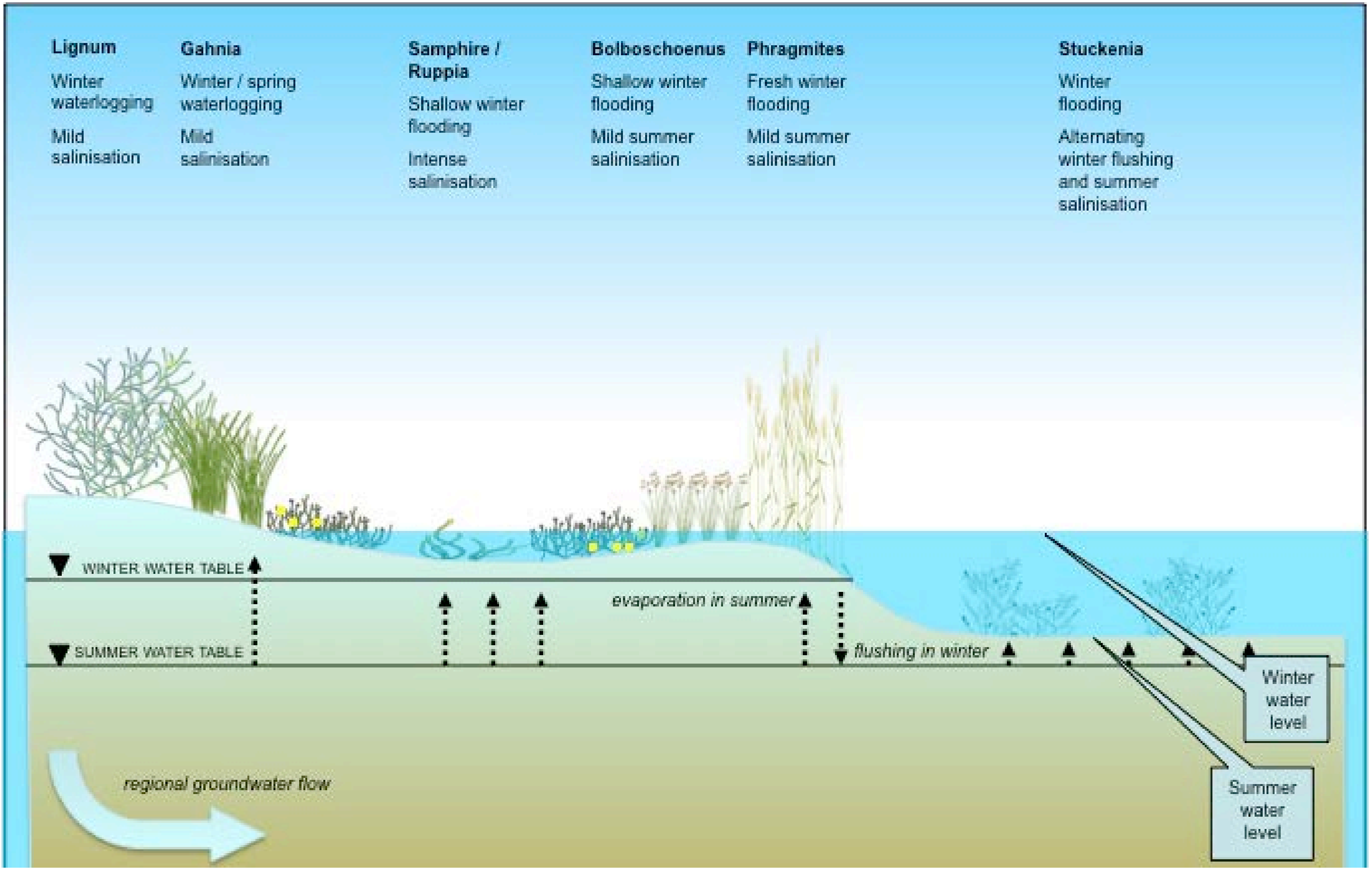


Figure 9: Conceptual model for vegetation species and processes in Hospital Swamps.

3.3.2 Vegetation Ecological and Hydrological Objectives

a) Aquatic Herbfield

Aquatic Herbfield is present in open water areas throughout Reedy Lake, but is best developed in the deepest parts of the wetland in the Big Hole and in excavated channels. These areas are flooded at all times, except when the wetland is drained, at depths of more than 1 m at full supply level. Aquatic Herbfield is also present between the reed beds and the lakeshore in depths of approximately 0.1 to 0.4 m, which is typically flooded in spring and exposed in autumn.

Aquatic Herbfield grows in a freshwater environment in winter and spring. Accumulated salts in the lake are diluted by inflowing water and flushed by lake outflows. Deep flooding in winter and persistent flooding in summer suppress groundwater discharge and maintain a low-salinity environment in the surface soils of the lake.

This plant community comprises a range of semi-emergent and submerged aquatic macrophytes. Dominant plant species are *Vallisneria americana*, *Myriophyllum salsugineum* and *Triglochin procerum*. Growing within beds of these plants are dense accumulations of the floating plants *Wolffia australiana, Lemna* spp. and *Azolla filiculoides*. The beds are patchy and tend to be most extensive in sheltered areas near the base of tall reedbeds.

The Aquatic Herbfield species tolerate a wide range of depths. *Vallisneria americana* growths to depths of 5.5 m in clear water, but the preferred depth appears to be shallower, in the order of 1.5 m (Roberts and Marston 2000). *Vallisneria americana* does not appear to have a clearly defined growing season (Nielsen and Chick 1997, Britton and Brock 1994). *Myriophyllum salsugineum* is reported in similar conditions, and typically occurs in depths of less than 2 m in the River Murray (Walker, 1994).

The Aquatic Herbfield species have soft tissues that are supported by the water column and respond readily to changes in water level. When water depths increase they elongate existing tissues or rapidly producing new leaves and stems, and leaves float down with the water surface as water levels fall (Cooling, 1996).

The plants of the Aquatic Herbfield occur in both permanently inundated habitats, such as the weir pools of the River Murray (Walker, 1994) and seasonally inundated habitats such as the wetlands of the Northern Tablelands in New South Wales (Brock 1988 and 1991, Brock and Casanova 1991). The distinctive niche for this community appears to occur where the depth in the spring and summer growing season exceeds the tolerance of emergent wetland plant species such as *Phragmites australis,* but is not so deep as to exceed the requirements of the herbfield species themselves. This is likely to be provided in areas flooded to a depth of 0.5 to 1.5 m in Reedy Lake for at least three months between September and February. It is also defined by the freshwater conditions that are provided in the central areas of Reedy Lake.

Aquatic Herbfield appears to have increased in extent and complexity between 1983 when surveyed by Yugovic and 2011. Open water was mapped as ‘bare areas’ but Yugovic noted the presence of aquatic herbfield species. However, the extensive beds observed in 2011, and the bed of *Villarsia reniformis* in particular, were not reported. It is possible that grazing of the lakebed in the years prior to the Yugovic survey suppressed this community.

Most likely depth preference is more than 1 m but no deeper than 2 m if water is turbid. *Vallisneria americana* does not appear to have a clearly defined growing season (Nielsen and Chick 1997, Britton and Brock 1994).

Decomposition of submerged aquatic macrophytes increases nutrient levels in wetlands and are significantly higher than rates for charophytes. When plants are growing nutrient levels are lower than when plants are decomposing. Plant decomposition is accelerated by wetting and drying.

b) Reed Beds

Phragmites australis Reed Beds form the most extensive plant community in Reedy Lake. Reed Beds occupy almost all areas flooded to a depth of between 0.3 and 0.7 m at full supply level. The stands are very dense and individual shoots reach heights of more than 2.5 m.

The beds are subject to almost permanent inundation, with only the outer, shallowest areas exposed in most years in autumn. The entire beds are only exposed when the lake is deliberately drained. The beds therefore experience permanent waterlogging or shallow flooding with an annual fluctuation of 0.3 to 0.5 m.

The reed beds have formed in an area where low to moderate salinities have been interpreted. Saline groundwater discharge to the wetland bed is suppressed by persistent flooding and regular through-flow events export accumulated salt. Elevated salinities may occur when water levels are low and saline groundwater may discharge to the wetland soils.

Phragmites australis is tolerant of high salinities and occurs throughout the world in estuarine environments which alternate seasonally between brackish and saline conditions. In some environments, this salinity regime defines a niche which is tolerated by *Phragmites australis* but excludes species with similar depth requirements but with salinity tolerances that are higher (e.g. *Juncus kraussii* or *Avicennia maritima*) or lower (e.g. *Baumea arthrophylla*). *Phragmites australis* seeds will germinate at rates of 36.5% in 5 g/L and 11% at 10 g/L salinity and adults will tolerate salinities up to persistent concentrations of 18 g/L. Nevertheless, freshwater conditions are preferred and in the absence of competition or disturbance, *Phragmites australis* will achieve densities exceeding 10 kg / m^2 in freshwater soils (Hocking 1989a and Adcock and Ganf 1994). Increasing wetland salinity can lead to the decline and loss of *Phragmites australis* beds, such as when coastal barriers in the Gippsland Lakes system were removed and the lakes were exposed to more marine conditions (Marston 2000).

Phragmites australis is similarly tolerant of a wide range of water regimes. An annual depth range of 0 to 1 m, from late winter to early summer with inundation for 80 to 225 days is likely to promote optimum growth (Roberts and Marston 2000). *Phragmites australis* had among the widest tolerances of any common riparian plant to water regimes on the River Murray and occurs in seasonally waterlogged, perennially flooded and seasonally inundated habitats (Blanch et al. 1999 and 2000; Walker, 1994). Once established, stands are highly tolerant of drought and below-ground perennating tissues can survive several years without inundation (Roberts and Marston 2000).

Reeds are somewhat sensitive to the timing of the flood peak because seasonal shoot production takes place in late spring and shoots grow to a height appropriate for the water depth at that time. If water levels fall quickly after this stage, reeds are left with excessive shoot growth and an inefficient morphology. Similarly if water levels rise to an annual peak in late summer, when fewer shoots are being produced, existing stems and leaves will be submerged and be less productive. Even so, minor changes in water regime may affect stand vigour, but are unlikely to significantly degrade them.

The water regime of Reedy Lake conforms to the estimated ideal conditions for *Phragmites australis* growth in terms of the depth range, persistence of flooding, timing of the seasonal peak in water level and predominantly freshwater environment. Reed beds are currently expanding and it is likely that in time will occupy a greater area than at present.

c) Bolboschoenus caldwellii Sedgeland

Bolboschoenus caldwellii Sedgeland occurs at the fringes of Reedy Lake where it forms dense, nearly monospecific stands. It occurs together with *Eleocharis acuta, Distichlis distichophylla, Samolus repens* and other salt tolerant herbs. The community grows at depths approximately 0.2 m below and above the full supply level where plants are subject to shallow flooding or waterlogging for two to four months of the year.

Bolboschoenus caldwellii has perennial tubers and rhizomes. Shoots are produced annually in spring to reach a height of 0.3 to 0.9 m tall, and then die back in autumn. Plants grow taller shoots in deeper water, but this comes at the expense of tuber growth and asexual reproductive potential (Blanch et al. 1999a; Seibentritt and Ganf 2000).

Bolboschoenus caldwellii grows predominantly in brackish environments with salinities of 20 to 45 g/L (1:5 dilution of dried soil) reported from dense stands in Clydebank Morass and Dowd Morass in the Gippsland Lakes. Seedlings appear to be more sensitive to salinity than mature plants with tubers able to resprout in salinities more than three times the salinity reported for germination (Kantrud 1996). In the closely related species *Bolboschoenus medianus*, high salinity promotes dormancy in adult plants, with a shift in biomass allocation from culms to tubers (Morris and Ganf 2001).

In Reedy Lake, *Bolboschoenus caldwellii* occupies an area which is interpreted to alternate between highly saline conditions in summer and fresh to brackish conditions in winter. Groundwater at the western, northern and eastern fringes of the lake appears to be more saline than the surrounding landscape, suggesting that groundwater is evaporating, rather than discharging, at the lake fringes and accumulating high concentrations of salts where the water table is close to the surface. The highly saline soil environment in autumn is relieved in winter and spring when high lake levels provide a shallow layer of fresh groundwater and overlying fresh surface water. The senescence of *Bolboschoenus caldwellii* in autumn to hardy perennating (long surviving) tubers is most likely an adaptation to seasonally fluctuating soil salinities and water levels. While the water regime at the fringes of Reedy Lake are within the water regime tolerances of *Phragmites australis,* reeds may be excluded by high soil salinities.

The extent of *Bolboschoenus caldwellii* has increased between the Yugovic survey in 1983 and 2011. *Bolboschoenus caldwellii* is readily grazed and was most likely suppressed by cattle in the period prior to the 1983 survey.

d) Open Water with Stuckenia pectinata and Chara sp. Marshland

Stuckenia pectinata and *Chara* sp. occur in the main basin of Hospital Swamps where they form a marshland that is flooded to approximately 0.5 m in spring and dries over summer and autumn. As well as alternating between a flooded and a dry state on a seasonal basis, the main basin alternates between saline and fresh conditions. Hospital Swamps is adjacent to the Mt Duneed lava flow which has high groundwater salinities ranging from 20,000 EC at the western end of Hospital Swamps to 50,000 EC in the east. Saline groundwater contributes to high wetland salinities in summer and autumn when surface water levels are low. Inflows in winter and spring will flush accumulated salts and suppress groundwater discharge, creating seasonally fresh conditions.

This environment supports the salt tolerant aquatic macrophytes *Stuckenia pectinata* and *Chara* spp. which grow when winter inflows fill and flush the main basin and tolerate the high salinities in summer. Both plants have resting stages that tolerate the saline conditions of the wetland bed during autumn.

Stuckenia pectinata grows preferentially in water depths of 0.8 to 1.2 m and has limited tolerance of flowing water (Holm, 1997). The preferred substrate is mud and silt. The plant grows from tubers and will regrow if stems are broken

e) Samphire / Ruppia

Sarcocornia quinqueflora herbfields occur at the fringes of the basins of Reedy Lake and Hospital Swamps. These areas are subject to intermittent flooding when the wetlands are surcharged by high inflows, but are generally waterlogged through winter and spring and dry over summer and autumn. Shallow basins in Hospital Swamps are fringed by *Sarcocornia* with *Ruppia maritima* becoming the dominant species in the deeper central areas. Overbank flows are estimated to occur 3 times per year (Water Technology 2011).

The salinity of these environments is strongly influenced by groundwater and its interactions with surface water. In summer and autumn, evaporative concentration of salts from the shallow saline water table creates highly saline soils which permit only salt-tolerant species to survive, including *Sarcocorina quinqueflora* and *Distichlis distichophylla*. In winter and autumn surface flooding dilutes and may flush accumulated salts, providing a shallow brackish environment in which *Ruppia maritima* grows.

f) Gahnia Sedgeland

Gahnia sedgeland grows in a similar hydrological environment to Samphire, but in lower salinities. It is found at the western end of Hospital Swamps where Armstrong Creek enters the system. The wetland basin in this area fills in winter and spring, which brings the water level up to the base of the Gahnia sedgeland, creating seasonal waterlogging and intermittent flooding when the wetland is surcharged by storm events. In summer, waterlogging will persist for some time until the water table recedes. The root zone will be subject to increasing salinisation as salts evaporate from the water table and accumulate in the soil.

A summary of these objectives and water requirements are shown in Table 3 and Table 4.

Table 3: Vegetation-based ecological objectives and hydrological requirements for Reedy Lake.

Hydrological Component	Timing	Ecological Objective
Rising water levels	July to August, annually.	• Stimulate aquatic plant growth • Dilute accumulated salt
Bankfull (+1.1 m AHD)	September to October, annually.	• Create open water habitat • Promote growth of submerged aquatic macrophytes and emergent macrophytes such as *Juncus, Schoenoplectus* and *Bolboschoenus* • Waterlog Lignum, *Distichlis* and Samphire communities • Flush accumulated salt
Overbank flows	July to December for 1 to 3 days, 1 to 5 times per year	• Inundate Lignum, *Distichlis* and Samphire communities
Reedbeds exposed	December to May, annually	• Expose upper wetland bed and promote growth of herbland plants including *Mimumuls*, *Eleocharis acuta*, *Selliera radicans* • Shorten the growing season of Phragmites and suppress growth

Table 4: Vegetation-based ecological objectives and hydrological requirements for Hospital Swamps.

Hydrological Component	Timing	Ecological Objective
Main wetland basin flooded to more than 0.3 m AHD	June to August, annually.	• Initiate *Stuckenia* and *Chara* growth
Inflows sustained; main wetland basin 0.5 m AHD	September to November, annually.	• Continuous flushing of salt from deep wetland basins • Inundation of reedbeds and *Bolboschoenus* beds fringing the main basin • Sustain growth of *Stuckenia* and *Chara* • Promote growth of *Myriophyllum* in southern part of main basin • Waterlog *Gahnia filum* sedgelands
Freshes raise water level to 0.7 m AHD	September to November, annually.	• Inundate shallow wetland basins and promote growth of *Ruppia* • Inundate *Gahnia filum* sedgelands
Inflows intermittent; water levels to recede to less than 0.3 m AHD	December to January, annually.	• Increase wetland salinity as groundwater discharge increases in proportion to surface water • Shallow wetland basins exposed
Inflows rare; wetland bed dry	February to May, annually	• Soil salinity increases in shallow wetland basins and deep wetland basin • *Chara* and *Stuckenia* die back • Limited colonisation of wetland bed by annual herbland plants • Reeds and other emergent macrophytes become dormant • High soil salinity excludes reeds

3.3.3 Role of Hydrology in Vegetation Change

a) Changes in Vegetation Structure

Extensive changes in vegetation in the seasonally waterlogged periphery of Reedy Lake and Hospital Swamps occurred between 1983 and 2010 and reflect the removal of stock. Reedy Lake has a long history of grazing which extends probably from settlement up to the 1970s when grazing licences were gradually withdrawn through to the early 1980s when grazing completely ended. Grazing in Hospital Swamps ended earlier, in the early 1970s.

The 1983 survey was undertaken soon after grazing had ended, when vegetation responses to the removal of grazing were in their early stages. The seasonally waterlogged perimeter of Reedy Lake supported extensive areas of exotic grassland, particularly in the floodway between the wetland and the Barwon River in the west. By 2010 *Muehlenbeckia florulenta* had expanded in this area, almost doubling its cover to 94.3 ha while the area of exotic grassland decreased from to 15.9 ha. Similarly, grazing suppressed the extent of *Bolboschoenus caldwellii* in the persistently waterlogged and intermittently flooded lake edge, which instead supported *Sarcocornia quinqueflora* Herbfield. This community has decreased in extent from 44 to 9 ha while the extent of *Bolboschoenus caldwellii* Sedgeland has increased from 35 to 128 ha.

Stock are also likely to have suppressed the growth of reeds in Reedy Lake and Hospital Swamps in the period leading up to the 1983 survey. The impact of stock would have been greatest on the banks of the Barwon River where reed growth is promoted by fresh groundwater rather than by flooding and the reeds were accessible to stock for most of the year. This area supported exotic grassland in 1983 with only patches of *Phragmites australis* Grassland present. By 2010 the shoreline was dominated by dense, continuous stands of reeds, in places more than 2.5 m high. A lesser response would be expected in the central part of the lake where flooding or boggy conditions limited stock access. Indeed, graziers lobbied for Reedy Lake to be operated at lower levels in the 1960s to allow stock greater access to the wetland bed.

Changes to vegetation in the seasonally waterlogged perimeter of Hospital Swamps are less extensive. Grazing ended there earlier, approximately ten years before the 1983 survey, and vegetation had more time to respond and equilibrate to its absence. Furthermore, the seasonally waterlogged areas that stock would access comprise a smaller proportion of Hospital Swamps than Reedy Lake. The main change has been the decline of *Distichlis distichophylla* Grassland, Exotic Grassland and Samphire Herbfield and the arrival of *Muehlenbeckia florulenta* Shrubland.

The colonisation of exotic grasslands by *Muehlenbeckia florulenta* represents an increase in native vegetation extent and an improvement in fauna habitat quality. However, the *Bolboschoenus caldwellii* sedgelands have significantly lower botanical diversity than the *Sarcocornia quinqueflora* Herbfields they have replaced. While samphire herbfields support a diverse community of native grasses, herbs and forbs, beds of *Bolboschoenus caldwellii* and *Phragmites australis* are almost monospecific. Nevertheless, extensive, closed beds of vegetation are important habitat components for several fauna species such as nesting waterbirds and have an important role in the lake ecosystem.

b) Carp in Reedy Lake

The extent of *Phragmites australis* and *Typha orientalis* in Reedy Lake has fluctuated dramatically between 1983 and 2010, with carp strongly indicated as the dominant influence. The extent of reedbeds declined from 233 ha in 1983 to 154 ha in 1995 (Ecological Associates 2006) before recovering to 352 ha in 2010. The decline in reedbeds in the 1980s and early 1990s corresponded to the development of a large population of carp. By 1994 most of the submerged aquatic vegetation reported by Yugovic (1985) had been lost and clumps of reed beds were dislodged and were drifting in the lake (Ecological Associates 2006). In 1994 the lake was drained to reduce the carp population: an estimated 5,000 to 10,000 fish were stranded. The lake was drained again in 2005 with an estimated 2,500 large carp stranded in the lake.

Carp control appears to have reversed the decline in reedbeds and allowed the recovery of submerged and semi-emergent aquatic vegetation.

c) Water Regime and Reed Beds in Reedy Lake

Grazing is implicated as a strong influence on the extent of reed beds at Reedy Lake by the change from exotic grassland to reedbeds on the Barwon River frontage between 1983 and 2010. Grazing would also have suppressed the growth of reeds on the lake bed, as implied by the reported demands of graziers to lower lake levels in Reedy Lake to allow greater access to stock. Carp are also implicated as a major influence by the expansion of reedbeds since periodic drying events were introduced in 1995/96 (Figure 6).

Together, these factors can explain how reeds declined after the Yugovic survey and increased beyond the 1983 extent once carp were controlled and growth could continue in the absence of grazing. After these two factors, the salinity and water level regime appears to have a relatively minor and invariable role in vegetation dynamics at Reedy Lake.

The salt and water environment in Reedy Lake has been largely stable since the 1970 when the last modifications to the hydraulics of the system were completed. These included:

- raising the sill of the outlet between the Reedy Lake and Lake Connewarre to increase the full supply level and to exclude saline estuary water;
- installing a flap gate on the outlet to Lake Connewarre to prevent sea water inflows;
- raising the Lower Breakwater and increasing the potential to fill the lake; and
- lowering and regulating the inlet channel to allow the lake to be filled at any time.

All of these actions contributed to an increase in the depth and permanence of Reedy Lake and reduced its salinity. The altered conditions probably made conditions more favourable for *Phragmites australis* growth. *Phragmites* grows well in areas that are subject to spring and summer inundation to a depth of 0.2 to 1.0 m and a greater wetland depth and permanence would have expanded the available habitat. It is intolerant of high salinities, but can grow in saline soils when flooded by freshwater. The potential for soils and surface water to develop high salinities from groundwater discharge is greatest when the wetland is dry, and this was suppressed by the modifications. Once established, stands of *Phragmites* are resilient to disturbance and tolerate sustained periods of drought, flooding or high salinity (Table 5).

Table 5: Vegetation community outcomes under various water regimes.

Elevation m AHD	Current	Deep Control	Dry Control	Saline Control
0	Aquatic Herbfield	Aquatic Herbfield	Aquatic Herbfield	Aquatic Herbfield
0.1	Aquatic Herbfield	Aquatic Herbfield	*Phragmites australis*	Aquatic Herbfield
0.2	Aquatic Herbfield	Aquatic Herbfield	*Phragmites australis*	Aquatic Herbfield
0.3	Aquatic Herbfield	Aquatic Herbfield	*Phragmites australis*	Aquatic Herbfield
0.4	*Phragmites australis*	Aquatic Herbfield	*Phragmites australis*	*Phragmites australis*
0.5	*Phragmites australis*	Aquatic Herbfield	*Phragmites australis*	*Phragmites australis*
0.6	*Phragmites australis*	*Phragmites australis*	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*
0.7	*Phragmites australis*	*Phragmites australis*	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*
0.8	*Bolboschoenus caldwellii*	*Phragmites australis*	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*
0.9	*Bolboschoenus caldwellii*	*Phragmites australis*	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*
1.0	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*	Lignum Shrubland	Lignum Shrubland
1.1	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*	Lignum Shrubland	Lignum Shrubland
1.2	*Bolboschoenus caldwellii*	*Bolboschoenus caldwellii*	Lignum Shrubland	Lignum Shrubland
1.3	Lignum Shrubland	*Bolboschoenus caldwellii*	Lignum Shrubland	Lignum Shrubland

3.4 Waterbirds

3.4.1 Introduction

Waterbirds are those bird species that depend on water for feeding by swimming, diving or wading, or for the provision of nesting sites.

Waterbirds constitute an important component of the Lower Barwon wetland complex aquatic ecosystem, with a diverse range of species present in, at times, significant numbers. The diversity of species recorded are in response to the variety of wetland types that make up the wetland complex, but also in the long-term, abundant and diverse native bird populations are indicative of wetland health (Reid and Brooks 2000). For each species suitable foraging, refuge and breeding habitat must be maintained within the wetland complex. In addition, many terrestrial bird species, particularly insectivores, are also reliant on wetland productivity.

To understanding the requirements of the bird species that use these wetlands it is necessary to understand when the birds use the wetlands, and the specific elements of habitat and microhabitat present that allow the birds to obtain the resources that they require.

Temporally the birds that use the Barwon River and its associated wetlands can be broadly split into four general groups based on when they are present at the site:

- non-breeding summer migrant wader species, which migrate north to breed in autumn and winter;
- breeding or foraging species that respond to local flooding events and wetland productivity, which may move on a regional or large scale within Australia;
- species seeking summer and drought refuge; and
- resident species that use the site all year round.

Australian waterbirds are generally opportunistic in their patterns of movement, feeding ecology, habitat use, and patterns of reproduction and moulting (Kingsford and Norman 2002), making them highly adaptive to flow variability particularly through their ability to disperse in search of ideal wetland habitat within a region.

For waterbirds the suitability of habitats vary as a consequence of such factors as the structure and resources found in particular vegetation associations, the physical and chemical characteristics of a waterbody, which can be associated with such factors as water flow magnitude and cycles of inundation and drying, and the productivity of the wetlands.

The Lower Barwon wetland complex consists of a diverse range of wetland types providing a mosaic of habitat types suitable for a wide variety of waterbird species. Under the Ramsar convention and the Directory of Important Wetlands in Australia (Environment Australia 2001), the Lake Connewarre region has two types of Marine and Coastal Zone Wetlands (A) and three types of Inland Wetlands (B) within the wetland complex: (A6) Estuarine waters; permanent waters of estuaries and estuarine systems of deltas; (A8) Intertidal marshes; includes saltmarshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes; (B4) Riverine floodplains; includes river flats, flooded river basins, and seasonally flooded grassland; (B5) Permanent freshwater lakes (> 8 ha); and (B10) Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes. Under the Department for Sustainability and Environment (DSE) Wetlands_1994 classification, wetlands within the lower Barwon wetland complex have been broadly classified into 11 different types based on water regime and vegetation or hydrologic attributes, (Table 6).

Table 6: Broad wetland types present in the Lower Barwon wetland complex. Department for Sustainability and Environment Wetlands_1994 classification.

Wetland		Area (ha)	Classification	
Name	ID Number		Water Regime	Vegetation or hydrologic attributes
Reedy Lake	739680	272.6	Deep freshwater marsh	Reed
		557.6		Open water
	717682 710682	18.5 7.2	Shallow Marsh	Herb
Hospital Swamps	730659	30.8	Meadow	Herb
	738647 733642	40.0 142.2	Permanent Saline	Shallow (< 5 m)
Lake Connewarre	770658	965.9	Permanent Saline	Shallow (<5 m)
		5.5	Semi-saline	Salt pan
Salt Swamp	782634	125.5	Semi-saline	Salt meadow
Lake Connewarre Reserve		1047.3	Semi-saline	Salt flats
Connewarre Swamp		89.9	Semi-saline	Island
Barwon River estuary	814610	22.8 99.1 13.6	Permanent Saline	Intertidal flats Shallow (<5 m) Mangroves
		25.1	Semi-saline	Salt flats
Murtnaghurt Swamp	785597	21.2 7.4	Semi-saline	Sea rush
		51.5		Salt pan
	790610	31.5		Salt flats
	794614	3.1		

3.4.2 Waterbird Drought and Summer Refuge

The more permanent wetland elements and estuary in the Lower Barwon wetland complex provide important summer and drought refuge for a wide variety of bird species, with seasonal migrations to the wetlands from regions across inland parts of Australia as habitat dries out on a seasonal basis or as a consequence of drought.

Refuges are habitats or environmental factors that convey spatial and temporal resistance and/or resilience to biotic communities impacted by biophysical disturbance (Sedell et al. 1990). They may be considered part of an environmental continuum, being places (or times) where the negative effects of disturbance are lower than in the surrounding area (or time) (Lancaster and Belyea 1997). Organisms require refuge from both biotic (e.g. predation) and abiotic (e.g. drought) disturbance. Refuges exist at a range of spatial and temporal scales: from the smallest (e.g. microhabitat) to the largest (e.g. drainage basin) spatial scale, and may be required across a range of temporal scales from minutes to years (Magoulick and

Kobza 2003). Consequently the nature of a refuge varies among species, being dependent on the species adaptations, habitat requirements, spatial and temporal scale and the nature of the disturbance.

The habitat values provided for these species by the wetland complex relate to sustaining the individuals within the population, rather than providing for the higher order demands of non-breeding migratory species or species reliant on the region for breeding.

3.4.3 Waterbird foraging habitat

Construction of the lower breakwater in 1898 and subsequent modernisation in 1950 has divided the Lower Barwon Wetlands into an estuarine zone of saline and semi-saline wetlands (Lake Connewarre, Connewarre Swamp, Salt Swamp, and the Barwon River Estuary), below the breakwater, from permanent and semi-permanent freshwater wetlands (Reedy Lake and Hospital Swamps) above, with Murtnaghurt Swamp now effectively isolated as a coastal lagoon. Provision of healthy and productive habitat for waterbirds in the wetlands above the lower breakwater is dependent on the pattern of flooding in the Barwon River and the consequent annual cycles of inundation and drying in the wetlands. But, below the breakwater the flow of the Barwon is only one element in a variety of factors that determine the productivity and availability of the habitat for waterbirds. Estuaries differ from other aquatic habitats in their exposure to a cycle of continuously changing salinity, water level and temperature within an area with shelter, soft sedimentary deposits and a constantly renewed supply of energy and nutrients (Barnes 1974). An important feature of estuaries for birds is the presence of extensive intertidal mudflats (Prater 1981), formed by the deposition of sedimentary particles.

For a complex bird community to exist in an area, the foraging habitat requirements are diverse, requiring a mosaic of shallow gently sloping margins as well as deep water and reed beds. Natural or artificial waterbodies that offer a mosaic of varying water depths and vegetation communities tend to have species rich communities of invertebrates, and carry higher numbers of species and individuals of waterbirds (Broome and Jarman 1983). The composition and abundance of waterbird communities on a wetland often reflect the availability (type and quantity) of food (Kingsford and Porter 1994, McDougall and Timms 2001). Consequently, when considering the response of waterbirds to a flooding regime within a wetland, it is essential to consider the impact of the temporal and spatial flow patterns on prey items and habitat composition.

Wader distributions and densities often reflect the availability of preferred prey species, both in terms of prey species abundance and the ability of birds to access prey. The latter is a function of physical foraging habitat, such as preferred water depths of substrate types, and a diversity of bird physical adaptations to feed on a wide variety of food types, with feeding behaviour closely associated with such factors as bill size and shape, or leg length (Prater 1981). Many waterbirds can adapt their feeding behaviours allowing them to access a variety of food sources, if the opportunity arises, or if conditions do not allow their usual feeding methods (Chandler 2009). Habitat use can be influenced by the proximity of roost sites, water quality (especially salinity), the availability of preferred habitat, and the need for refuge.

Waterbird foraging habitat in the region can be broadly categorised based on species feeding adaptations and the characteristics of preferred habitat. These microhabitats include: deep and open water (>0.3 m deep); shallow water (0 – 0.3 m deep); areas inundated during tidal flows and with wind seiche; emergent and fringing vegetation; mud and sand flats; saltmarsh; mangroves; and supratidal or flood zones.

1. Deep and open water (>0.3 m deep)

In waterbodies that are permanent or inundated for long periods of time, algae, epiphytes, macroinvertebrates, zooplankton, and fish found through the water column and in the vegetation beds together constitute a complex food web supporting a variety of birds (Paracuellos 2006). Maintenance of permanent water within a perennial wetland complex is consequently important.

Most wading birds use water up to 30 cm deep, generally walking on the substrate as they forage. Other species, and some of the waders, forage in deeper water either for similar food sources found on or near the surface, or for alternative food sources in the deeper water column and on the substrate.

A range of waterbird feeding guilds use deep, open, water particularly diving waterbirds (Broome and Jarman 1983).

While larger birds will use deeper water to forage, they generally prefer shallow water when food is available (Gawlik 2002), as it requires less energy to obtain the available food (Lovvorn 1994).

Turbidity has implications for the diversity and abundance of food resources available in deeper water, with highly turbid water limiting the primary productivity to the upper parts of the water column or waterbody fringes.

2. Intertidal/seiche zones

The substrate exposed and inundated through tidal movement in the Barwon River estuary, or through the force of wind moving over water – which can cause a surge of water to inundate the lee shore of a waterbody, particularly in a shallow gently sloping bed of a larger water body such as Lake Connewarre or Reedy Lake – provides important foraging habitat for a wide variety of waterbird species.

Some species forage in the shallow receding or encroaching water, other species forage on the recently exposed sand or mud flats, some forage at the moving interface of water over substrate as the water encroaches and recedes, and some forage amidst the inundated fringing vegetation.

The state of the tidal cycle, or temporal and spatial pattern of water inundation and retreat, alters the area of habitat available for foraging waterbirds and also affects prey behaviour and substrate penetrability, which in turn affects the harvestability of prey or other food source. Substrate type (e.g. mud, sand, rock) can affect the density of harvestable prey by affecting the prey's behaviour, for example by changing the depth to which they bury themselves, making them more or less susceptible to predation (Prater 1981, Esselink and Zwarts 1989).

In tidal environments most shorebird species segregate themselves in intertidal habitat according to preferences for sedimentary penetrability and water depth. On the Barwon River below the Lower Breakwater there is an interplay between tidal flows, river flows, and sedimentation patterns which provides extensive areas of foraging habitat for a diverse range of waterbird species, of which some merit significant national and international conservation ratings.

3. Supratidal/flood zones

Shallow flooding of wetlands, floodplains and deltas provides highly productive foraging habitat for waterbird species (Colwell and Taft 2000), and the associated marked increase in productivity is the basis of many waterbird reproductive events (Crome 1988, Junk et al. 1989, Scott 1997).

The cycle of growth and decay, and thus greater availability of nutrients in the water column (Baldwin and Mitchell 2000), resulting from inundation and exposure of vegetation along the river and wetland margins, is the basis of a complex food web that provides food to the vertebrates that forage in, on and around the water (Baxter et al. 2005).

Water bodies that are permanent or ephemeral systems that lose their drying phase, have been shown to support a lower density and diversity of birds, have lower invertebrate productivity, and have higher abundance of introduced fish and rates of anaerobic decomposition of organic matter (Crome 1988, Kingsford et al. 2004, Gawne and Scholz 2006). Turbidity can also be affected, and this can lead to reductions in euphotic depth and primary productivity. For wetland ecosystems that have evolved in response to seasonal drying, permanent inundation would likely lead to ecological degradation and displacement by an alternative community of flora and fauna.

Reduction in frequency and duration of flood events would normally lead to reduced floodplain productivity, which in turn would lead to reduced supply of nutrients and carbon to the main river channel. Ultimately, this would lower productivity within the river and the estuary.

4. Shallow water (<0.3 m deep)

Wading birds predominantly forage in water depths up to approximately 0.30 m. The water depth used by the different waterbird species when foraging is strongly linked with neck and leg length (Baker 1979, Zeffer et al. 2003), which dictates where a species will have the most success in foraging. Worldwide the greatest diversity and abundance of foraging waterbirds is found in water depths of between 0.10 and 0.20 m (Isola et al. 2000, Taft et al. 2002). Natural or artificial waterbodies that offer an array of water depths and vegetation associations tend to have rich communities of invertebrates, and carry higher numbers of species and individuals of waterbirds (Broome and Jarman 1983). Piscivores feed on fish in shallow water in preference to those in deeper water (Gawlik 2002). The density of prey at which the birds will stop searching for food increases with increasing depth; the value at 0.28 m as almost double that at 0.10 m (Gawlik 2002). Maximising the area inundated up to 0.30 m in depth will enhance species diversity and numbers of waterbirds able to forage in a wetland complex.

Within the Lower Barwon River wetland complex waterbirds, such as snipe, moorhen, egrets, herons, spoonbills, bitterns, ibis, brolga, a wide variety of ducks and geese, and shorebirds will feed predominantly in this zone.

5. Mud and sand flats

In wetlands, shallow inundation of mudflats facilitates ecosystem productivity and replenishes mudflat prey for waterbirds. Subsequent exposure and drying of the wetland sediments facilitates a suite of biotic and abiotic processes that do not occur in permanently inundated sediments. This cycle provides for a complex food web including food for the vertebrates that forage in, on and around the water (Baxter et al. 2005). This, in turn, sustains many species of fish and provides favourable conditions for breeding in a suite of waterbird species (Crome 1988, Junk et al. 1989, Scott 1997).

As wetland water levels drop, mudflat exposure ensures mudflat resources are available to waterbirds. With shallower water the fish community becomes more susceptible to avian predation.

The shores of the Lower Barwon River and estuary, shoreline of lakes and edges of many lateral wetlands are fringed at lower water levels by sand and mud flats of several metres to hundreds of metres in width. A community of invertebrate macrofauna is found living within and on these flats, providing the basis of a complex and productive food web under normal conditions. These extensive mudflats and shallow waters are particularly important for shorebirds. The tides, seasonal and annual changes in water level, and changes with flooding regime and wind direction, rainfall, and evaporation result in patterns of inundation and exposure that vary the accessibility and extent of this habitat available to shorebirds (Brookes et al. 2009). Changing silt loads carried by the Barwon River under regulated flow affect the aerial extent of mudflats, and the nutrient supply to the associated food web, changing the waterbird biomass supported in the region.

Reduced flow reaching the estuary and reduced temporal and spatial variability in flow mean that mud and sandflats may be exposed for longer periods of time, resulting in more solid surfaces, affecting the habitat selection and foraging success of waders, as pack depth and prey density depend on the penetrability of the sediment. Constriction of foraging habitat area has implications for the abundance of foraging birds in the wetland complex.

6. Emergent and fringing vegetation

The presence of a healthy macrophyte community within and fringing a wetland or along the edges of a river is important as either a direct or indirect food source, and/or through provision of essential refuge or roosting sites for many waterbird species. These vegetation communities support a distinct subgroup of waterbirds, e.g. many waterfowl, rails, bitterns, snipe, and reed warblers. For this group of waterbirds, use of an area is influenced by the structural and cover pattern of the vegetation emergent from the waterbody and around its fringe, rather and the actual plant species present.

Abundance of macroinvertebrates is usually positively correlated with macrophyte abundance and diversity (Boulton and Brock 1991, Hargeby et al. 1994, Safran et al. 2000). In wetlands, total and breeding waterbird species richness have been shown to increase as percent cover of emergent vegetation increases from no cover (Hargeby et al. 1994, VanRees-Siewert and Dinsmore 1996, Safran et al. 2000, Fairbairn and Dinsmore 2001). The point at which diversity begins to decline at very high levels of cover is unclear.

7. Saltmarsh

Coastal saltmarshes are intertidal communities dominated by flowering plants, principally herbs and low shrubs (Saintilan 2009). This vegetation community is an important component of the Lower Barwon River wetland complex. Samphire vegetation tolerates, but does not require, inundation (Wilson 1999). The intertidal occurrence of saltmarsh plants in the Lower Barwon wetland complex is really a continuation of a network of saline aquatic environments. For example Salt Lake contains large areas of this community but is maintained by fluctuating saline groundwater levels. Samphire shrublands occur around the periphery of relatively saline seasonal and permanent wetlands. Dominant species include *Tecticornia* spp. and *Sarcocornia* spp.

Saltmarsh is of direct importance to many avian species by providing habitat in which individuals can breed, feed and roost (Saintilan 2009). Saltmarsh can act as a drought refuge for Australian breeding waders and many migratory waders will roost and feed in saltmarsh (Spencer et al. 2009). In Australia little is known of wader use of saltmarsh habitats, but it has been documented as important habitat for several shorebird species in Africa, Europe and North America (Spencer et al. 2009). Species that commonly feed in saltmarsh in Australia include: Curlew Sandpiper, Marsh Sandpiper, Red-necked Stint, Australian White Ibis, Straw-necked Ibis, Cattle Egret, Black Swan, Chestnut Teal, Australian Shelduck, Sharp-tailed Sandpiper, Masked Lapwing, Red-capped Plover, Black-tailed Godwit, Common Greenshank, Eastern Curlew, Latham Snipe, and Pacific Golden Plover (Spencer et al. 2009).

The nationally critically endangered Orange-bellied Parrot (*Neophema chrysogaster*), which frequents wetlands in the study area, feeds on the fruit of *Sarcocornia quinqueflora* (Croft et al. 1999). In general it is the more consistently inundated saltmarshes that constitute the best habitat for Orange-bellied Parrots (Ehmke et al. 2009), with frequent short-duration inundation believed to provide the greatest calorific value and potentially highest quality *Sarcocornia* seed for the parrot (Mondon et al. 2009).

8. Mangroves

Mangroves have increased in area along the east coast of Australia often at the expense of adjoining saltmarsh (Saintilan 2009). Mangroves provide important habitat for birds that feed on insects, pollen or nectar (Frith 1979). They are also important to a variety of waterbirds as foraging and roosting habitat. Interactions between mangroves and shorebirds are complex and poorly understood (Geering et al. 2007). Mangroves generally on average export organic nutrients, providing benthic invertebrates with a food source in nearby habitats, thus secondarily enhancing food availability for shorebirds. Mangroves also stabilise mudflats and often act as buffers between urban impacts and low tide feeding grounds for shorebirds. Mangroves provide important roosting habitat for such species as grey-tailed tattler, terek sandpiper and whimbrel. But, conversely, many shorebirds will only roost in areas with clear fields of view and in some localities where mangroves have expanded into new areas; old roosting sites have been lost.

9. Aquatic vegetation

Submerged freshwater aquatic vegetation plant communities occur to varying extents in fresh, brackish, saline and hypersaline wetlands with open water across the wetland complex. Typical species include *Potamogeton* spp., *Myriophyllum* spp., *Triglochin* spp., *Crassula* spp, *Lepilaenna* spp., *Ruppia* spp., *Stuckenia pectonata*, and *Villarsia* spp. Across all of the wetlands in the complex elements of this vegetation provides important structural habitat for a variety of waterbird food sources (e.g. invertebrates and fish) and acts directly as a food source for many diving and dabbling herbivorous waterbird species, and turions of *Ruppia* can be an important food source for shorebirds (Paton 2005). Floating aquatics such as *Azolla* spp and *Lemna* spp also provide important habitat and forage for waterbirds.

Chara spp. are benthic aquatic alga with a plant-like habit that forms extensive and essentially monocultural beds in semi-permanent wetlands such as Hospital Swamps. These species serve a similar ecological role as freshwater aquatic vegetation in providing habitats for fish and macroinvertebrates, but often survives in saline environments where other plants are absent. An increase in *Chara* spp. biomass in a lake in the Netherlands was strongly correlated with an increase in the abundance of herbivorous waterbirds (Noordhuis et al. 2002), illustrating its likely importance to the productivity of higher trophic levels and in supporting wildlife populations. *Chara* beds may act as nutrient sinks in wetlands (Kufel and Kufel 2002), thus helping to control nutrient concentrations in the water column and maintaining ecosystem stability.

These beds of aquatic vegetation are the basis of a complex food web, providing forage for waterbirds through a complexity of interactions.

3.4.4 Foraging Guilds

Using foraging microhabitat, and principal food sources, 18 foraging guilds were identified across Reedy Lake and Hospital Swamps (Figure 10).

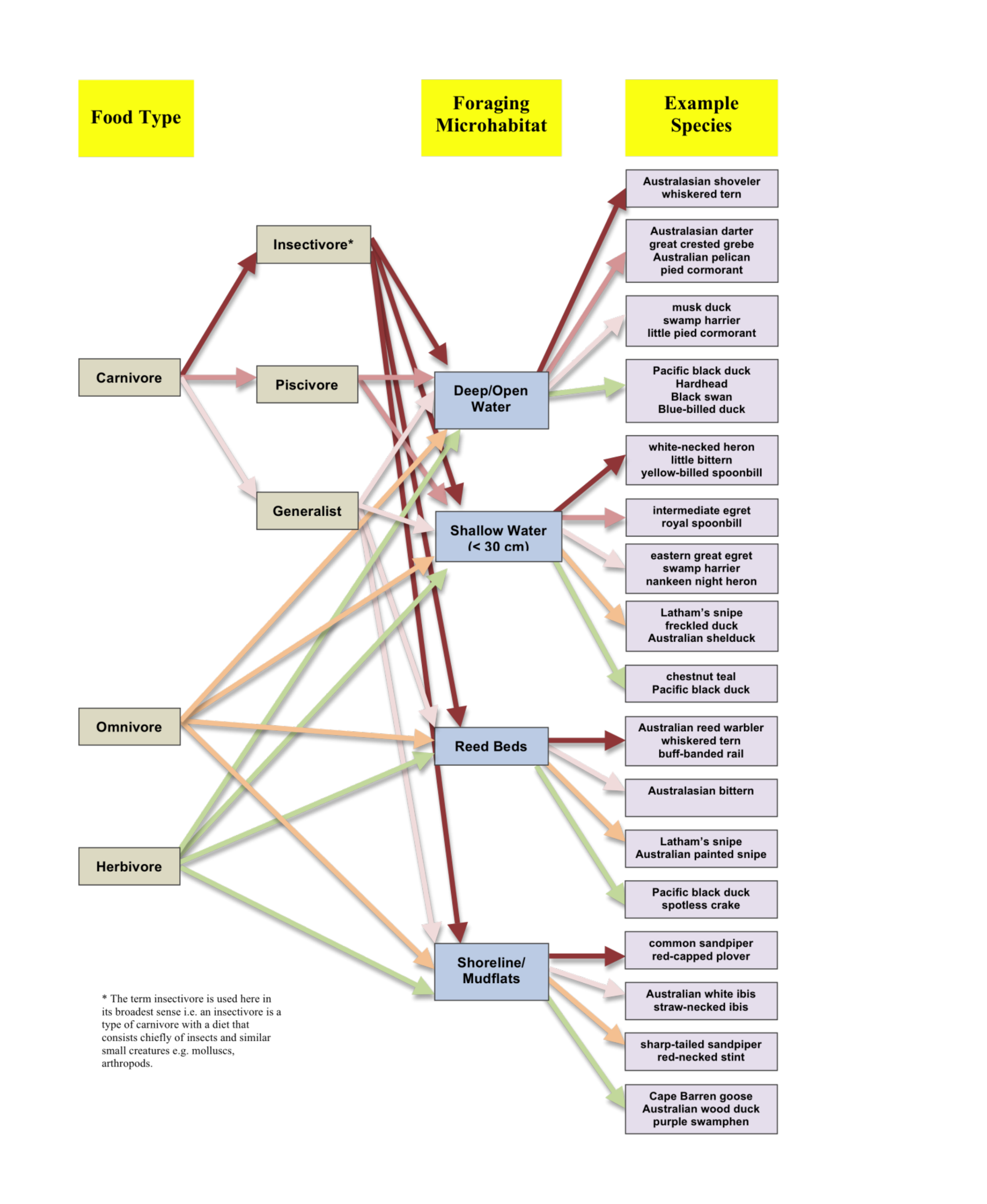


Figure 10: Avian foraging guilds associated with Reedy Lake and Hospital Swamps. Guilds are constructed based on the principal food sources and the main foraging microhabitat of the member species. Species illustrating each of these guilds are shown on the right.

These foraging guilds are reliant on temporal patterns of flow to maintain productive food sources and a mosaic of diverse habitats across the wetlands. These include:

- waterbirds which forage along shorelines and up to a depth of approximately 0.3 m, or in association with the seiche / flood zone across a range of substrates, all of which are reliant upon a temporal variation in inundation and exposure. Maintenance of the complex food web upon which these species are reliant depends on water quality and flow regimes. In the lower Barwon River wetland complex these species are predominantly migratory and Australian waders;
- piscivores that forage in deep or shallow water using a variety of techniques, but reliant upon a diverse and productive ecosystem to maintain their food source. Many of these species benefit from low water levels in a wetlands drying phase to increase foraging success;
- habitat specialists that maintain a strong association with dense fringing and emergent habitat for foraging, refuge and roosting requirements. These species are predominantly from the family Rallidae;
- herbivores that forage predominantly on vegetation in association with wetland fringes, shallow water, or deeper low turbidity water where beds of aquatic vegetation grow (predominantly waterfowl). Slow recession of water levels through summer and autumn benefit these species; and
- generalists that forage on a range of plant and / or invertebrate material in the water column in a wide variety of habitats near to shore or in open water (predominantly waterfowl).

The majority of waterbirds are plastic in their use of foraging habitat. The range of microhabitats in which each of the waterbird species are capable of foraging allows them to accommodate changes to the ecological character of the wetlands, as long as the overall wetland productivity is maintained. Where wetland productivity is reduced the populations of each bird species can be anticipated to decline proportionately. Because of their high mobility levels waterbirds will readily move to more productive habitats.

3.4.5 Waterbird Breeding

Waterbirds breed either as pairs in tree hollows (e.g. Australian Wood Duck, Australian Shelduck, Chestnut Teal, Pacific Black Duck, Pink-eared Duck), on or in aquatic vegetation (e.g. Australian Grebe, Australian Shoveller, Bitterns, Blue-billed Duck, Brolga, Crakes, Freckled Duck, Grey Teal, Hardhead, Musk Duck, Pacific black Duck, Pink-eared Duck, and Rails), on the ground (e.g. Australasian Shoveller, Chestnut Teal, Grey Teal, Hardhead, Black Duck), or in trees (e.g. Pink-eared Duck), or as colonial nesting species in nests on the ground on islands (e.g. Australian Pelican, Banded Stilt, Black Swan, Black-winged Stilt, and Cormorants), in trees (e.g. Cormorants, Egrets and Herons), or on platforms built on reeds, lignum or rushes (e.g. Ibis, Black Swan, Hoary-headed Grebe, Great Crested Grebe, and Magpie Goose; (Kingsford and Johnson 1998).

Colonial water birds require suitable places to build their nests in order to breed successfully. These sites include trees, bushes, Lignum, and dense stands of emergent aquatic plants all inundated for the duration of the nesting periods, and areas of open water, and islands.

For colonial stick-nesting waterbirds dense vegetation is essential for breeding (Kingsford and Norman 2002). Breeding in these species is dependent on flooded for at least four months (Briggs et al. 1997). In contrast with these species many Australian waterfowl are obligate breeders in nest hollows, requiring wetlands with trees of an appropriate age to bear hollows (Kingsford and Norman 2002). In the Lower Barwon wetland complex trees are no longer available to provide this nesting habitat, but artificial nesting boxes have been erected across the wetland to address this shortfall.

Environmental factors that stimulate breeding in waterbirds vary among species. Factors that may stimulate breeding include (Briggs 1990):

- flooding alone (e.g. Australasian Shoveler, Australian Pelican, Black Swan, Black-tailed Native Hen, Darter, Freckled Duck, Glossy Ibis, Great Crested Grebe, Grey Teal, Hoary-headed Grebe, Little Egret, Pink-eared Duck, Rufous Night Heron, Straw-necked Ibis);
- flooding in combination with seasonal cues (Australasian Grebe, Australian Shelduck, Chestnut Teal, Dusky Moorhen, Great Egret, Great Pied, Little Pied and Little Black Cormorants, Hardhead, Intermediate Egret, Pacific Black Duck, Pacific Heron, Purple Swamphen, Royal Spoonbill, White-faced Heron, Yellow-billed Spoonbill);
- rainfall and seasonal cues (e.g. Wood Duck); or
- seasonal cues alone (e.g. Blue-billed Duck and Musk Duck).

The timing, flow rate, area inundated and duration of flooding are important for initiating breeding and successful outcomes in colonial species (Kingsford and Auld 2005). For most Australian waterbirds, breeding occurs when food resources are approaching, or are at, a maximum (Kingsford and Norman 2002). Floods in winter rarely result in immediate breeding; with many species only initiating breeding as conditions warm and food resources increase in the spring. The lag between flooding onset and breeding relates to such factors as the time required for a large and complex food web to develop capable of supplying abundant food to allow birds to increase fat reserves and develop eggs, and to prepare behaviourally, and for hormone cycles to be initiated. Waterbirds that feed on animals lower in the food chain (e.g. Ibis feeding on invertebrates) can usually initiate breeding earlier than piscivores (e.g. Darter, Little Black Cormorant, and Intermediate Egrets), which require time for the fish population to develop (Crome 1988). The minimum lag from flood onset to breeding onset in most waterbird species is in the order of 2-3 months (Scott 1997), with breeding of most colonial birds in the Macquarie Marshes positively related to flow and wetlands area in the three months before breeding (Kingsford and Auld 2005).

Crome (1988) found that breeding for a wide variety of waterbird species only followed a rise in water level if the wetland had been completely dried out beforehand. This is not true for all waterbird species with Pacific Herons and Yellow-billed Spoonbills favouring sites that have not dried out before reflooding (Briggs et al. 1997).

There is a diversity of conditions required for successful breeding in colonial nesting waterbirds:

- the flood must take place from late winter / early spring;
- a flood in late winter / early spring must persist for a minimum of 4 (rapid breeders e.g. ducks) to 7 months for the successful breeding of most waterbird species;
- many waterbird species will not breed in wetlands with highly controlled water regimes (Briggs et al. 1997);
- inundation and exposure of wetlands needs to occur over seasonal and annual time frames, as long-term rapid and/or erratic changes in water levels within a wetland can result in low numbers of aquatic invertebrates (Briggs et al. 1997), the food of many waterbirds; and
- nearly all colonial nesting waterbirds are vulnerable to sudden drops in water level beneath nesting sites or in foraging areas - this can result in waterbirds abandoning their nests and young before they fledge (Kingsford 1998, Kingsford and Norman 2002).

Where the duration, extent and timing of inundation have changed impacts to breeding birds have been recorded. For example, as a consequence of altered water regimes in Barmah-Millewa Forest waterbird species that nest and/or feed on non-emergent macrophytes (e.g. Australasian Grebe, Black Swan, Black-winged Stilt, Eurasian Coot, Great Crested Grebe, Hoary-headed Grebe, Whiskered Tern) declined markedly in numbers due to the depletion of this habitat type, and stick nesting colonial waterbirds which generally nest in trees (e.g. Australian Darter, Great Egret, Great, Little Pied and Little Black Cormorants, Intermediate Egret, Little Egret, Nankeen Night Heron, and White-necked Heron) also declined due to decreased nest security associated with water receding too early, and low food availability (Leslie 2001).

3.4.6 Terrestrial birds and wetlands

Energy and nutrient flux between wetland and terrestrial food webs is important to the productivity and diversity of both aquatic and terrestrial ecosystems.

During and subsequent to a flood the related increase in primary productivity across a floodplain, and in the ephemeral wetlands, is the basis of a complex terrestrially based food web. Inundated overstorey provides foraging, refuge and breeding habitat for terrestrial fauna species. Following water recession the subsequent growth of understorey provides forage for herbivores again contributing significant productivity to the terrestrially based food web. Many species that forage in the region will move to the area for refuge and breeding. Heterogeneity in lowland floodplain macrohabitat has been shown to significantly increase local terrestrial avian biodiversity (Parkinson et al. 2002).

In addition to the increased productivity of the floodplain and fringing vegetation subsequent to inundation, there is ultimately an additional faunal-mediated transfer of energy and resources from the aquatic environments to the adjacent terrestrial environments, increasing the productivity of those terrestrial environments (Ballinger and Lake 2006). The emergence of adult insects from the water contributes significantly to riparian consumers such as insectivorous birds (Baxter et al. 2005). Densities and diversity of non-aquatic woodland bird species, for example, have been shown to increase significantly with the presence of wetlands in woodlands when compared with equivalent woodland habitat without wetlands (Parkinson et al. 2002, Ballinger and Lake 2006). This exchange may influence ecosystem productivity at the landscape scale (Ballinger and Lake 2006), contributing to breeding activity and success across a suite of terrestrial faunal species.

A diverse and abundant terrestrial avian fauna community is associated with the lower Barwon River wetland complex, with many of these species reliant upon wetland productivity and the presence of healthy floodplain and riparian vegetation as the basis of the community. Ballinger and Lake (2006) noted that the ecological impact of reduced floodplain inundation, as a result of river regulation, might have been significantly underestimated around the world.

3.4.7 Avian Conservation Values

A search of the Department for Sustainability and Environment VBA Flora and Fauna Dataset (inclusive to October 2010) for the Lower Barwon wetland complex (Reedy Lake, Hospital Swamps, Connewarre Lake, Barwon Estuary, Salt Swamp and Murtnaghurt Swamp), supplemented by records on mammals, reptiles and amphibians from the Geelong Field Naturalists Club, identified 207 vertebrate fauna species (three amphibians, 219 birds, six mammals, two reptiles) and two invertebrate species in association with the wetland complex (Appendix 1).

Of the 219 bird species, ten are introduced to Australia and 99 (100) are directly dependent on wetland habitat. Wetland dependent species are those that rely on food sources and/or habitat associated with wetlands for a significant component of their life history. Placement of the Brown Quail *Coturnix ypsilophora* within the wetland dependent group is problematic, as it prefers habitat composed of damp rank vegetation, and as such is closely linked to wetlands. The remaining 109 species are either terrestrial in habitat use or pelagic species moving near to shore. The terrestrial species are unlikely to depend directly on inundated wetland habitat, but they may benefit from wetland productivity either directly through increased food availability emergent from the wetland, or indirectly through increased productivity at lower trophic levels in the food web.

One hundred and thirteen of the bird species merit a significant conservation rating under either federal and/or state legislation, of which 64 are wetland dependent. Eighty-eight species are of conservation significance under the Environmental Protection and Biodiversity Conservation Act 1990 (EPBC Act), of which 82 species are declared as marine species under s248 of the Act. The nationally critically endangered orange-bellied parrot *Neophema chrysogaster* has been recorded in significant numbers in Connewarre Swamp and also at the Barwon Estuary and Salt Swamp, the nationally vulnerable Australian painted snipe *Rostratula australis* has been recorded in both Hospital Swamps and Salt Swamp, the nationally vulnerable plains wanderer *Pedionomus torquatus* has been recorded at the Barwon Estuary, and the nationally vulnerable Wandering Albatross *Diomedea exulans* has been recorded over Salt Swamp. Thirty-one species are listed under the China-Australia Migratory Bird Agreement (CAMBA), 28 under the Japan-Australia Migratory Bird Agreement (JAMBA), and 26 under the Republic of Korea-Australia Migratory Bird Agreement (RoKAMBA).

Thirty-seven of the species recorded in the Lower Barwon wetland complex merit a significant conservation rating within Victoria – 30 of which are wetland dependent. Twenty-five species are listed under the Flora and Fauna Guarantee Act (FFGA), five species are classified as critically endangered (intermediate egret *Ardea intermedia*, plains wanderer *Pedionomus torquatus*, orange-bellied parrot *Neophema chrysogaster*, Australian painted snipe *Rostratula australis* and grey-tailed tattler *Tringa brevipes*) as they are considered to be facing an extremely high risk of extinction in the wild in Victoria, 11 species as endangered (blue-billed duck *Oxyura australis*, freckled duck *Stictonetta naevosa*, Australasian bittern *Botaurus poiciloptilus*, little egret *Egretta garzetta nigripes*, Australian little bittern *Ixobrychus minutus dubius*, gull-billed tern *Gelochelidon nilotica macrotarsa*, fairy tern *Sternula nereis nereis*, grey-crowned babbler *Pomatostomus temporalis temporalis*, great knot *Calidris tenuirostris*, terek sandpiper *Xenus cinereus*, and the pelagic wandering albatross *Diomedea exultans*) considered to be facing a very high risk of extinction in the wild, and 19 species as vulnerable and considered to be facing a high risk of extinction in the wild. There are also 22 bird species recorded at the wetland complex that merit a near threatened conservation rating in Victoria.

3.4.8 Avian Demography of the Lower Barwon Wetland Complex

Context

The data on avian diversity and populations discussed below are presented to gain some insight into the implications of past management on bird use of the habitat available in Reedy Lake and Hospital Swamps. The ecological character of Reedy Lake has changed during the period 1970 to the present. Some of the key drivers of change in Reedy Lake are known at a qualitative level and the outcome of these changes, with respect to vegetation cover for example, have been quantified. Some of these changes have arisen as a consequence of changes to management practice including the removal of cattle grazing and the regulation of water flow into and out of the wetland, as well as changes arising from the invasion of the Barwon River system by carp (Figure 6). Together these changes have affected the extent of reed cover and submerged macrophyte cover within the wetland.

Many of these changes may have had implications for avian diversity in general and the abundance of individual species within Reedy Lake. During this same period the ecological character of Hospital Swamps does not appear to have undergone such marked changes. The wetting and drying pattern has remained relatively consistent and the extent of open water and reed cover has not apparently undergoing marked change.

Caution must be exercised in interpreting changes to bird populations in the context give. Any changes recorded in bird populations are correlative. The data presented do not allow direct causative links between observed changes to bird populations and habitat changes within the wetlands.

Overall Species Diversity

Bird species diversity and relative abundance of each species vary among wetland elements in the Lower Barwon wetland complex (Appendix 1). Data were obtained from the DSE VBA flora and fauna data set (Inclusive to October 2010). These data were supplemented with the Birds Australia data set from 2001 to January 2011. The DSE data set contains Birds Australia data from prior to 2001.

Recorded avian species diversity within the wetland complex for the entire data set is highest in the Barwon Estuary (166 species (76% of total diversity for the complex), of which 60 species are wetland dependent (61% of total wetland dependent species recorded)), with slightly lower diversity recorded in Lake Connewarre (144 species (66%), 76 wetland dependent (77%)) and the Reedy Lake (139 species (63%), 76 wetland dependent (77%)) and Hospital Swamps (139 species (63%), 67 wetland dependent (67%)). Recorded diversity in Salt Swamp (80 species (37%), 25 wetland dependent (25%)) and Murtnaghurt Swamp (62 species (28%), 25 wetland dependent (25%)) is markedly lower, at least partially as a consequence of a lower survey effort at these sites. Habitat heterogeneity among wetland elements within the wetland complex produces varying avian species composition, with each wetland providing specialised habitat components not present elsewhere within the complex.

Recorded avian diversity varies markedly among years within each wetland for all species (Figure 11), wetland dependent species (Figure 12) and for terrestrial and marine species

Caution must be taken when interpreting these data as survey effort is not equal between years, nor are all sites always surveyed within any one year. The recorded increase in diversity over the last 50 years is predominantly a product of improved survey methodology and increased survey frequency, rather than changes in avian community composition. Prior to 1980 survey effort in the wetland complex was irregular and patchy. Since 1980, mainly though the Birds Australia Old Atlasing Project, survey effort increased, became more regular and more focused on individual wetlands. At this time two other annual surveillance programs were initiated: the Australian Waders Study Group (AWSG) undertook an annual surveillance program for shorebirds across many wetlands in the complex; and annual surveys for waterfowl were undertaken to inform the regulation of Duck Hunting across the State. In turn, increased survey effort since 1998, associated in particular with the Birds Australia New Bird Atlasing Project, has markedly increased the recorded species diversity across the wetland complex and allowed diversity within each wetland to be analysed with more confidence.

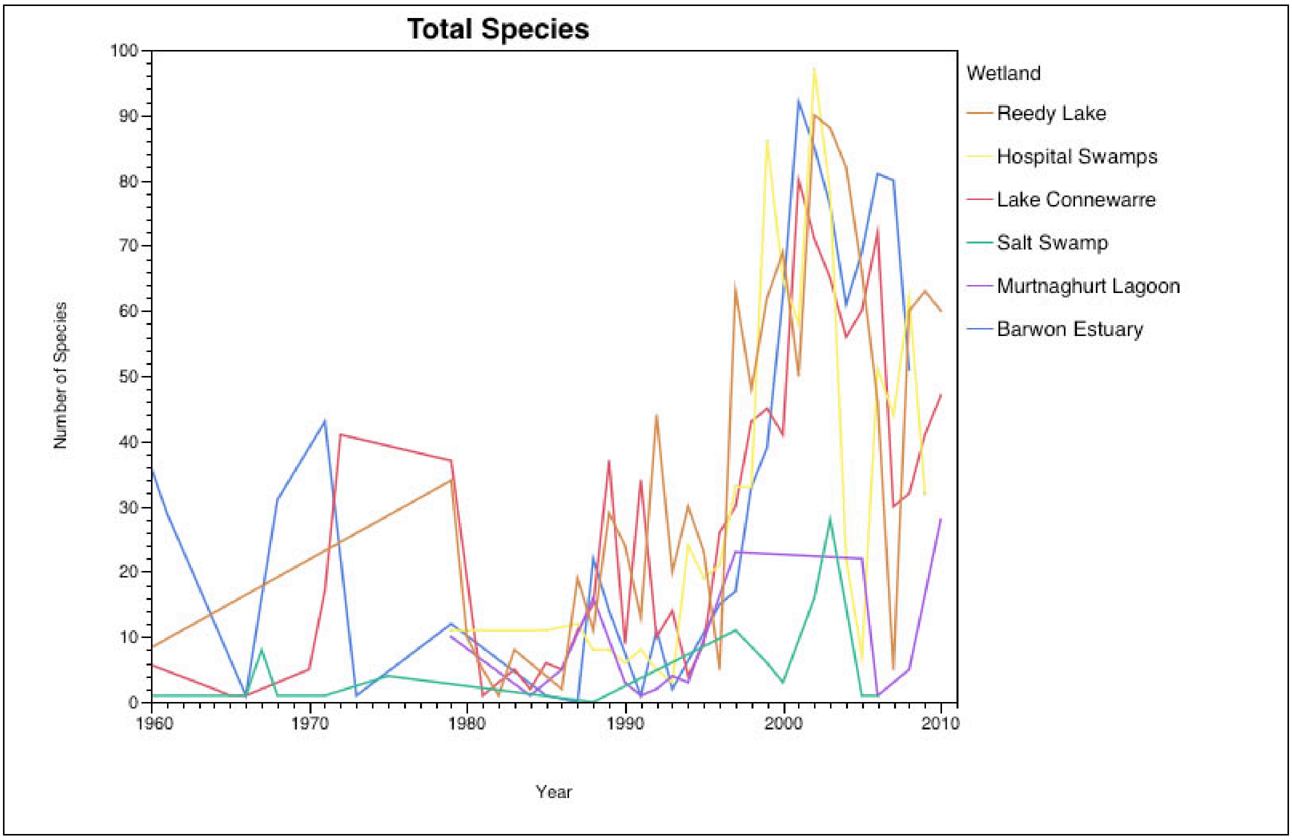


Figure 11: Total annual avian species diversity for each of the Lower Barwon Wetlands. Total avian diversity across all wetlands in the wetland complex is 219 species. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Birds Australia data set (2001 to January 2011). Caution must be taken when interpreting these data as survey effort is not equal between years, nor are all sites always surveyed within any one year.

Where survey effort is relatively equal among years (e.g. 1998 to 2010) large changes to annual total recorded diversity within each of the wetlands (Figure 11) are evident. The stepped changes evident in each wetland's community composition within the wetland complex at times result from changes in the diversity of wetland dependent species (Figure 12) and at other times arise as a consequence of changes in the diversity of terrestrial and/or marine species (Figure 13). These changes in species diversity within a wetland may occur independently of what is occurring in other wetlands within the complex.

Importantly even where total species diversity appears relatively constant between years, there are underlying changes to species composition within the total diversity, and changes to the relative abundance of each species. As such these data must be interpreted with caution.

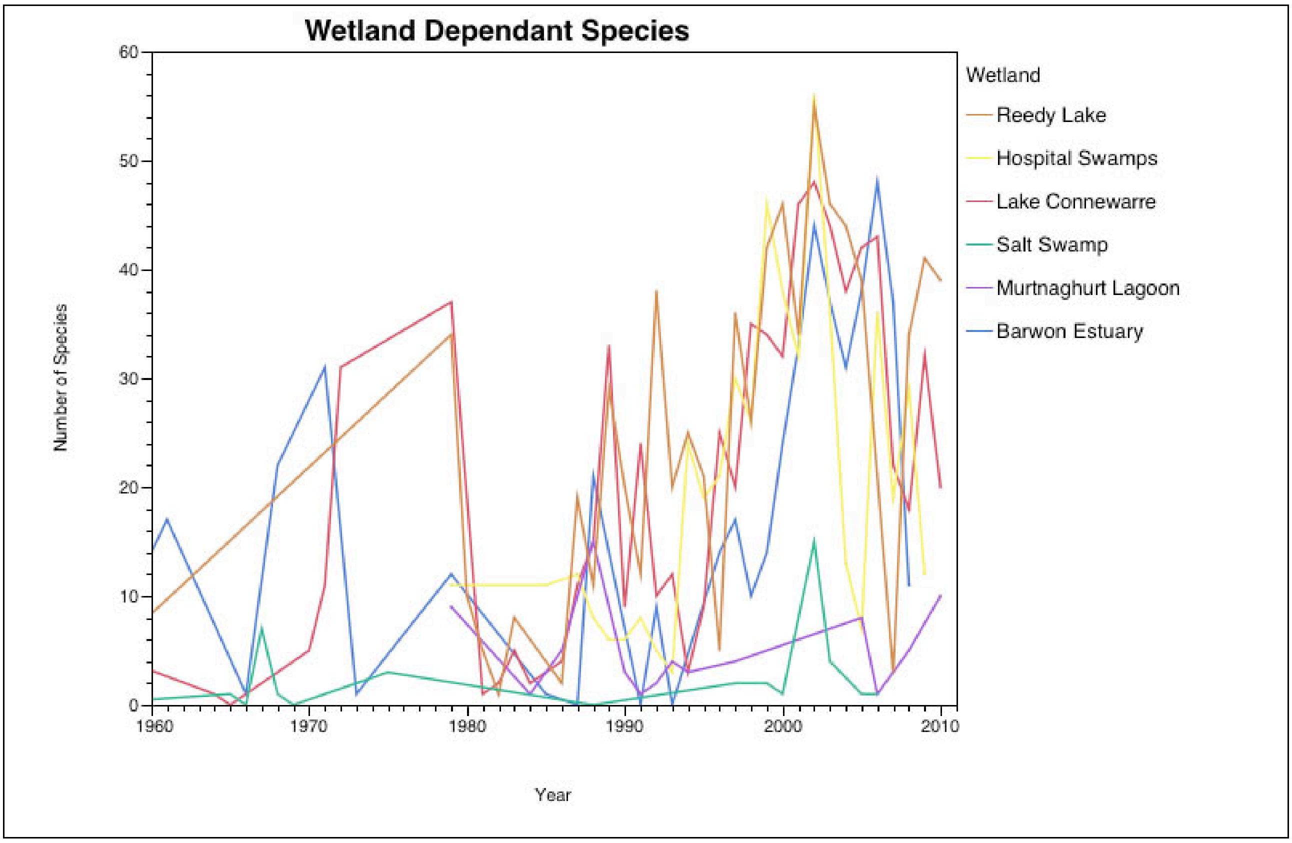


Figure 12: Total annual wetland dependent avian species diversity for each of the Lower Barwon Wetlands.

Total wetland dependent avian diversity across wetlands in the wetland complex is 100 species. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Birds Australia data set (2001 to January 2011).

To gain some understanding of how changes to wetland productivity and health may have impacted on the avian species that use a wetland, it is necessary to examine what has happened to the species composition and relative abundance of some of the foraging guilds within each of the wetlands in the wetland complex.

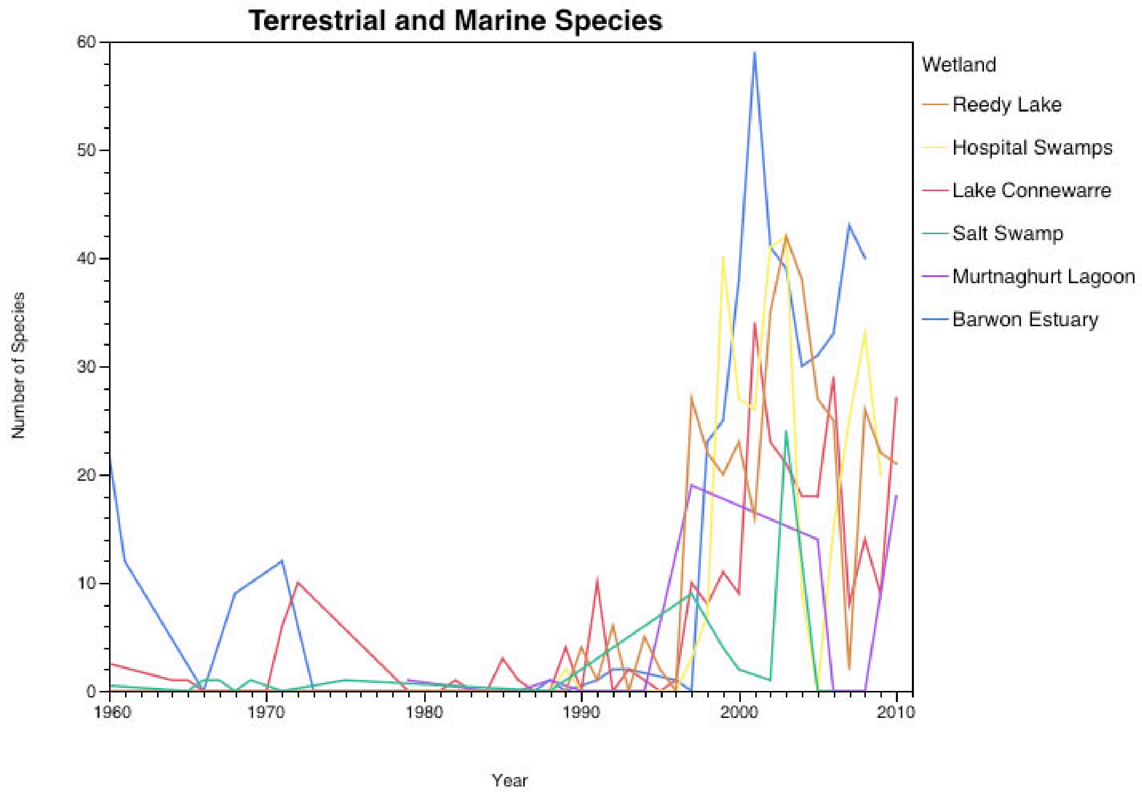


Figure 13: Total annual terrestrial and marine avian species diversity for each of the Lower Barwon Wetlands. Maximum recorded terrestrial and marine avian diversity across all wetlands is 119 species. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Birds Australia data set (2001 to January 2011).

Waterfowl

The Victorian Department for Sustainability and Environment (DSE) and Field and Game Australia Inc (F&G) maintain a monitoring program of waterfowl on wetlands across Victoria, including wetlands in the lower Barwon wetland complex. These surveys have been carried out since the late 1970's to 2010. Data from these surveys have generally been included in the DSE VBA flora and fauna data set, but the data set is incomplete. All of the relevant survey data were extracted from the DSE VBA flora and fauna data set. Field and Game Australia have provided their data set for the wetland complex from 1998 to 2010 and these data were used to supplement the extracted data where necessary. The proportion of each wetland surveyed was generally recorded as a component of both data sets, allowing a calculation of total waterfowl abundance for each wetland to be extrapolated. Up to two surveys were carried out each year (late February and early November), but data from a number of years pre 1998, and for the spring and summer 2006/2007 were not available.

Herbivorous Waterfowl

An analysis of herbivorous waterfowl populations showed a marked decline in Reedy Lake for many species, with markedly different patterns apparent in Hospital Swamps (Figure 14). Eurasian coot populations show a marked decline cross all wetlands during the period 1979 to 2011, with the largest declines evident in Reedy Lake. In Reedy Lake long-term declines in grey teal, chestnut teal, pacific black duck and hardhead numbers are also evident. Such declines are not evident in Hospital Swamps, where populations have cycled markedly, but large numbers are regularly recorded across the monitoring period. The chestnut teal has shown a marked increase in abundance in Hospital Swamps over the last five years, compared with historically very low numbers.

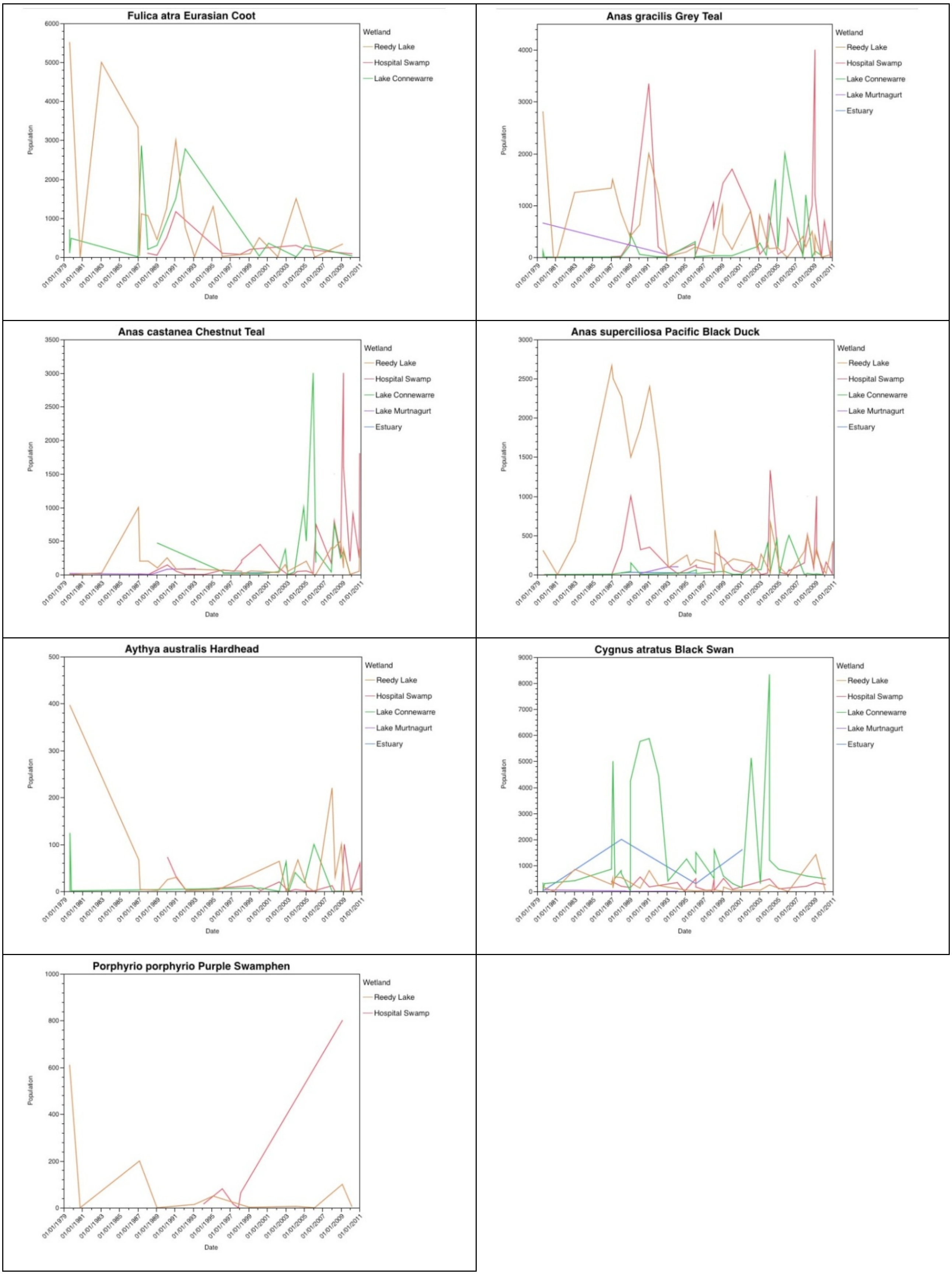


Figure 14: Count of herbivorous waterfowl for each of the Lower Barwon Wetlands. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Field and Game data set (1998 to January 2011).

In Reedy Lake the hardhead population was very low between 1987 and 2002. Between 2002 and 2010 hardheads used the lake of an irregular basis in moderate numbers with an increase in 2007 to over 200 birds, returning to levels not recorded since 1987.

The black swan population is predominantly associated with Lake Connewarre. Population levels fluctuate markedly in Reedy Lake, with number generally below 200 since 1991. Recently in 2009 the population climbed above 1000 birds, suggesting high food levels for the black swan in this year.

The blue-billed duck has only been recorded within the wetland complex in Reedy Lake in 1981 and the late 1980's and early 1990's.

Omnivorous Waterfowl

In Reedy Lake the omnivorous Australasian Shelduck has undergone a long-term and marked decline in abundance, with many years since 1996 where populations were less than 3% of that recorded in 1983. Such declines are not evident in Hospital Swamps, where populations have shown a recent marked increase since 2004 to very high numbers (3000 birds) in 2009, equivalent to that recorded in Reedy Lake in 1983.

The freckled duck has been irregularly recorded in Reedy Lake in low numbers since the 1980's.

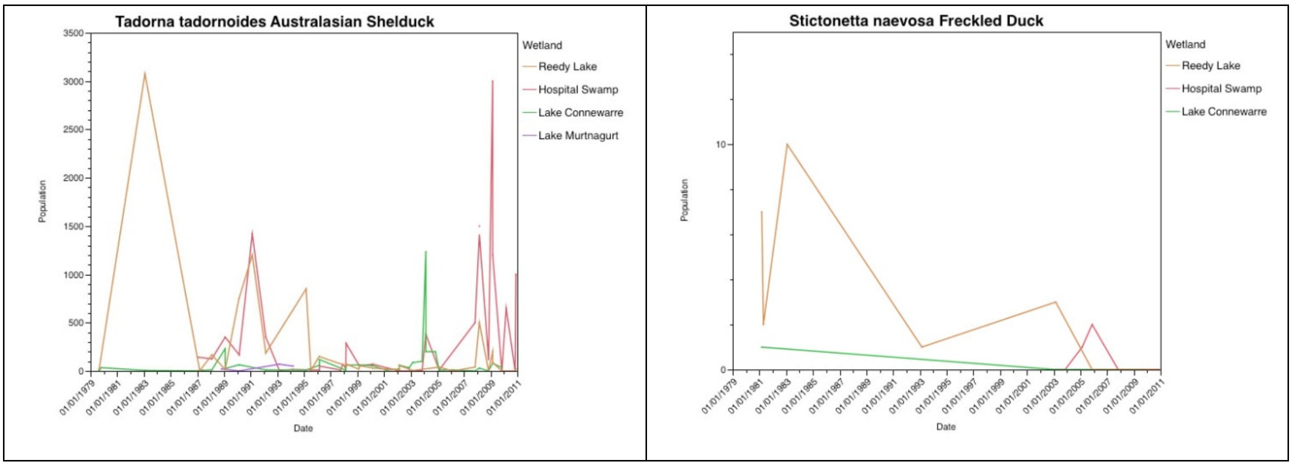


Figure 15: Count of omnivorous waterfowl for each of the Lower Barwon Wetlands. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Field and Game data set (1998 to January 2011).

Carnivores

In Reedy Lake the carnivorous Australasian shoveller has varied in abundance between zero and 500 birds since a high of nearly 700 in 1980 (Figure 17). Since 2005 the numbers have been very low with less than 50 birds recorded in each survey. Numbers of Australasian shoveller have shown similar patterns in Hospital Swamps. In 2006 a large influx of over 2000 birds was recorded in Lake Connewarre. Numbers of the musk duck have been low in Reedy Lake since 1993 (Figure 17).

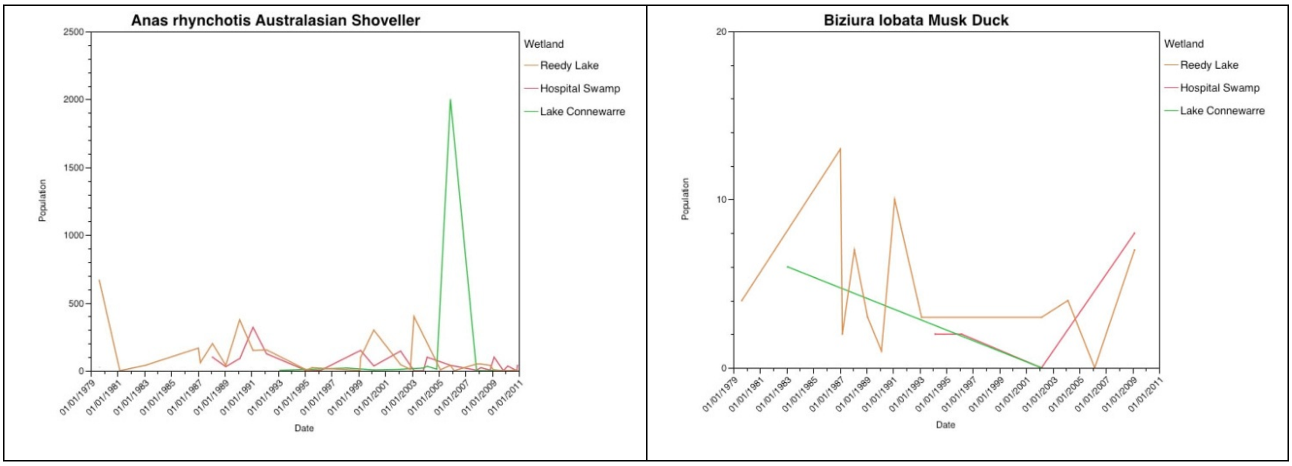


Figure 16: Count of carnivorous waterfowl for each of the Lower Barwon Wetlands. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010), supplemented with the Field and Game data set (1998 to January 2011).

The Australian Pelican has been found on Reedy Lake in very high numbers at times (Figure 17). Nearly 200 birds were recorded on the lake in 1993, and over 50 birds were recorded in 2000 and 2003, but at other times the pelican is not recorded foraging on the wetland, although data are not always available. Pelican numbers in Hospital Swamps show similar patterns in population size, but show temporal variation between the times at which each wetland has pelicans present.

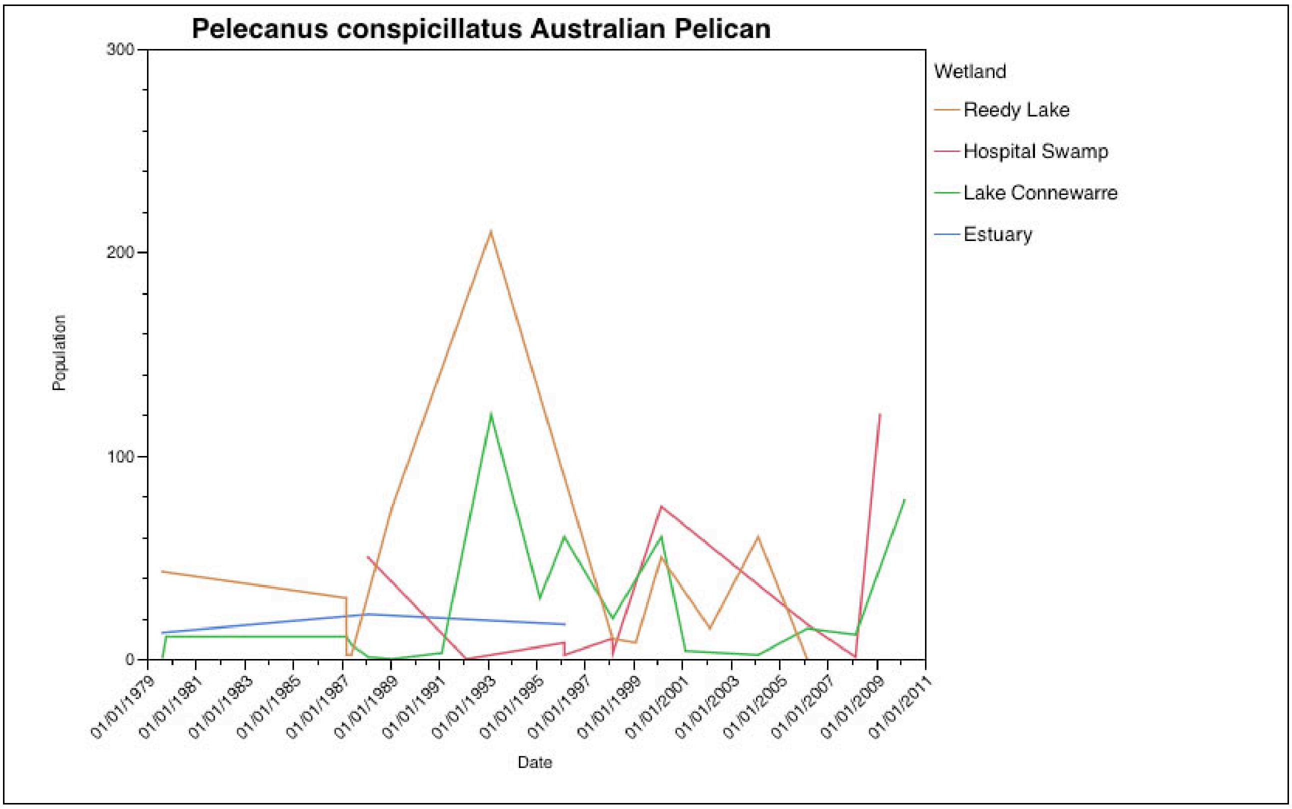


Figure 17: Count of Australian pelicans for each of the Lower Barwon Wetlands. Data: Department for Sustainability and Environment VBA flora and fauna data set (inclusive to October 2010).

Waders

A long-term monitoring program of waders (shorebirds) across the wetland complex has been in place since 1981. During this period generally two surveys have been taken each year in each wetland, with one in late summer (late February) and a second in mid-winter (June). Surveys in Salt Swamp have only been included since 2004. Because of the relative consistency in survey effort, frequency and timing across most of the wetlands in the wetland complex, valid comparisons may be made between wetlands for both species diversity and individual population estimates.

Waders are an important component of the avifauna for all wetlands in the wetland complex, with a high diversity of species using each of the wetlands (Figure 18) on an annual basis. Many of these species are highly abundant (Figure 19) constituting a major component of the vertebrate fauna biomass during late summer/early autumn. Because most of the wader species using the wetland are summer migrants there is a strong annual cycle in diversity and abundance evident across the wetlands.

Within the wetland complex the wetlands vary in their importance to waders. Lake Connewarre regularly provides important summer foraging habitat for between five and 12 wader species, with total wader populations at times between 8000 and 9000 birds (1994, 2004, 2007 and 2008). These number have varied markedly between years, with populations of less than 500 recorded in 1983, 1985, 1990, 1996, 2000, 2005, and 2009. Such variation in abundance may arise because birds are not using the wetland in that year, or because they are not foraging on the wetland during the survey period. It is not possible to differentiate between either of these explanations or to assign a reason for the birds' absence. Hospital Swamps also regularly provides important summer foraging habitat for waders, but the use of the wetland shows a greater variation in species diversity and abundance, with the periods of low abundance more frequently observed than in Lake Connewarre. Between three and 13 wader species are recorded annually, with a total wader population above 8000 birds recorded in 2000. These number have varied markedly between years, with populations of less than 500 recorded in 1983, 1984, 1987, 1990, 1993, 1994, 1997, 2004, 2005, and 2007. Reedy Lake regularly has a high diversity of waders present in the wetland, but these species are rarely in high abundance relative to those recorded in Hospital Swamps and Lake Connewarre. In Reedy Lake annual wader diversity varies between three and 12 species, but over the 30 year survey period populations above 1500 birds were only recorded in 1985, 1986, and 2005. The count in 1985 was markedly above all other records with over 7000 waders recorded on the wetland.

Three wader species constitute the majority of birds recorded across the wetland complex in any year. The red-necked stint is often the most abundant species with counts of over 5000 birds recorded on a wetland (Figure 20). The curlew sandpiper (Figure 21) and sharp-tailed sandpiper (Figure 22) are the next most common species with populations between 3000 and 4000 birds recorded on individual wetlands. In recent times red-necked stints and curlew sandpipers are rarely recorded feeding on Reedy Lake, but populations of around 1000 red-necked stints were recorded in 1983 and 1985, and populations of around 1000 curlew sandpipers were recorded in 1985, at other times few birds were recorded. Significant populations of both species were recorded on Hospital Swamps more frequently, but irregularly through until the present. Red-necked stints were recorded in high abundance in 1985 and consistently between 1999 and 2003 and over 2000 curlew sandpipers were recorded in 1985 and 1995, and consistently between 1998 and 2001.

High wader abundance on Reedy Lake is strongly related to the use of the wetland by sharp-tailed sandpipers (Figure 22), with populations of black-winged stilts (Figure 23), masked lapwing (Figure 24) and common greenshanks (Figure 25) also having relatively high populations at times.

Sharp-tailed sandpiper populations are regularly above 1000 in Hospital Swamps (12 years in 30), but there are extended periods with very low counts in Reedy Lake, particularly 1989 to 1994, and 1998 to 2003.

The use of Hospital Swamps by the black-winged stilt changed over the survey period, with the birds rarely recorded in small numbers in the 1980’s, but populations sustained at relatively high levels from 1994 onwards, with a peak of over 600 birds in 2001. In contrast Reedy Lake was regularly used throughout the 1980’s and early 1990’s, with a peak count of nearly 700 birds in 1985, but for regular periods from 1999 to 2003 and 2006/2007 no birds were present. In between these two period peaks of 400 birds were present in 2003 and 2005.

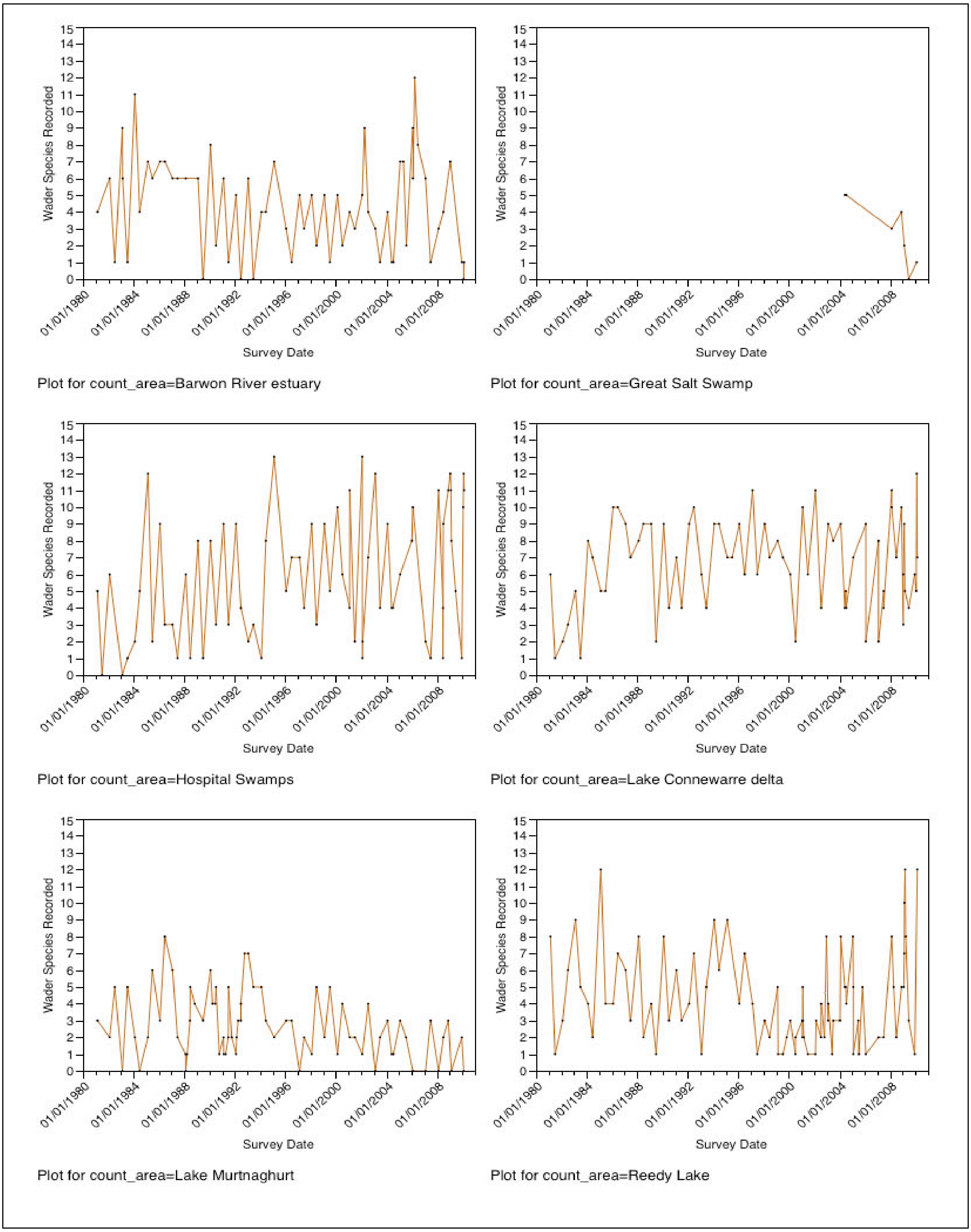


Figure 18: Wader species diversity for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

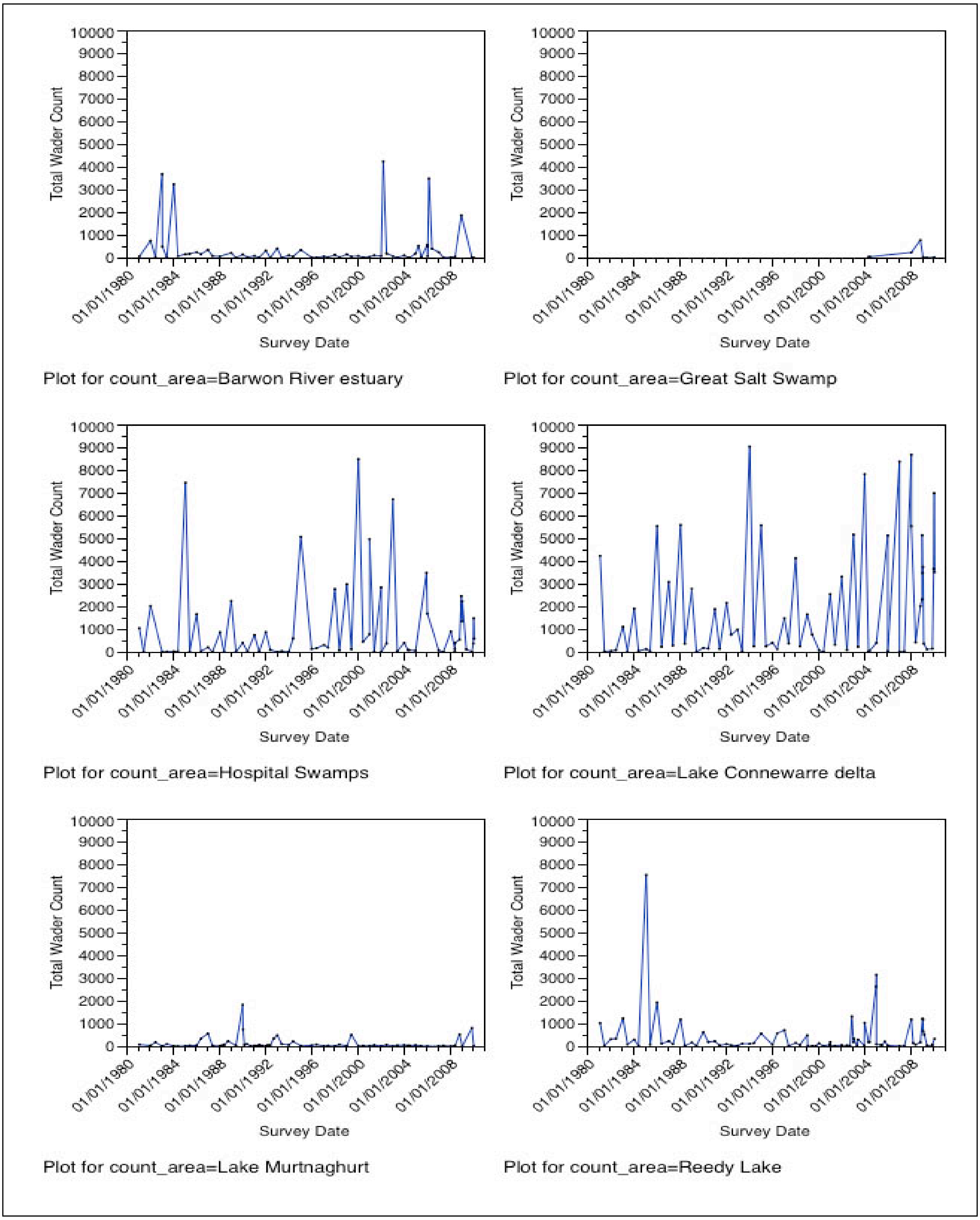


Figure 19: Wader species total abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

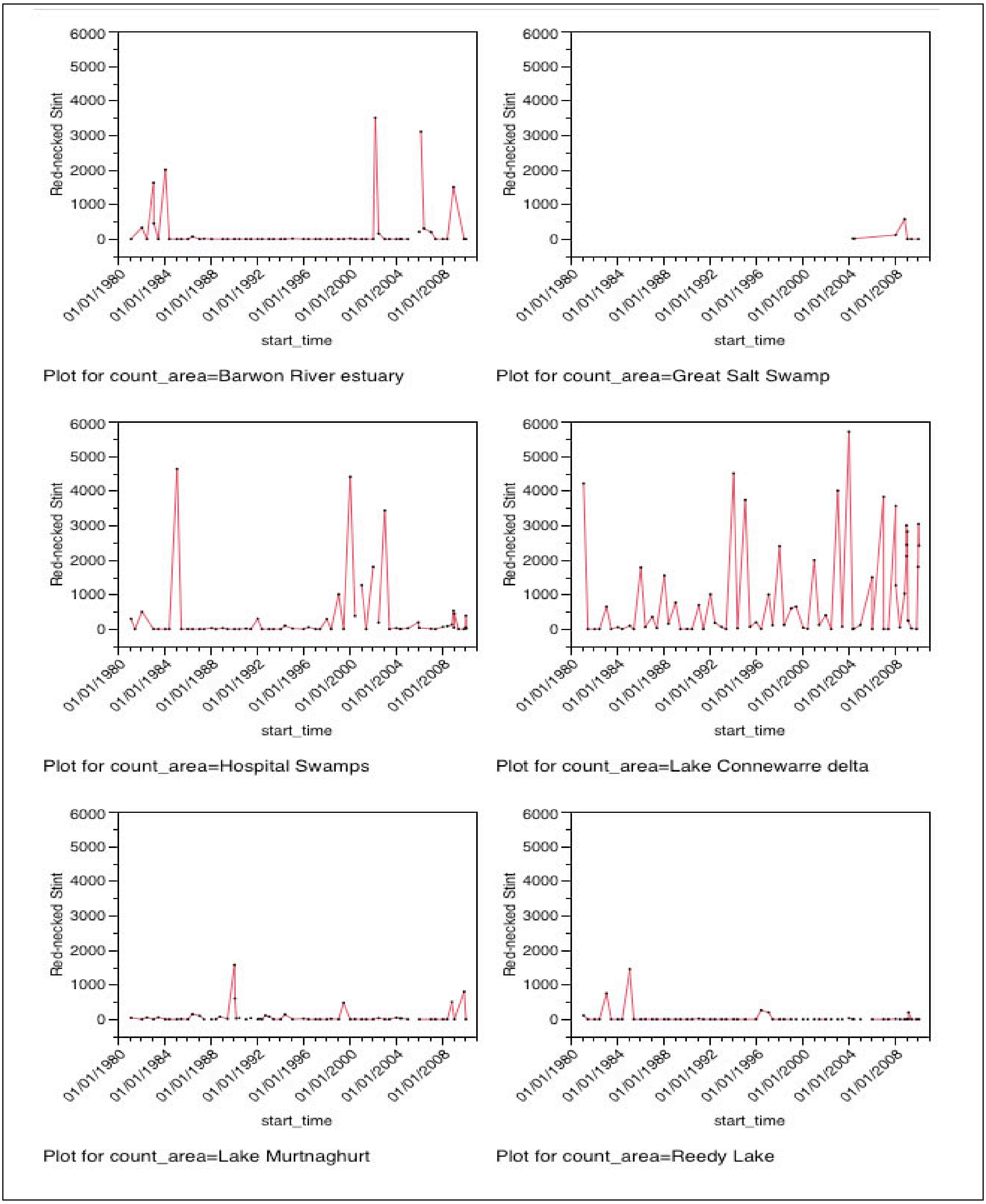


Figure 20: Red-necked stint abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

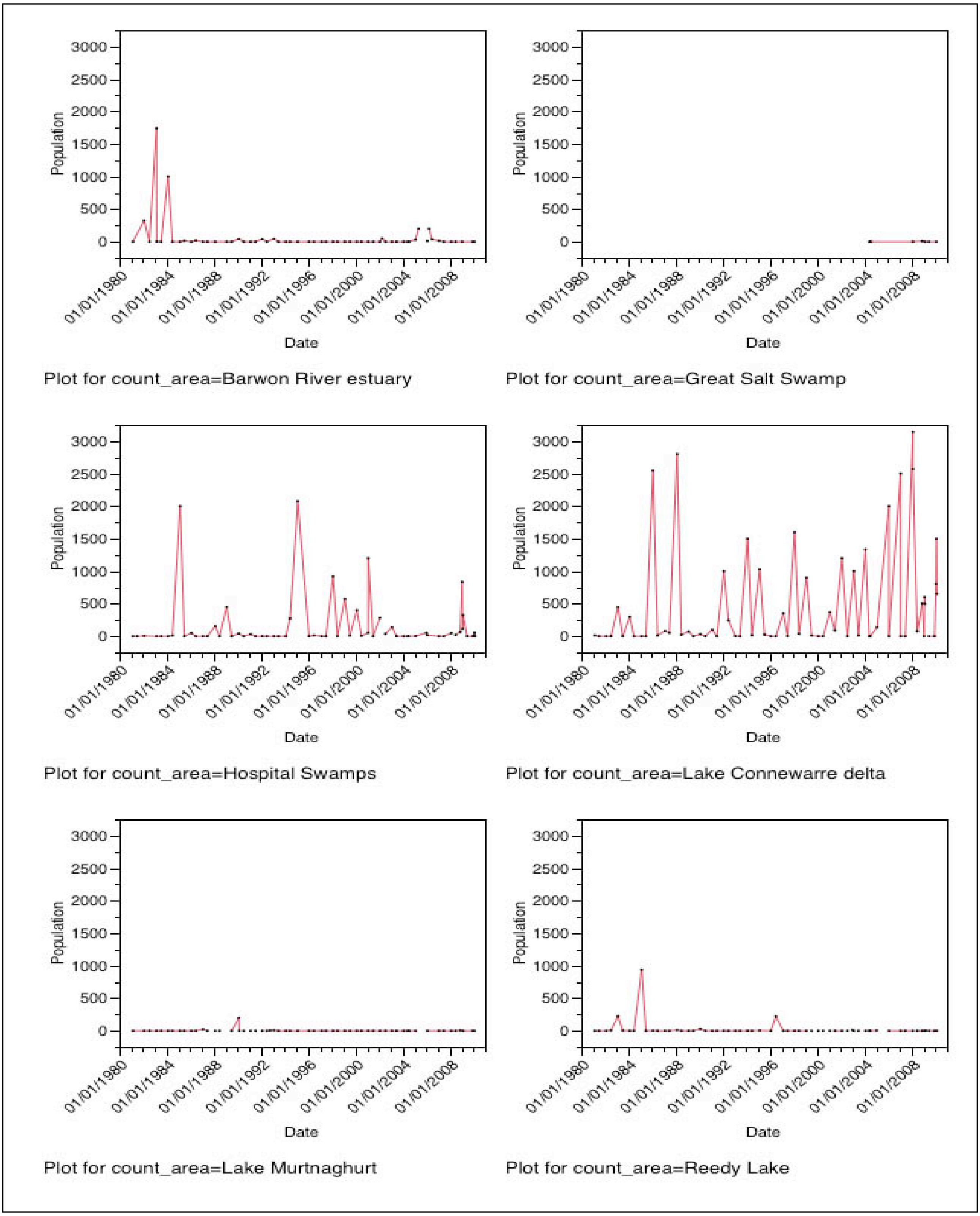


Figure 21: Curlew sandpiper abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

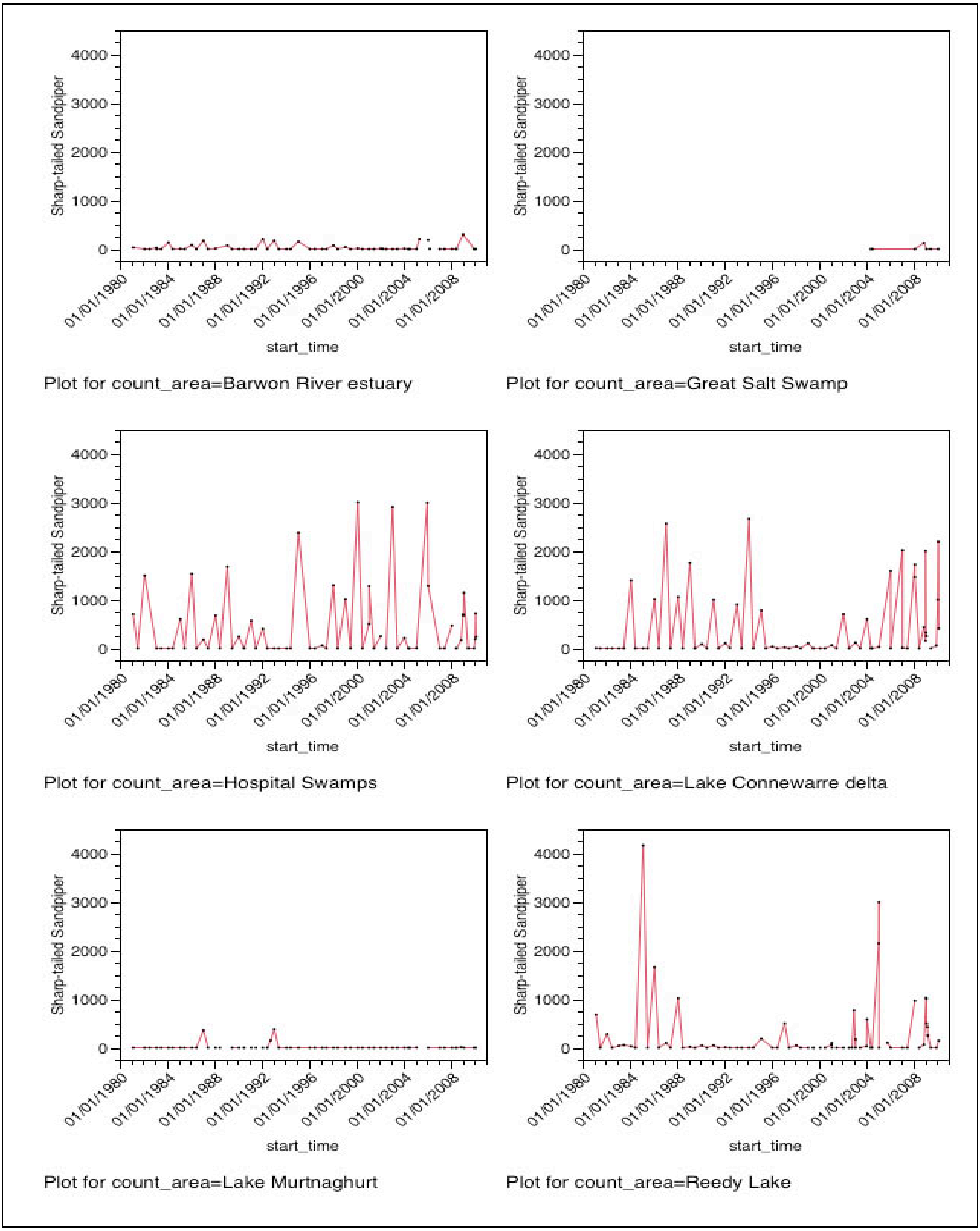


Figure 22: Sharp-tailed sandpiper abundance for each of the Lower Barwon Wetlands.
Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

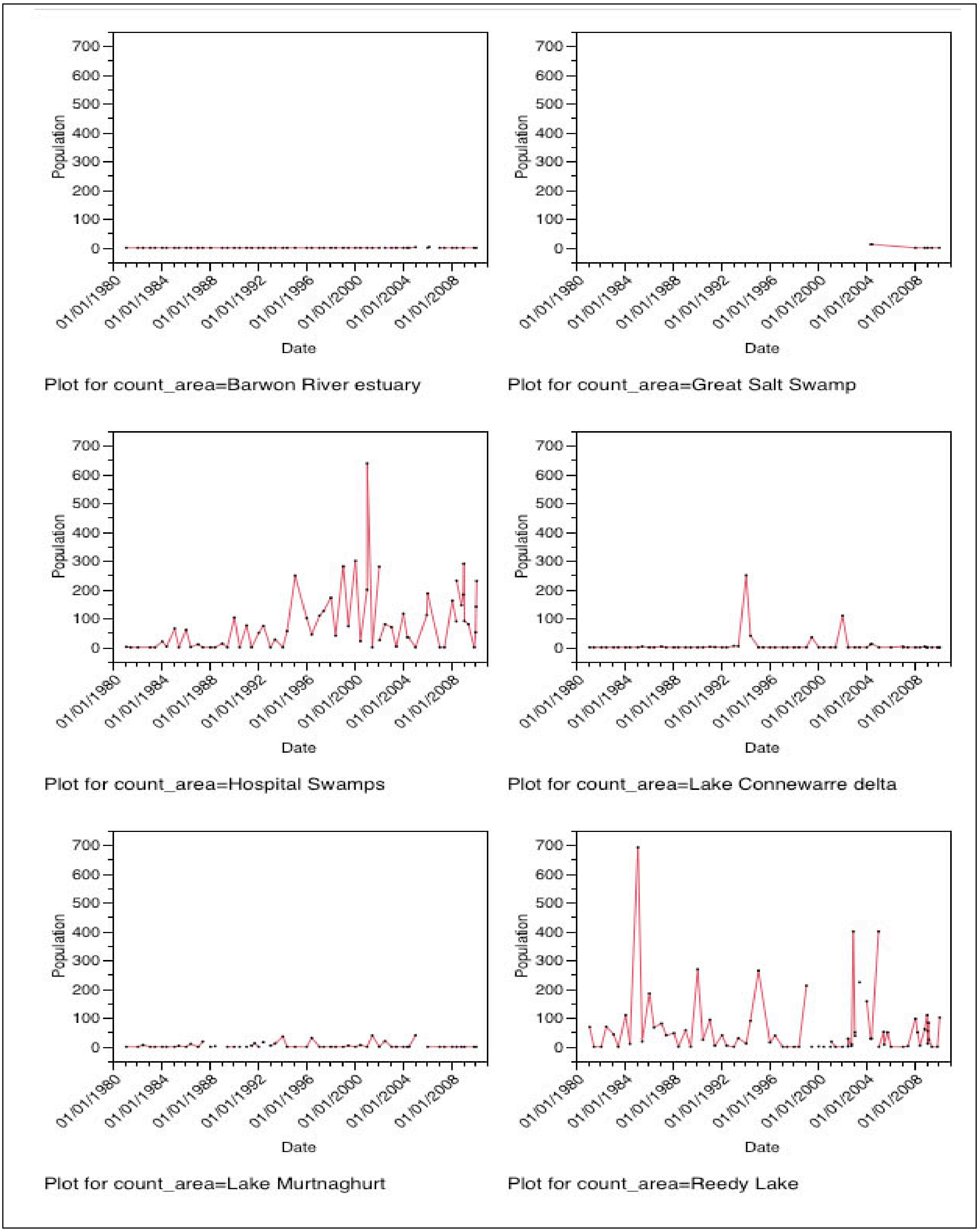


Figure 23: Black-winged stilt abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

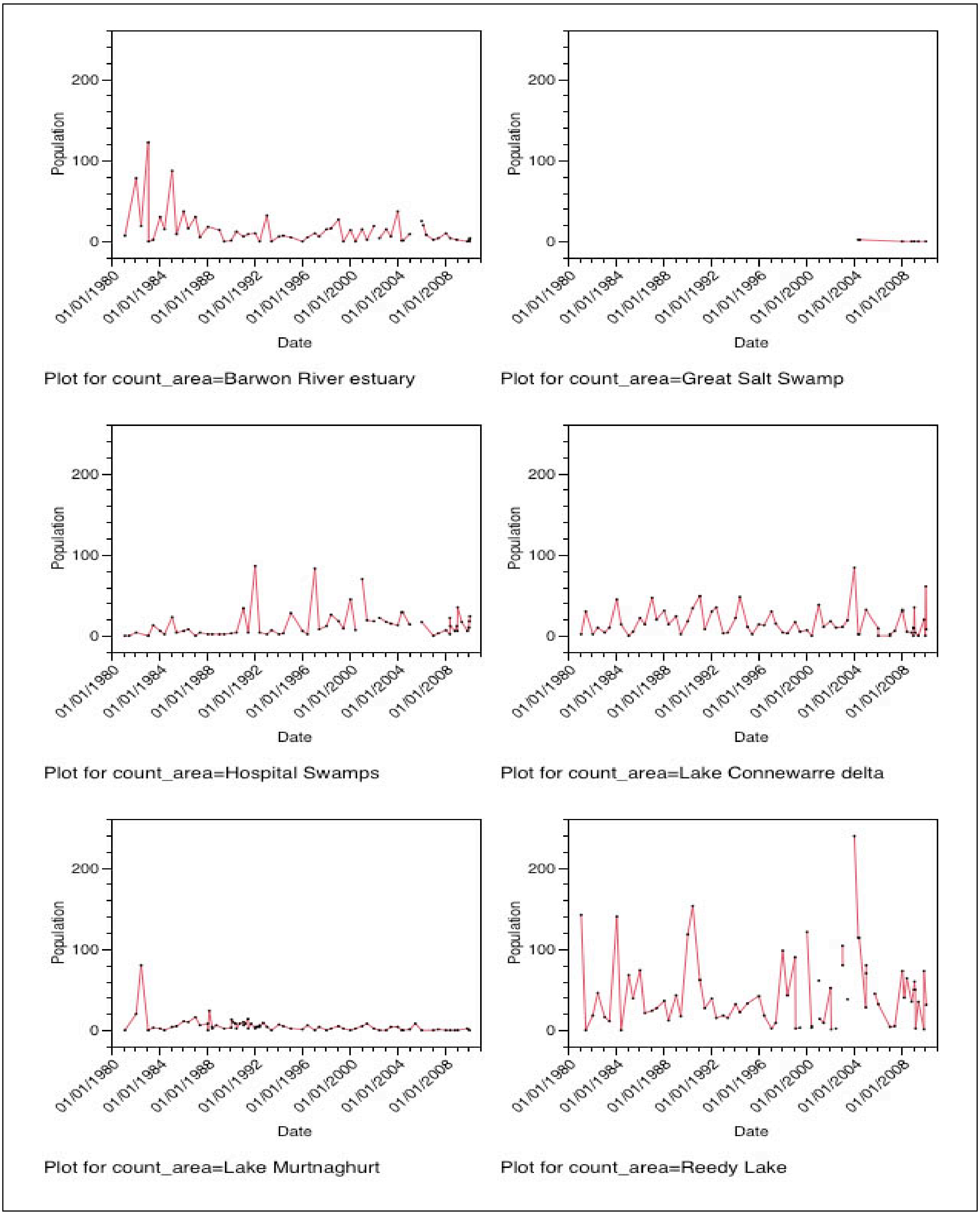


Figure 24: Masked lapwing abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

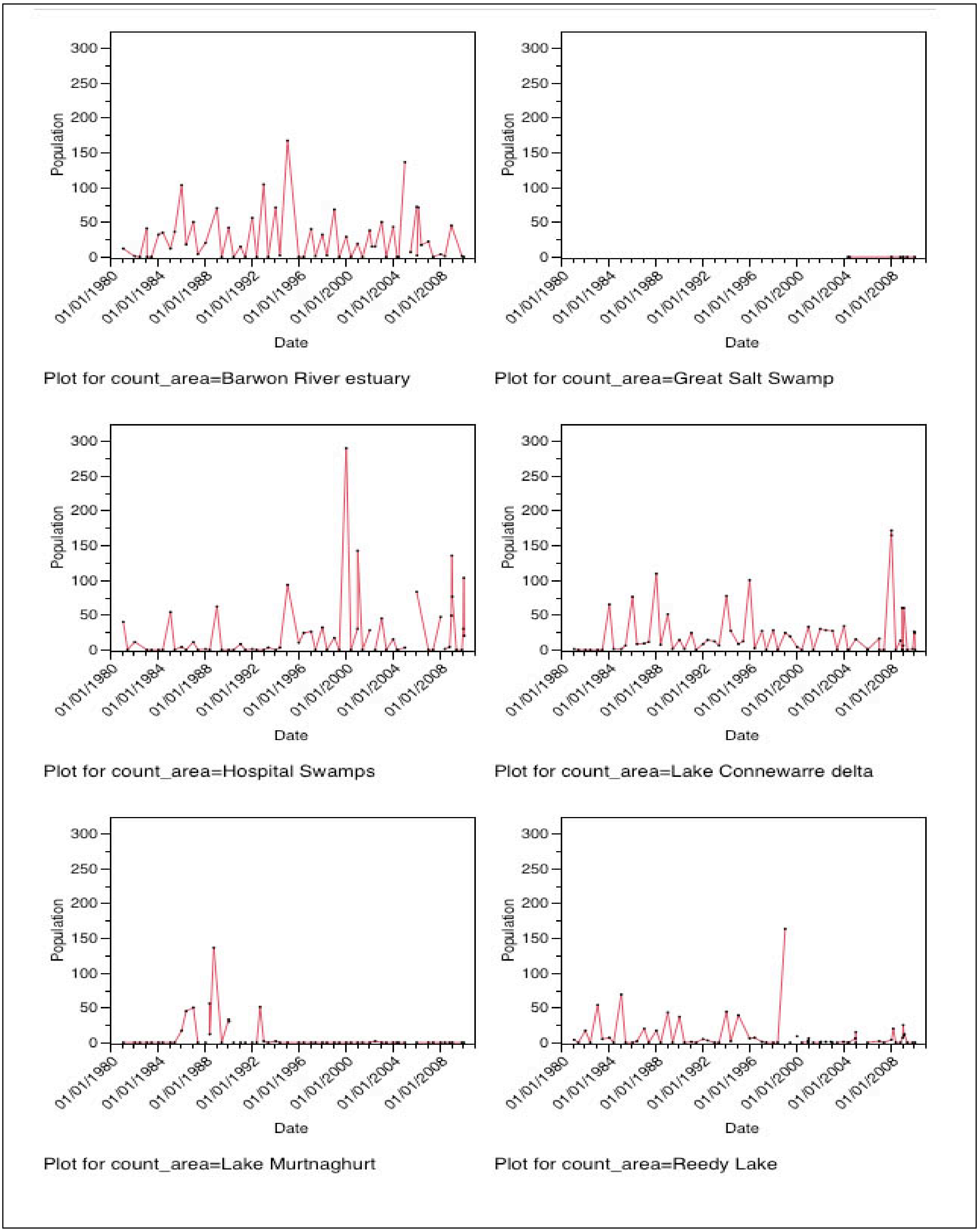


Figure 25: Common greenshank abundance for each of the Lower Barwon Wetlands. Data: Birds Australia - Australian Wader Study Group long-term monitoring program (1981 to 2010).

Masked lapwing populations have varied within fairly consistent levels across both Reedy Lake and Hospital Swamps during the monitoring period.

The common greenshank population recorded in Hospital Swamps has shown a long-term increasing trend since 1980. This increase is particularly marked since 1994, with high populations occurring on average one in two years compared with over one in three prior, and the size of the peak populations increasing from around 50 to between 100 and 300 birds. Reedy Lake has shown a converse trend with relatively low populations recorded since a peak of over 150 birds in 1999.

Overall, records since 1980 indicate that Hospital Swamps and Reedy Lake have different patterns of use by waders and that there have been different wader population trends in both wetlands. The diversity and number of waders using Hospital Swamps shows a generally increasing trend, while Reedy Lake appears to be less frequently used by the more abundant wader species that feed across the wetland complex, with the high populations recorded in the 1980's rarely observed in the first decade of the 21st century. The contrasting trends for the two closely linked wetlands indicate a long-term change in ecological character in Reedy Lake over the monitoring period. This change suggests that the foraging conditions that have, in the past, attracted large populations of waders are now occurring less frequently.

Foraging Guilds

The Birds Australia New Atlas surveys provide a relatively intense data set between 1998 and 2010 for all bird species across the wetland complex. Data recorded does not always give information on abundance, but the quality of the information available, with respect to presence/absence of a species in any one year, is high. These data allow a comparison of changes to species composition within any one foraging guild.

In both Hospital Swamps and Reedy Lake there is a medium term cycle in the diversity of deep water herbivorous and carnivorous avian species and open water carnivorous species (Figure 26). In both of the wetlands, diversity of species in these guilds appears to reach a maximum between 2001 and 2004, with a decline in diversity to very low levels between 2006 and 2007. In Reedy Lake this decline was probably associated with the programmed drying of the lake. Since this low point, guild diversity in Reedy Lake has again gradually increased, and to a lesser extent in Hospital Swamps. Similar cycles in diversity are also apparent in the estuary wetlands, although the decline in species diversity in 2006 and 2007 is not as severe. It is difficult to disentangle the impact of a regional dry climatic pattern from the wet/dry management cycle implemented in Reedy Lake. Broad-scale factors that are affecting both wetlands appear to be important in driving this cycle in diversity. The decline in deep water and open water avian diversity was probably driven by the limited number of overbank flows in the Barwon River between 2001 and 2007, with the impact of specific wetland management actions in Reedy Lake acting on top of this regionally driven pattern. Overall the trend across the wetland complex over the last 10 years is for a decline in the diversity of deep-water herbivorous and carnivorous species and open water carnivorous species.

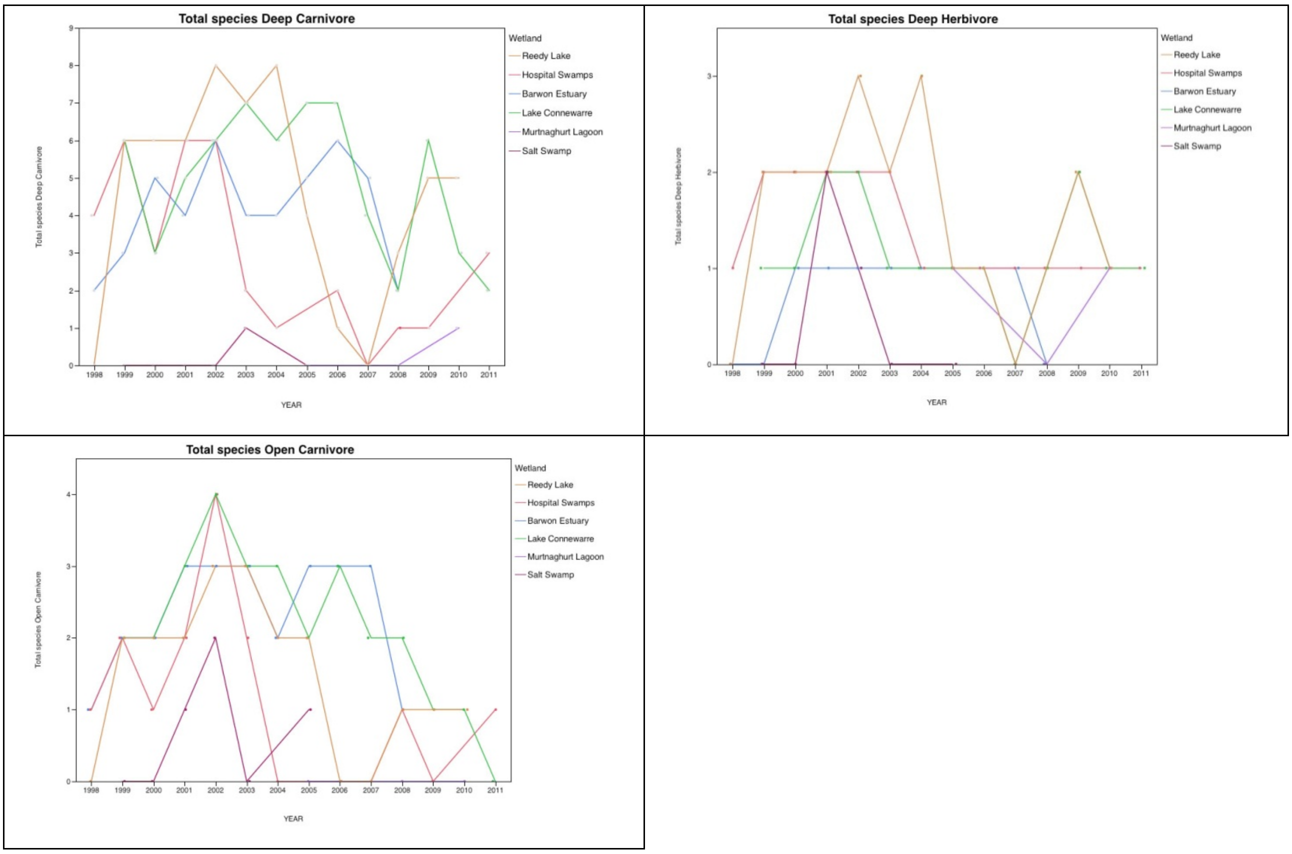


Figure 26: Changes in annual deep-water foraging carnivorous and herbivorous, and open water carnivorous avian species diversity for each wetland within the lower Barwon River wetland complex. Data source: Birds Australia New Atlas 1998 to 2010.

In both Hospital Swamps and Reedy Lake there is a medium term cycle in the diversity of species associated with reed beds (Figure 27). In both of the wetlands, diversity of species in these guilds appears to reach a maximum between 1999 and 2003, with a decline in diversity to very low levels in 2004 in Hospital Swamps and in 2006/2007 in Reedy Lake. In Reedy Lake this decline was probably associated with the programmed drying of the lake. Since this low point, guild diversity in Reedy Lake has again gradually increased. In Hospital Swamps a second cycle with a peak in the diversity of birds foraging in association with reed beds occurred in 2006/2007. The diversity of species in these guilds is lower in estuary wetlands, but similar cycles in diversity are apparent. Again it is difficult to disentangle the impact on birds using the wetlands of a regional dry climatic pattern from the wet/dry management cycle implemented in Reedy Lake. The decline in avian diversity associated with the reed beds in both wetlands was probably driven by the limited number of overbank flows in the Barwon River between 2001 and 2007, with the impact of specific wetland management actions in Reedy Lake acting on top of this regionally driven pattern. Overall the trend across the wetland complex over the last 10 years is for a decline in the diversity of species within feeding guilds associated with reed beds.

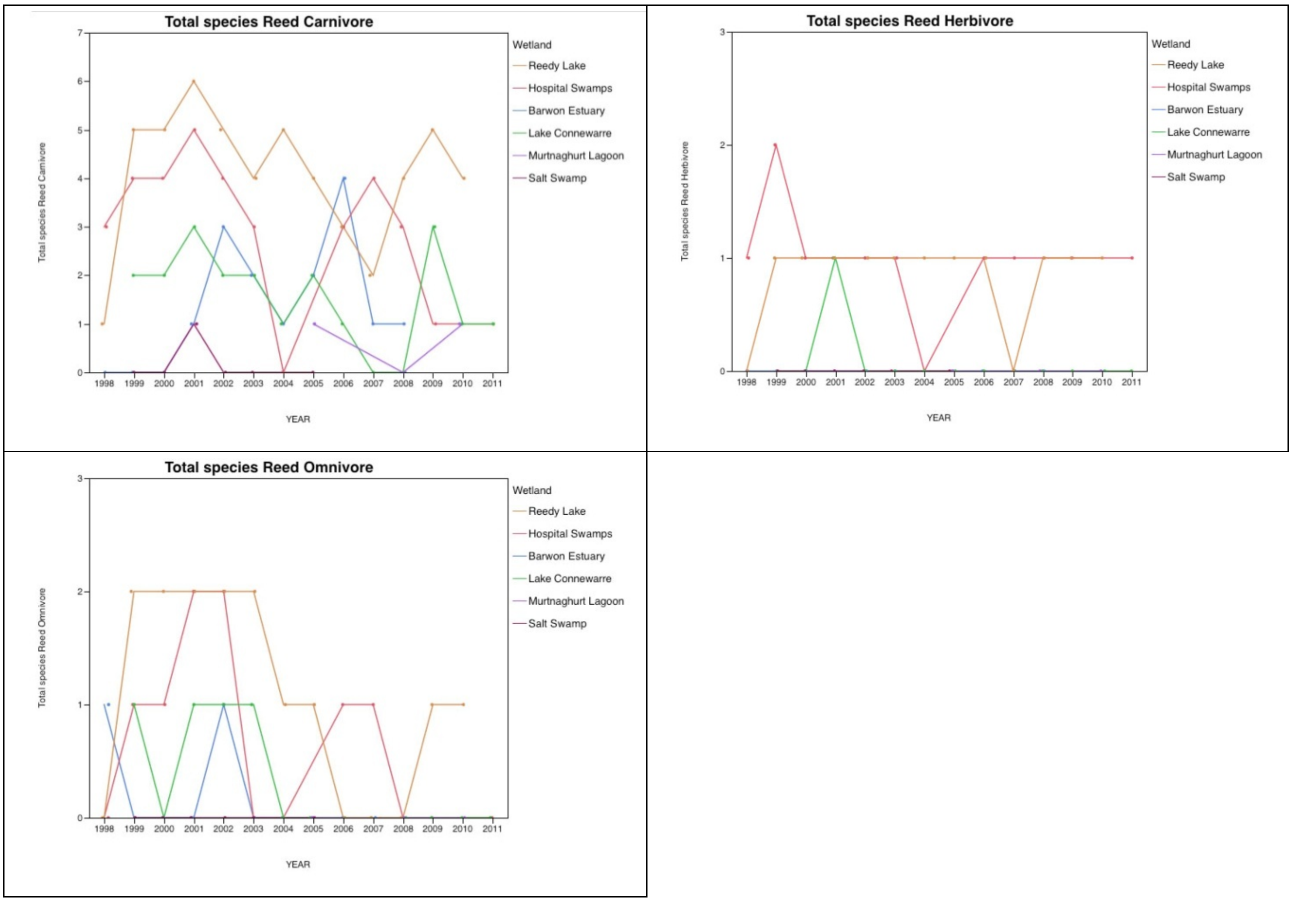


Figure 27: Changes in annual reed foraging carnivorous, herbivorous and omnivorous avian species diversity for each wetland within the lower Barwon River wetland complex. Data source: Birds Australia New Atlas 1998 to 2010.

In both Hospital Swamps and Reedy Lake there are medium term cycles in the diversity of species that forage in shallow (<30 cm) water (Figure 28). In both of the wetlands, diversity of species in these guilds appears to reach a maximum between 1999 and 2002, with a decline in diversity in 2004 in Hospital Swamps and to very low levels in 2006/2007 in Reedy Lake. In Reedy Lake this decline was probably associated with the programmed drying of the lake. Since this low point, guild diversity in Reedy Lake has again increased to or approached the levels of diversity recorded at the peak of the first cycle. This has not occurred in Hospital Swamps, and the range of species using the wetland has remained markedly lower than the peak in 2002. The diversity of species in the shallow water herbivorous guild is lower in estuary wetlands, but similar for the carnivorous species, but similar cycles in diversity are apparent. Again it is difficult to disentangle the impact on birds using the wetlands of a regional dry climatic pattern from the wet/dry management cycle implemented in Reedy Lake. The decline in avian diversity associated with the shallow water habitat in both wetlands was probably driven by the limited number of overbank flows in the Barwon River between 2001 and 2007, with the impact of specific wetland management actions in Reedy Lake acting on top of this regionally driven pattern. Overall the trend across the wetland complex over the last 10 years is generally for a decline in the diversity of species within feeding guilds associated with shallow water. This pattern is not apparent in Reedy Lake where diversity has rapidly increased to moderately high levels following the drying and subsequent filling of the lake.

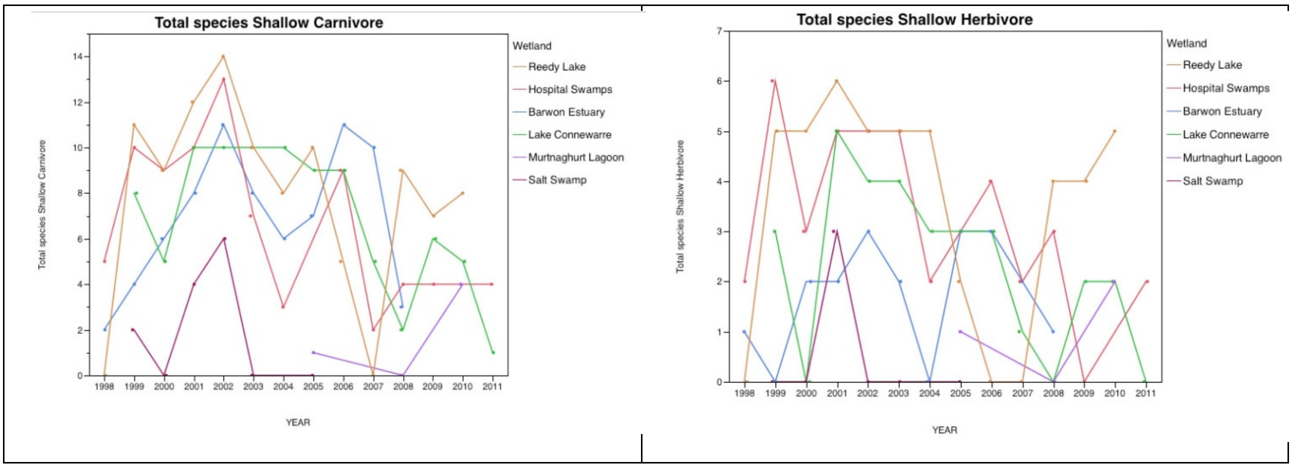


Figure 28: Changes in annual shallow (<30 cm) water foraging carnivorous and herbivorous avian species diversity for each wetland within the lower Barwon River wetland complex. Data source: Birds Australia New Atlas 1998 to 2010.

In both Hospital Swamps and Reedy Lake there are medium term cycles in the diversity of species that forage along the shoreline and on recently exposed mudflats (Figure 29). In Reedy Lake diversity of species in this guild reached a maximum in 2000, 2003 and 2009, with marked declines in diversity in 2001 and 2006/2007. In Hospital Swamps a markedly different pattern in diversity was apparent with no decline over time.

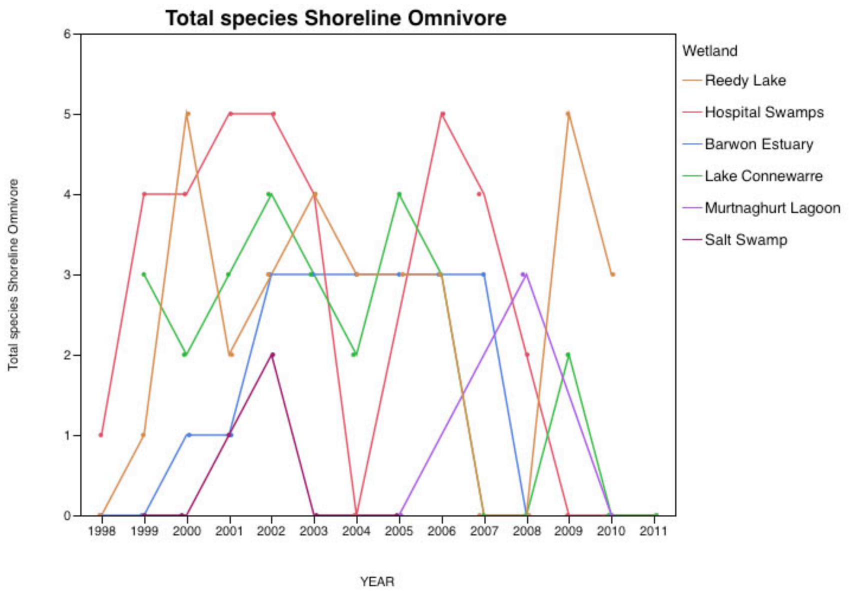


Figure 29: Changes in annual shoreline and mudflat foraging omnivorous avian species diversity for each wetland within the lower Barwon River wetland complex. Data source: Birds Australia New Atlas 1998 to 2010.

Two peaks in diversity are evident in 2001/2002 and again in 2006. No species in this guild were recorded in Hospital Swamps in 2004 and in 2009. The cycles in diversity in this guild do not appear to be associated with the limited number of overbank flows in the Barwon River between 2001 and 2007. The drying of Reedy Lake caused the low species diversity in 2006, but the cause of other troughs and peaks in diversity are not apparent. Overall the trend for species diversity in the omnivorous guild associated with shoreline foraging species over the last 10 years is for strong but independent cycles in diversity between wetlands.

3.4.9 Waterbird Conceptual Models

The maintenance of a diversity of habitat types and the provision of an annual cycle in water levels are key factors in supporting diverse waterbird communities in relatively high abundances in Reedy Lake and Hospital Swamps. These responses are complex and driven by multiple processes (Figure 30). There are four habitat elements present within these wetlands (Deep/open water, shallow water [<30 cm], reed beds, and shoreline/mudflats) that provide suitable habitat for the 17 foraging guilds and the diversity of breeding requirements previously identified.

a) Representative Objective 1 – Deep/open water

Areas of relatively deep and open water in Reedy Lake (Figure 31) and Hospital Swamps (Figure 33) over winter and through spring provide key foraging habitat for four foraging guilds, breeding habitat for species such as the crested grebe, and refuge habitat for a wide variety of species that use other elements of the wetland complex to forage in. This habitat is retained in some sectors of Reedy Lake through summer and autumn (Figure 32) but is lost in late summer in Hospital Swamps (Figure 34). As such it provides ongoing foraging habitat and important summer and drought refuge on a regional scale, particularly for waterfowl.

Waterbird microhabitat complexity within deep water at Reedy Lake and Hospital Swamps is maintained through providing interfaces with reed beds, providing diverse and healthy aquatic macrophyte beds, annual provision of a complex and productive invertebrate element of the food web, and a diverse and abundant fish population, from a variety of age classes.

b) Representative Objective 2 – Shallow water (<30 cm)

As they annually fill and subsequently dry, a region of shallow water habitat is constantly shifting across the beds of both Reedy Lake (Figure 31 and Figure 32) and Hospital Swamps (Figure 33 and Figure 34). The changes in substrate type inundated, and changes in the extent of inundated semi-emergent, emergent and fringing vegetation as the wetland elements fill and empty, provide important components in the diversity of microhabitats used by the waterbird species that forage in this region.

In both Reedy Lake (Figure 31) and Hospital Swamps (Figure 33) rising water levels in late winter and through spring inundate mudflats and shoreline vegetation. As water temperatures rise in spring these regions provide nutrient and carbon sources that result in the development of highly productive food webs. Waterbirds seeking to build up fat stores prior to breeding, and to feed young during nesting, rely on these productive environments within the shallow regions of the wetlands to successful reproduce.

Extensive areas of shallow water are produced in Reedy Lake through summer and autumn (Figure 32), and in Hospital Swamps as water levels lower in late summer (Figure 34). Trapped abundant fish and invertebrate populations become available to the specialist wading waterbirds as water levels gradually drop with evaporation, exposing fauna within submerged macrophyte beds and large areas of sandy and muddy substrate. The region of shallow water gradually shifts from the higher fringing vegetation, down through a mosaic of emergent and semi emergent reed beds, to finally expose areas of aquatic macrophytes. These regions provide important food sources for large populations of migratory waders building energy stores in preparation for their northward migration. Tubers within the mud become available to birds such as brolga and magpie geese and a wide range of herbivorous and omnivorous species feed in the shallow water on the available vegetation.

c) Representative Objective 3 – Reed beds

Diverse reed bed mosaics provide important foraging and nesting habitat for many cryptic waterbird species and nesting habitat for a variety of species that generally forage in other nearby wetland and fringing habitats. Colonial nesting waterbirds, such as ibis, which generally nest in trees within inundated forests, use reed beds in which to build their nesting areas in Reedy Lake. A diversity of reed bed types is achieved through annual cycles in water depth, and complexity in wetland margin topography amongst other things.

Extensive areas of this habitat type are found in Reedy Lake (Figure 31 and Figure 32) and in Hospital Swamps (Figure 33 and Figure 34). While an important habitat component within a wetland complex, simplified (e.g. *Typha* and *Phragmites*) and extensive regions of reed beds that dominate a wetland to the exclusion of other plant species and habitat types, result in low avian diversity through the loss of essential foraging habitat provided by these other habitat types. It is the diversity of interface zones between the variety of reed bed types and the other habitat elements that are critical to providing the microhabitat complexity necessary to support a diverse waterbird community.

The roots, tubers, leaves and fruit of the plants within the reed beds provide important food sources for many bird species, but also are the basis of the food web on which many of the insectivorous and carnivorous waterbird species depend.

d) Representative Objective 4 – Shoreline/mudflats

Rising water levels in late winter and through spring inundate mudflats and shoreline vegetation in both Reedy Lake (Figure 31) and Hospital Swamps (Figure 33). When inundated muddy substrates are important for some waterbird species that forage in shallow water.

In summer and autumn when the wetlands are drying out and the muddy substrate is exposed or in very shallow water (0-2 cm), organisms such as the macrobenthic fauna and plant storage organs in the mud, or on its surface, become an important and abundant food source for a wide variety of waterbird species (Figure 32 and Figure 34). These species include many of the migratory waders found across the wetland complex in large number.

New plant growth and germination from seeds in areas recently exposed also provides important foraging habitat for herbivorous waterbirds that forage above the shoreline.

The rate of exposure of the mudflat and the timing of when the largest area of mud flat becomes available to wading and shoreline foraging birds are important in maximising the benefit to waterbirds. Ideally the drawdown of the wetlands will continue through summer and into autumn, maximising the period when these food sources are available.

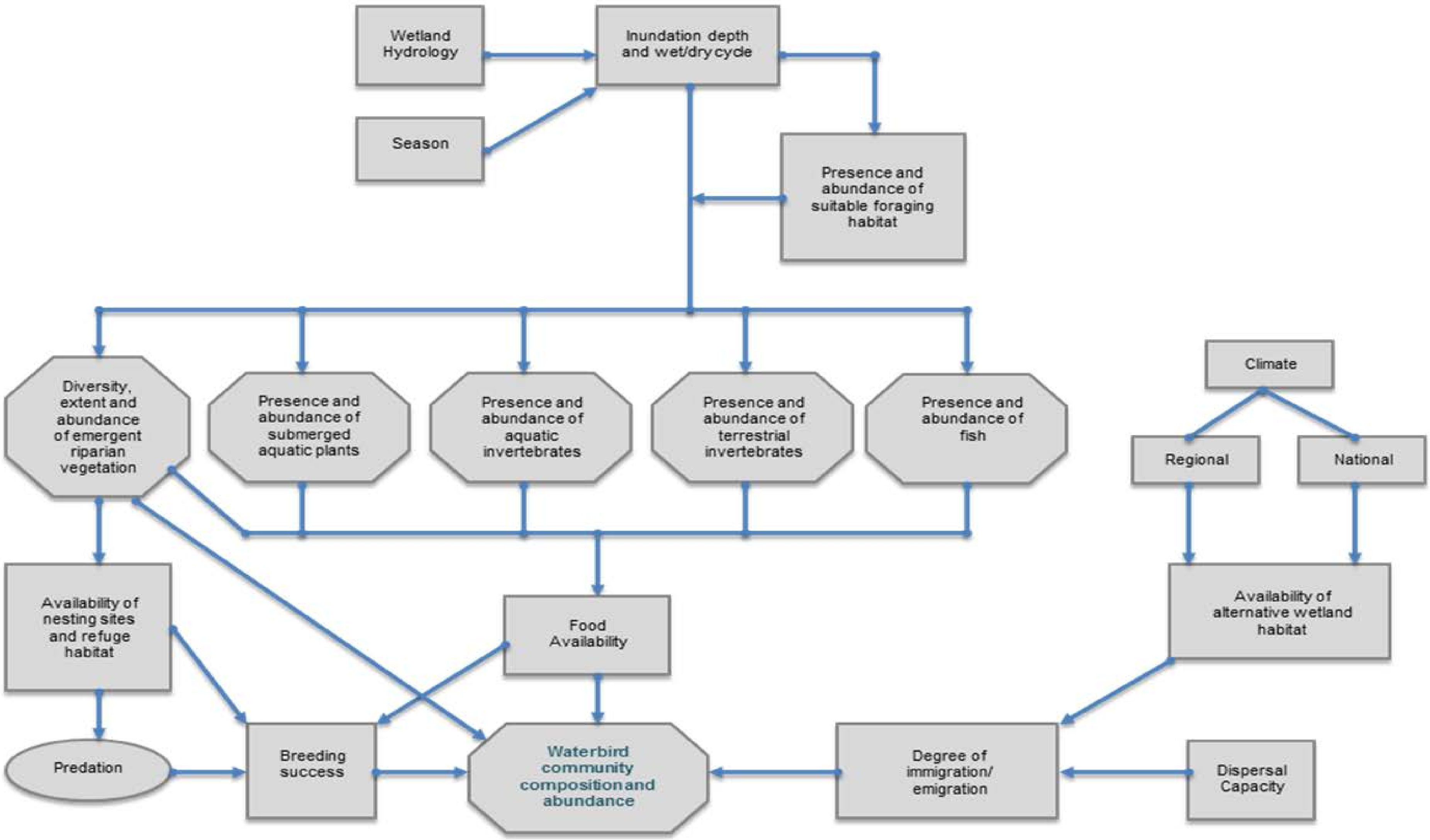


Figure 30: Factors driving waterbird diversity and abundances of Waterbirds in the Lower Barwon Wetlands.

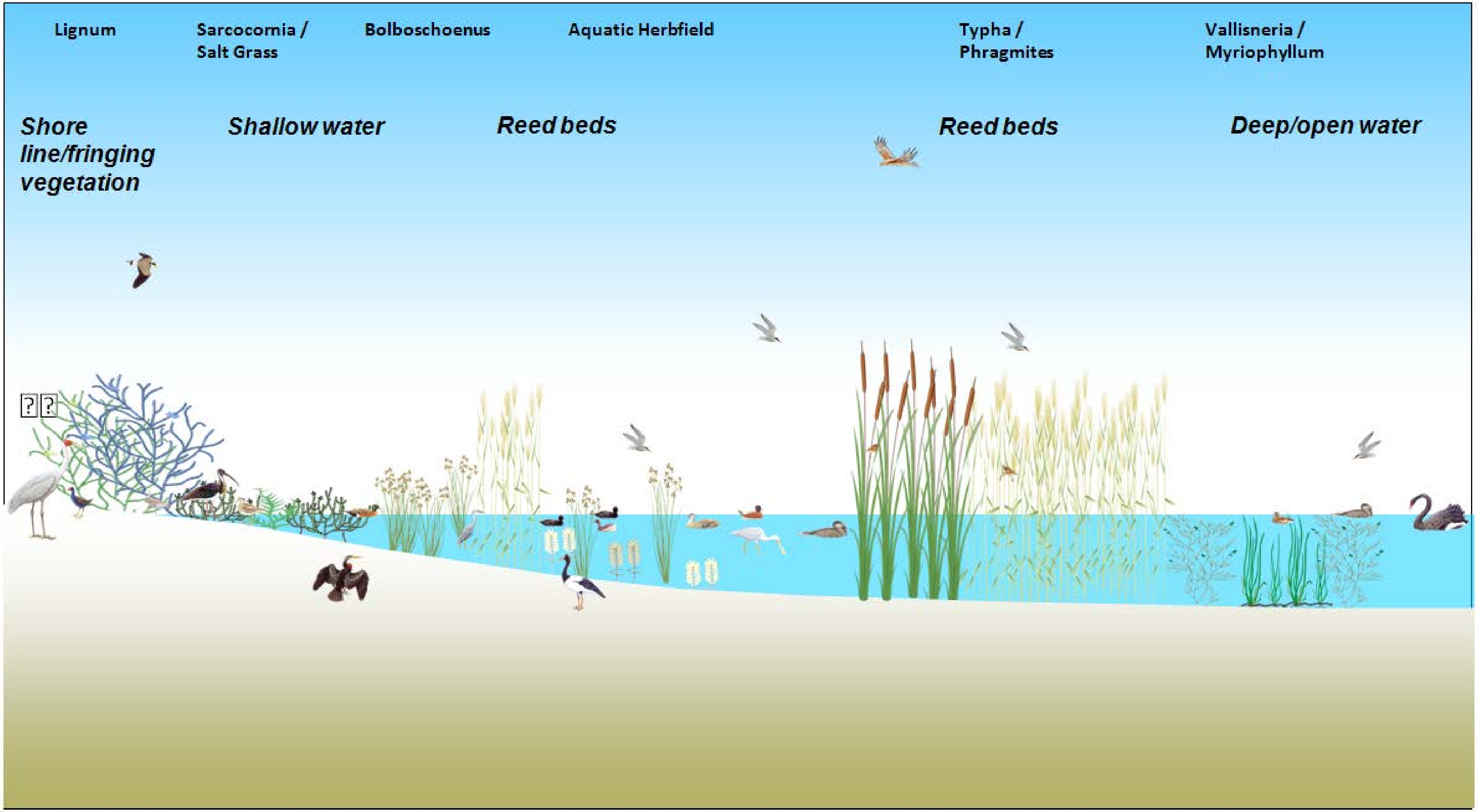


Figure 31: Waterbird Conceptual Model of Reedy Lake in Spring.

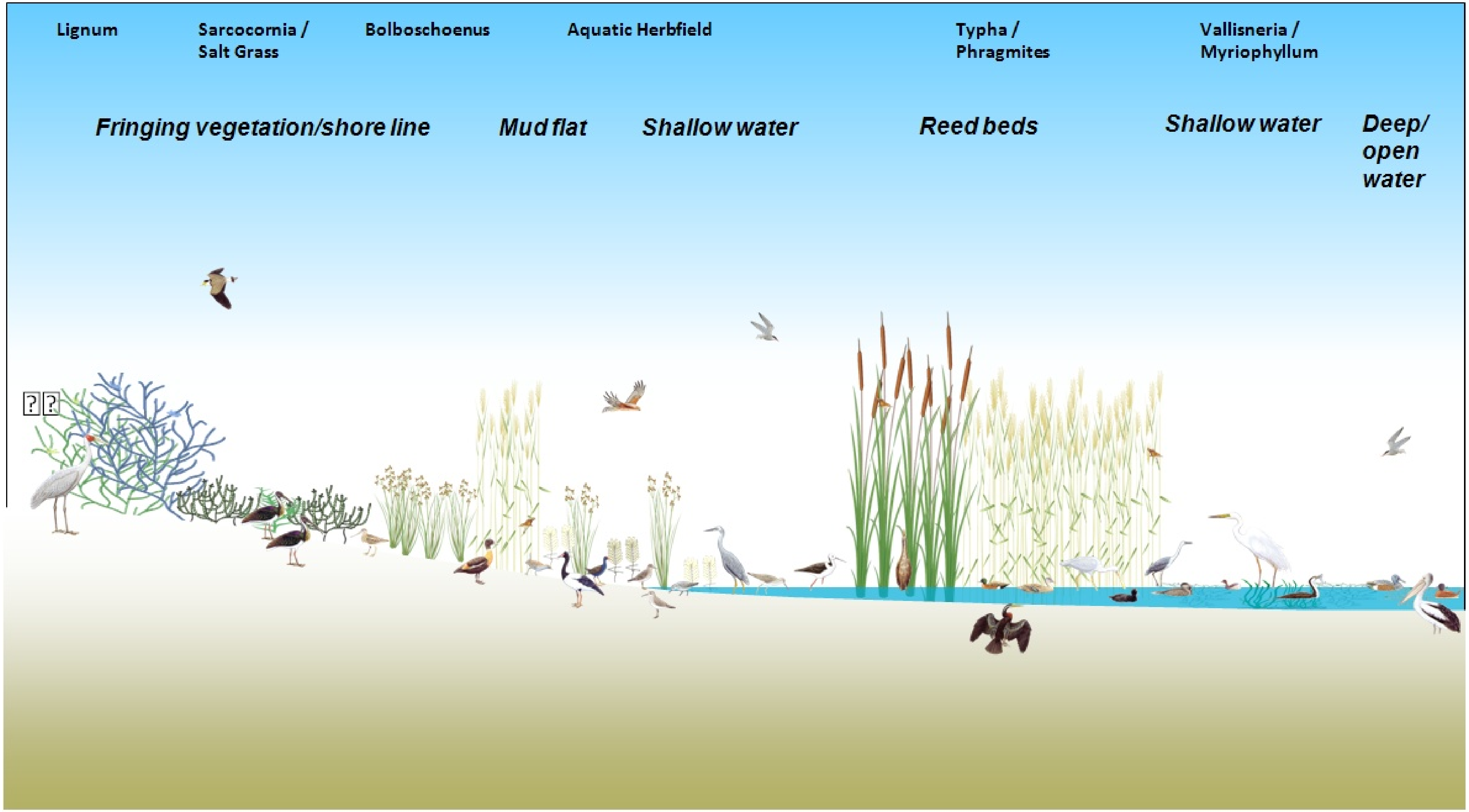


Figure 32: Waterbird Conceptual Model for Reedy Lake in Late Summer/Autumn.

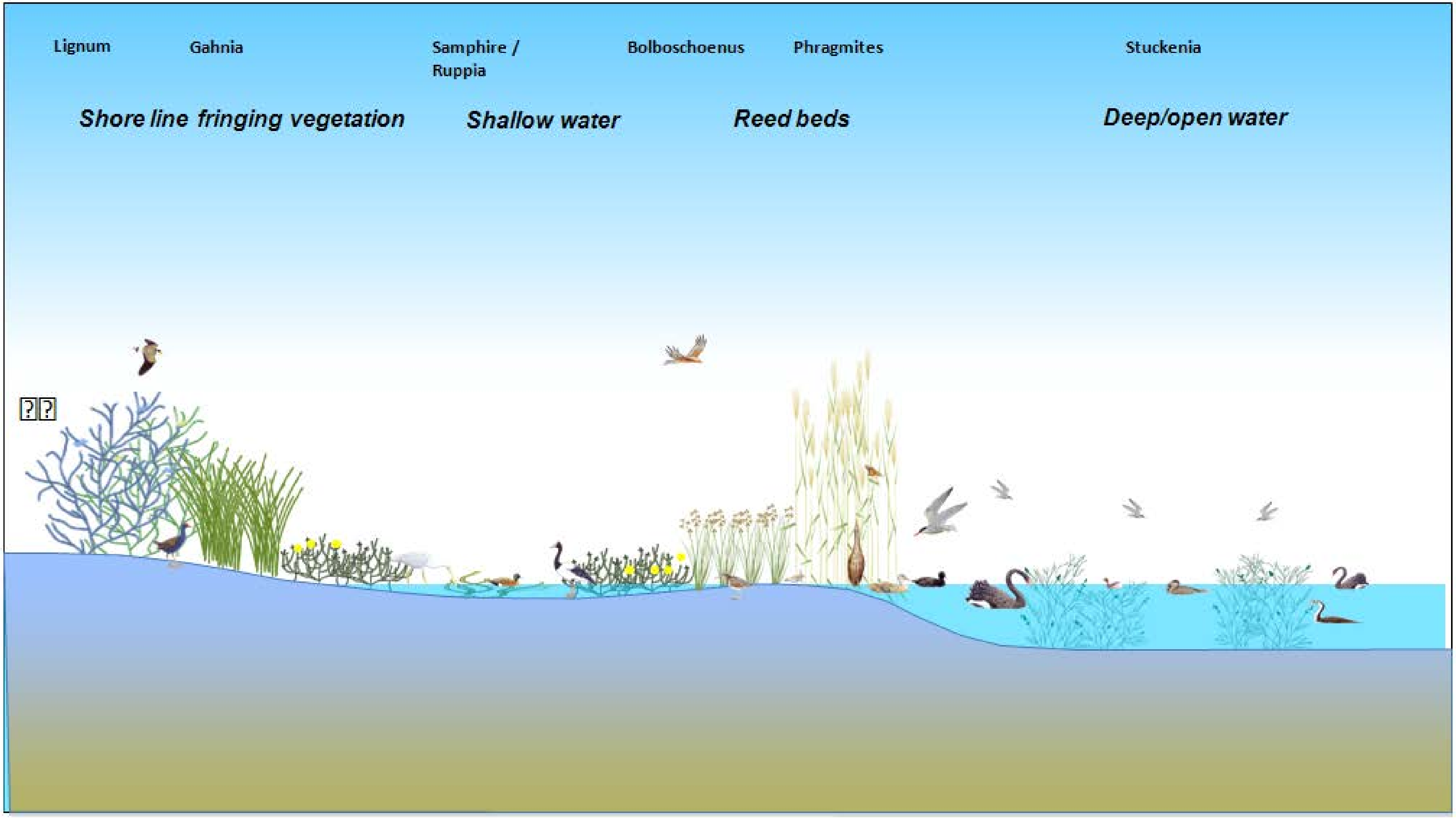


Figure 33: Waterbird Conceptual Model in Hospital Swamps in Spring.

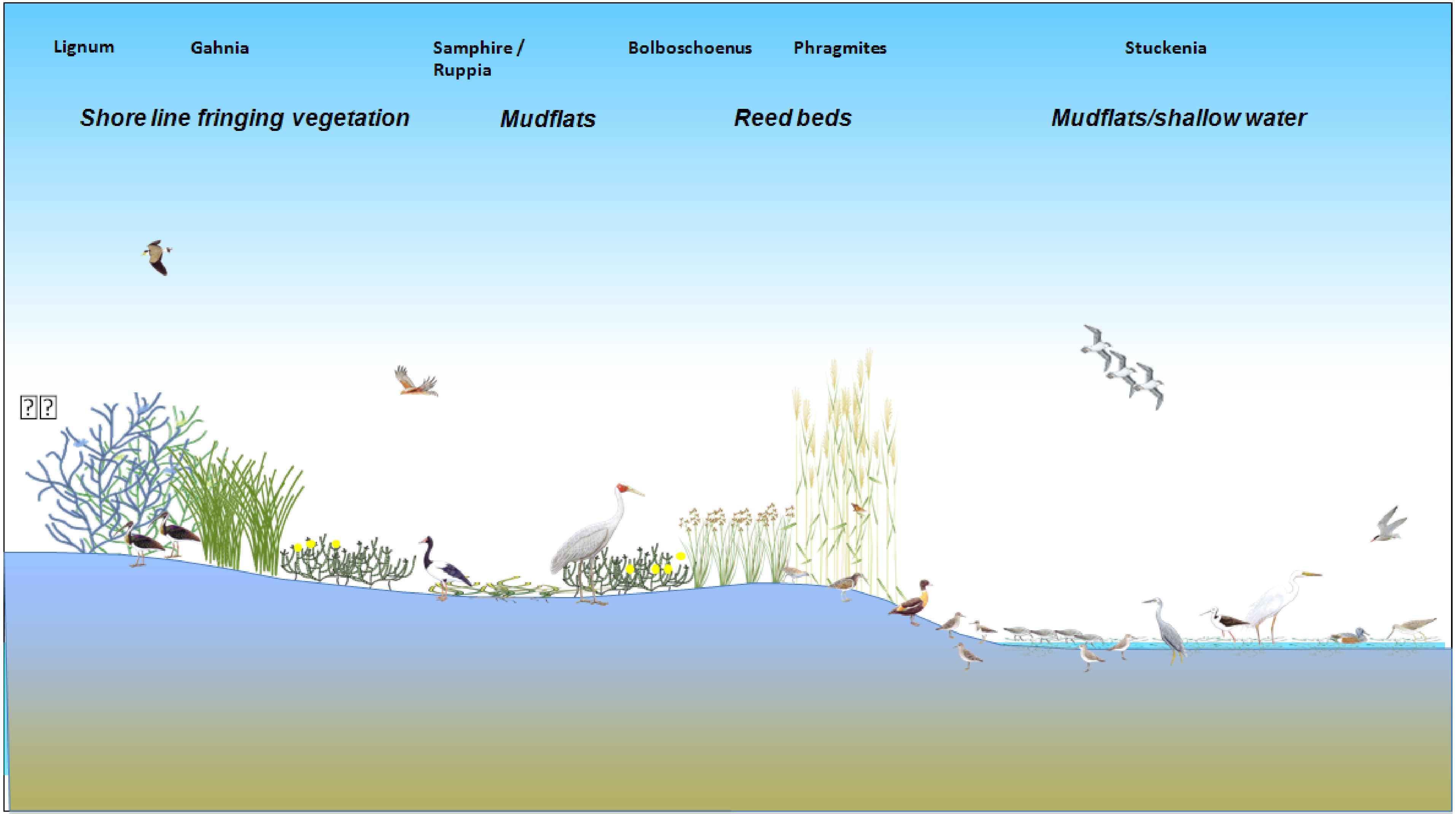
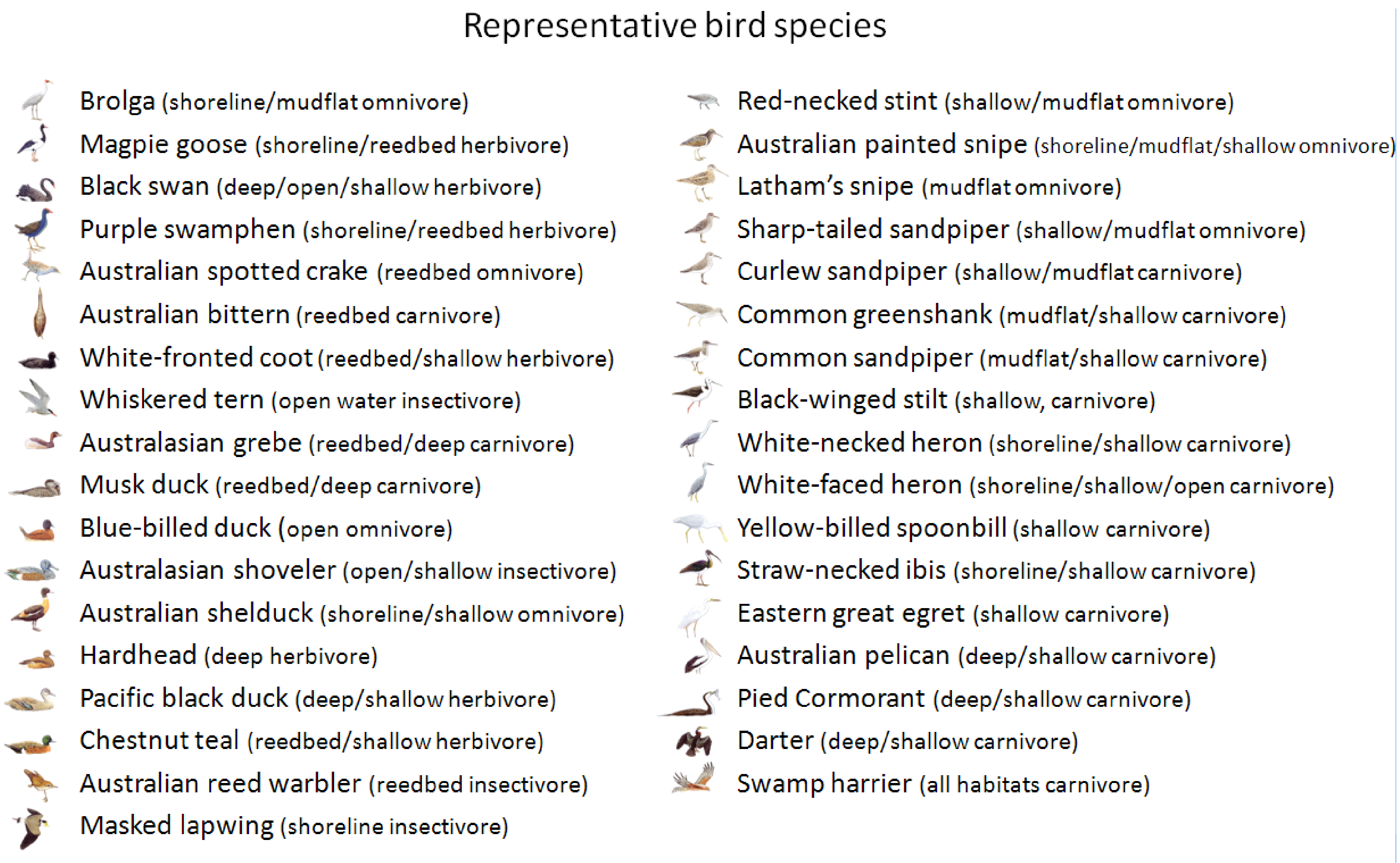


Figure 34: Waterbird Conceptual Model for Hospital Swamps in Late Summer.



Legend for Figures 30 to 33.

3.4.10 Waterbird Ecological and Hydrological Objectives

The complex of wetland elements within Reedy Lake and Hospital Swamps provide a wide variety of habitat types suited to a diverse range of waterbird species and other vertebrate fauna e.g. frogs. These habitat types exist within a range of plant associations, which are intricately linked with particular hydraulic/hydrological environments.

a) Reedy Lake

Within Reedy Lake the existing habitat diversity for waterbirds includes deep and open water, a range of emergent and fringing vegetation types, regions of annual zones of inundation and drying, extensive shallow water (<0.3 m) regions, mudflat areas and saltmarsh. This habitat diversity within Reedy Lake and in turn the diversity and abundance of waterbirds that can use the lake is threatened by habitat simplification brought about by two ecosystem components and processes.

The first is the ongoing spread of a *Phragmites* dominated community across the Lake. A wetland that consists of a dynamically balanced mosaic of emergent fringing marshland (e.g. *Phragmites*, *Bolboschoenus*) and open water habitat types is needed to ensure a diverse and abundant avian community use Reedy Lake. Extensive reed beds are an important component of the lake. But, where these beds spread to the extent that they engulf the existing complexity of open water elements and other habitat types that lie within and along the intricately folded edges, then key elements of habitat complexity are lost. It is the diversity of habitat types and the complexity and extent of interface between the habitat types that is critical in maintaining a diverse fauna community through provision of foraging and breeding habitat. Maintenance of high water levels through summer and into autumn is not a desirable outcome for the Reedy Lake waterbird community because of the increase in extent of *Phragmites* and the reduced lake productivity that would result.

The second involves habitat engineering by an overabundant carp population. These exotic fish, when in high abundance, reduce the variety of plant communities present in the lake, reduce the extent of reed beds, and change the physical and chemical character of the water column. An associated decline in wetland productivity and diversity of habitat can be expected to reduce the diversity and abundance of birds that would use the wetland. Carp control within the wetland requires the wetland to be dried periodically.

Reedy Lake has relatively low bed levels and in most years will retain water over summer, acting as a summer and drought refuge for waterbird populations. Emergent macrophytes will be excluded from these areas, given a typical annual cycle of inundation to over + 0.9 m AHD, providing open water foraging and refuge habitat for waterbirds.

Effective management of the wetland for birds must provide appropriate levers to ensure that a diversity of habitat types is maintained in proportion as a mosaic across the wetland and that carp populations are effectively controlled. The hydrological objectives required to achieve these outcomes may periodically result in a lower abundance and diversity of waterbird species able to utilise the wetland. Over the long-term the benefits to the waterbird community of a productive and diverse wetland outweigh this short-term loss of habitat. Consequently, considering the above and environmental flow requirements for all key waterbird species recorded in the lake, flow related ecological objectives were identified and a list of key hydrological objectives outlined for Reedy Lake (Table 7). These involve annual hydrological events,which provide habitat for resident bird populations, and events which occur three years in five and provide breeding opportunities and habitat for visiting bird species.

Table 7: Waterbird based ecological objectives and hydrological requirements for Reedy Lake.

Hydrological Component	Timing	Ecological Objective
Rising water levels	July to October, annually	Stimulation of bird breeding - Nesting for some waterbirds, including rails, snipe and waterfowl, and Swamp Harriers in inundated reed beds, and for birds requiring waterbodies next to reed beds. Waterbird food supply - foraging along shallow margin for insectivorous guilds with inundation
Bankfull (+0.90 m AHD). Inundation of all wetland habitat types.	September to October, annually	Waterbird food supply and breeding habitat provision Waterfowl, piscivorous and herbivorous waterbird foraging while inundated Nesting habitat for colonial and other waterbirds in inundated reed bed, and for birds requiring broad waterbodies and deep water next to reed beds
Overbank flows (>+0.90 m AHD)	July to December for a brief period at least once a year, three years in five	Flooding of Lignum and samphire communities for waterbird and terrestrial avian species foraging habitat
Deep water (minimum depth greater than 0.6 m).	All year, three years in five	Waterbird summer and drought refuge. Waterbird refuge from predators Breeding habitat for medium and long-term breeding species Specialist waterbird species habitat requirements and food supply - diving and open water surface feeding carnivorous, piscivorous and herbivorous bird foraging
Gradual recession of water level to expose mudflats and submerged and emergent vegetation communities.	November to May, three years in five	Waterbird food supply. Foraging • on tubers and other vegetation on exposed and shallowly inundated wetland floor; • on exposed wetland fringe and in shallows (less than 30 cm) for a many shorebird species and other waterbird species from all guilds; and • increased foraging success for piscivores in shallow habitat.

b) Hospital Swamps

Within Hospital Swamps the existing habitat diversity for waterbirds includes transient regions of open water, a range of emergent and fringing vegetation types, regions of annual zones of inundation and drying, shallow water (<0.3 m) regions, mudflat areas and saltmarsh.

The extent and diversity of vegetation and habitat types within Hospital Swamps has been relatively stable in the medium term providing foraging habitat for an abundant and diverse waterbird community.

Ongoing maintenance of habitat type diversity, through ongoing provision of the annual water level cycle that has achieved this outcome, is necessary to support the existing diverse waterbird community in Hospital Swamps. The drying of Hospital Swamps in late summer or early autumn is important in maintaining wetland health and appears to be a key prerequisite in order for some waterbird species to breed on a wetland.

Given the above considerations and using the environmental flow requirements for all key waterbird species previous defined, waterbird flow related ecological objectives were identified and a list of key hydrological objectives outlined for Hospital Swamps (Table 8). All hydrological stages are required annually.

The potential for an increase in storm water inflow via drains into Armstrong Creek from developments to the south west of Hospital Swamps has implications for the swamps ecology. If the patterns of inflow are similar to the patterns of inundation from the Barwon River – i.e. inflows are small or non-existent over summer and autumn – then the swamps can be expected to continue in an annual wet/dry cycle. Assuming that the water quality is good, the implications of this continued pattern are considered minor for waterbirds.

Should summer storm water inflows be sufficient to remove the annual drying and salinisation of the swamps, then marked changes and probably simplification of the vegetation communities across the wetlands can be anticipated, with a concomitant reduction in waterbird community diversity.

Table 8: Waterbird based ecological objectives and hydrological requirements for Hospital Swamps.

Hydrological Component	Timing	Ecological Objective
Rising water levels	July to October, annually.	Stimulation of bird breeding - Nesting for some waterbirds, including rails, snipe and waterfowl, and Swamp Harriers in inundated reed beds, and for birds requiring waterbodies next to reed beds. Waterbird food supply – release of carbon and nutrients as a basis of a productive food web. Provision of foraging habitat with inundation along shallow wetland margins for insectivorous guilds.
Bankfull (+ 0.5 m AHD). Inundation of all wetland habitat types	August to October, annually.	Waterbird food supply and breeding habitat provision. Waterfowl, piscivorous and herbivorous waterbird foraging while inundated. Nesting habitat for colonial and other waterbirds in inundated reed bed, and for birds requiring broad waterbodies and deeper water next to reed beds.
Freshes raise water level to +0.70 m AHD	September to October, annually.	Inundation of higher silled shallow wetlands for waterbird and terrestrial avian species foraging habitat
Gradual recession of water level to expose mudflats and submerged and emergent vegetation communities	November to February/March, annually.	Waterbird food supply. Foraging: • on tubers and other vegetation on exposed and shallowly inundated wetland floor; • on exposed wetland fringe and in shallows (less than 30 cm) for a many shorebird species and other waterbird species from all guilds; and • increased foraging success for piscivores in shallow habitat.
Dry	March/April to June, annually.	Maintenance of wetland character – Important for some waterbird species that wetlands undergo an annual wet dry cycle. Waterbird food supply. Foraging: • on tubers and other vegetation on exposed and shallowly inundated wetland floor; • on mudflats for a diversity of shorebird and other waterbird species from all guilds; and • for piscivores and carnivores on exposed fish community.

3.5 Fish

Fish of the Lower Barwon wetlands and estuary complex are diverse and an important ecological component of the system. At least 48 species have been recorded within the freshwater and estuarine sections of the Barwon system overall (Tunbridge 1988; DCNR 1995; DSE Fauna Database accessed Feb 2005). The Lower Barwon wetlands and estuary complex itself has 34 native species present (Table 9). Reedy Lake has 16 native species; Hospital Swamps has 19 native species recorded whereas 31 native fish species are found in Lake Connewarre (estuary; Tunbridge 1988; DCNR 1995; Zampatti & Grgat 2000; Raadik, T. 2000; NRE 2001; Zampatti & Koster 2002; Dahlhaus et al. 2007; DSE Fauna Database accessed Feb 2011). These fish can be divided into six categories based on their estuary use (Lloyd et al. 2010, Table 3 and section 7.3.1).

There are eight exotic species (introduced from outside Australia) also present in the system. These fish include eastern gambusia, carp and goldfish which are distributed worldwide. Other significant exotic species present, which along with eastern gambusia are known to be effective fish predators, are redfin perch, rainbow trout and brown trout. Native fish suffer significant predation pressure from these exotic fish (Zaret 1980, Fletcher 1986, Lloyd 1987).

Table 9. Known or likely locations of freshwater fish found in the Lower Barwon wetlands (Tunbridge 1988; DCNR 1995; Zampatti & Grgat 2000; Raadik, T. 2000; NRE 2001; Zampatti & Koster 2002; Dahlhaus et al. 2007; DSE Fauna Database accessed Feb 2011).

Classification	Common Name	Scientific Name	Reedy Lake	Hospital Swamps	Estuary Complex (Lake Connewarre)
Native Fish					
Estuarine Resident	Blue spot goby	*Pseudogobius olorum*	√	√	√
	Black bream	*Acanthopagrus butcheri*			√
Estuarine Dependent (Marine Derived – Anadromous)	Tupong	*Pseudaphrits urvilli*	o	o	√
	Small-mouthed hardyhead	*Atherinosoma microstoma*	√	√	√
	Pouched lamprey	*Geotria australiis*			√
	Short-headed lamprey	*Mordacia mordax*			√
	King George whiting	*Sillaginodes punctata*			√
Estuarine Dependent (Freshwater Derived – Catadromous)	Common jollytail	*Galaxias maculatus*	√	√	√
	Spotted galaxias	*Galaxias truttaceus*	√	√	√
	Broad-finned galaxias	*Galaxias brevipinnis*	√	√	√
	Short finned eel	*Anguilla australis*	√	√	√
	Australian grayling	*Prototroctes maraena*	√	o	√
	Estuary perch	*Macquaria colonorum*			√

Classification	Common Name	Scientific Name	Reedy Lake	Hospital Swamps	Estuary Complex (Lake Connewarre)
Estuarine Opportunists (Marine Derived)	Yellow-eyed mullet	*Aldrechetta forsteri*	√	o	√
	Flat-tailed mullet	*Liza argentea*	o	o	√
	Sea mullet	*Mugil cephalus*	o	o	√
	Bridled goby	*Arenigobius bifrenatus*		√	√
	Lagoon goby	*Tasmanogobius lasti*		o	√
	Tamar goby	*Afurcagobius tamarensis*		o	√
	Greenback flounder	*Rhombosolea tapirina*			√
	Longsnout flounder	*Ammotretis rostratus*			√
	Kingfish	*Argyrosomus japonicus*			√
	Australian ruff	*Arripis georgianus*			√
	Australian salmon	*Arripis trutta*			√
	Luderick	*Girella tricuspidata*			√
	Cobbler	*Gymnapistes marmoratus*			√
	Sandy sprat	*Hyperlophus vittatus*			√
	Bluefish	*Pomatomus saltatrix*			√
	Smooth toadfish	*Tetractenos glaber*			√
Estuarine Opportunists (Freshwater Derived)	Big-headed gudgeon	*Philypnodon grandiceps*	√	√	√
	Australian smelt	*Retropinna semoni*	√	√	√
Freshwater	Dwarf galaxias	*Galaxiella pusilla*	o	o	
	Southern pygmy perch	*Nannoperca australis*	√	√	
	Yarra pygmy perch	*Edelia obscura*	√	√	
Exotic Fish					
Estuarine Opportunists (Freshwater Derived)	Eastern gambusia	*Gambusia holbrooki*	√	√	√
	Goldfish	*Carassius auratus*	√	√	√
	Redfin perch	*Perca fluviatilis*	o	o	√
	Brown trout	*Salmo trutta*			√
	Rainbow trout	*Oncorhynchus mykiss*			o
	Carp	*Cyprinus carpio*	√	√	√
	Roach	*Rutilus rutilus*	o	o	o
	Tench	*Tinca tinca*	o	o	√

○ Expected in this site; √ Recorded in this site

Fish diversity is high in the estuarine complex with freshwater species, naturally euryhaline species and marine species all co-existing. The Australian grayling (*Prototroctes maraena*) is listed under both Victorian (FFG 1988) and Australian Government (EPBC 1999) Acts as a threatened species, but there is a significant breeding population in this reach of Barwon River system. Other significant species include dwarf galaxias (*Galaxiella pusilla*) and Yarra pygmy perch (*Edelia obscura*) are also listed under Victorian (DSE Advisory Listing) and/or Victorian (FFG 1988) and Australian Government (EPBC 1999) legislation (Table 10).

Table 10: Conservation status of significant native fish species found in the estuary complex.

Species	Significance		
	FFG	DSE	EPBC
Australian grayling	√	Vulnerable	Vulnerable
Dwarf galaxias	√	Near Threatened	Vulnerable
Yarra pygmy perch	√	Near Threatened	Vulnerable

3.5.1 Fish Assemblages

The fish within the Lower Barwon Wetlands and its estuary can be divided into six groups according to their biology, distribution and how they utilise the estuarine zone (Figure 35). These groups include some species which live solely within freshwater or the estuary or in both, migrating between these habitats and the sea:

- Freshwater;
- Estuarine Opportunists (Freshwater derived);
- Estuarine Dependent (Freshwater derived);
- Estuarine Residents;
- Estuarine Dependent (Marine derived); and
- Estuarine Opportunists (Marine derived).

Estuarine Residents are a range of estuarine specialised fish which utilise the abundant resources of the estuary and complete their entire life cycle in the estuary complex. They may penetrate upstream into freshwater which they can tolerate for some time. The blue spot goby is the only estuarine resident present within Reedy Lake and Hospital Swamps as they have wide salinity tolerances and are wetland specialists. Black bream are present in the estuary proper, where it is generally more saline.

Estuarine Dependent species are those fish which are dependent upon the estuary for spawning, as a nursery ground for their young, or for shelter and/or feeding. These species depend upon the estuary for one part of their life cycle. These fish are derived from either freshwater (catadromous) or marine (anadromous) ecosystems.

Marine derived fish (some are Anadromous) are estuarine dependent species which mostly live in the sea but migrate into the estuary to breed or for recruitment. Tupong and Small mouth Hardyheads, both marine-derived estuary dependent species, are present within both sites.

Freshwater derived (Catadromous) fish are those species which mostly live in freshwater, and which migrate downstream to breed in the estuary (e.g. Australian grayling and common, spotted and climbing galaxiids) or in the sea (*Anguilla australis*) and then return upstream.

Estuarine Opportunists are fish which live primarily in either marine or freshwater environments but opportunistically exploit the resources of the estuary. They are present within the two sites on a regular basis. These fish visit Reedy Lake and Hospital Swamps opportunistically to access food, shed parasites, and/or avoid unfavourable environments. These species are not likely to have a specific dependence on the water regime of these wetlands but may do better under some regimes than others.

Freshwater fish generally only inhabit freshwaters and would be resident solely within the wetlands and the adjacent Barwon River. They would rarely venture into Lake Connewarre except during very wet periods when the Lake was predominately freshwater. These fish include the wetland specialist species Yarra and southern pygmy perch and the equally wetland species dwarf galaxias. These species also share a strong dependence upon dense aquatic vegetation beds.

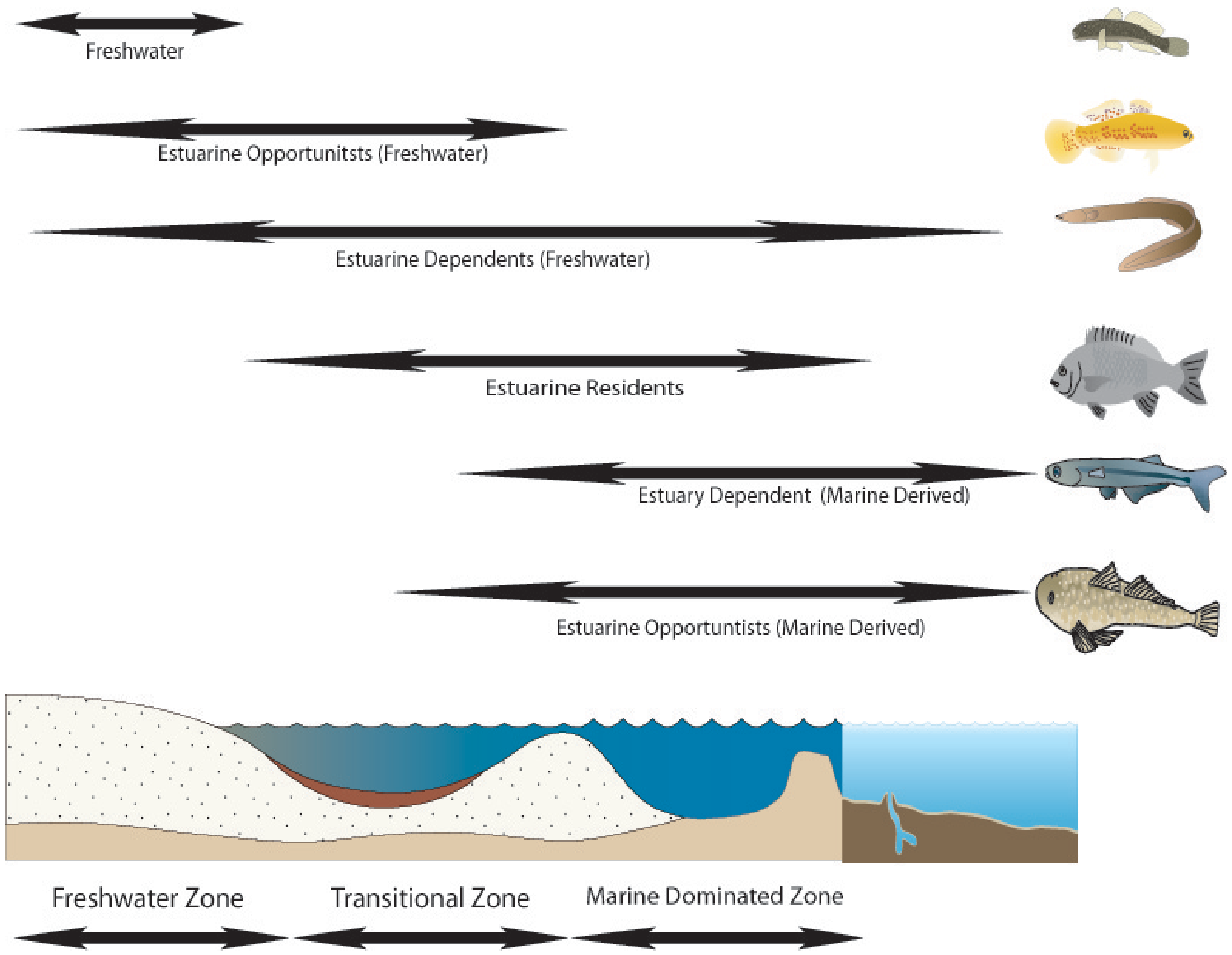


Figure 35: Classification of Fish in the Lower Barwon Wetlands and Estuary (after Lloyd et al 2010).

3.5.2 Fish in Reedy Lake

Reedy Lake is a freshwater wetland connected to the Barwon River (in high flows) and contains diverse aquatic habitats supporting 16 native species in the six estuary use categories. These habitats include open water, reed beds, and submerged aquatic plant beds. The lake has had a semi-permanent water regime in the past, with long periods of inundation. Freshwater derived fish are more dominant at this site (Table 11).

Table 11: Fish present within Reedy Lake (DSE Fauna Database accessed 2011).

Classification	Common Name
Estuarine Resident	Blue spot goby
Estuarine Dependent (Marine Derived – Anadromous)	Tupong
	Small-mouthed hardyhead
Estuarine Dependent (Freshwater Derived – Catadromous)	Common galaxias
	Spotted galaxias
	Broad-finned galaxias
	Short finned eel
	Australian grayling
Estuarine Opportunists (Marine Derived)	Yellow-eyed mullet
	Flat-tailed mullet
	Sea mullet
Estuarine Opportunists (Freshwater Derived)	Flat-headed gudgeon
	Australian smelt
Freshwater	Dwarf galaxias
	Southern pygmy perch
	Yarra pygmy perch

3.5.3 Fish in Hospital Swamps

Hospital Swamps is a brackish to saline wetland intermittently connected to the Barwon River and contains diverse aquatic habitats supporting 19 native species in the six estuary use categories. These habitats include open water, reed beds, and submerged aquatic plant beds. The swamp has a temporary water regime with some semi-permanent areas. The site supports a range of species but the marine derived fish are more dominant (Table 12).

Table 12: Fish present within Hospital Swamps (DSE Fauna Database accessed 2011).

Classification	Common Name
Estuarine Resident	Blue spot goby
Estuarine Dependent (Marine Derived – Anadromous)	Tupong
	Small-mouthed hardyhead
Estuarine Dependent (Freshwater Derived – Catadromous)	Common galaxias
	Spotted galaxias
	Broad-finned galaxias
	Short finned eel
	Australian grayling
Estuarine Opportunists (Marine Derived)	Yellow-eyed mullet
	Flat-tailed mullet
	Sea mullet
	Bridled goby
	Lagoon goby
	Tamar goby
Estuarine Opportunists (Freshwater Derived)	Flat-headed gudgeon
	Australian smelt
Freshwater	Dwarf galaxias
	Southern pygmy perch
	Yarra pygmy perch

3.5.4 Fish Conceptual Models

a) Representative Objective – Common Jollytail (Galaxias maculatus) - Estuarine Dependent (Freshwater Derived)

Common jollytails are a widespread and often abundant species in Australia found in coastal lakes and streams at low altitudes from Adelaide in the west to Southern Queensland in the east (McDowall and Fulton 1996). They are also present in New Zealand and South America having a Gondwanian distribution. They are a significant species in the ecosystem as a food source for other fish and birds and are a significant invertebrate predator (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984). Figure 36 shows the conceptual model for the common jollytail.

Habitat

Common jollytails are able to utilise a wide range of habitats and have a preference for still or slow moving waters. They are capable of withstanding freshwater to very high salinities (well above that of sea water.) They are known to also occur in landlocked populations (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984).

Movement

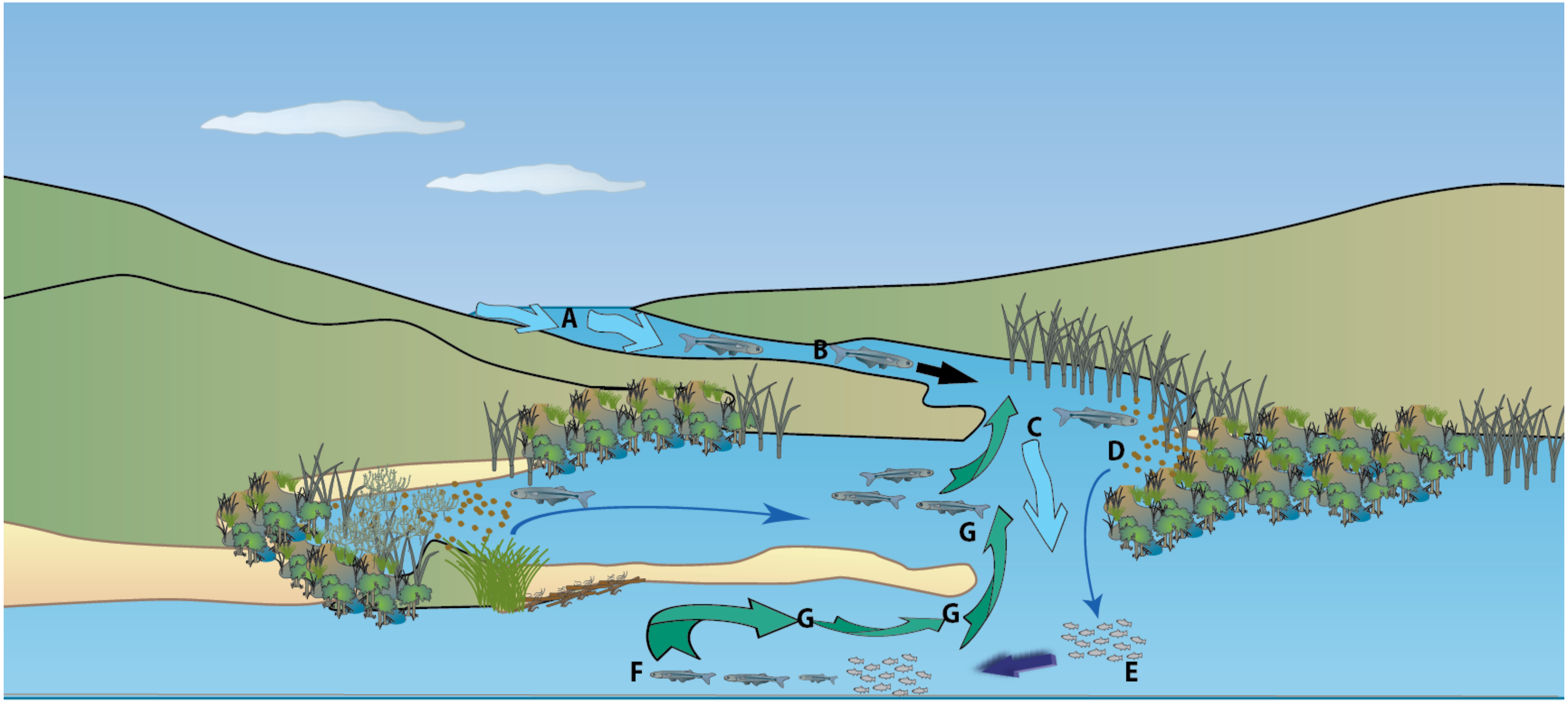
In autumn adults move downstream to the estuary to spawn on a full or new moon and a high spring tide. The eggs hatch and the small, slender larvae are washed out to sea. The juveniles spend winter at sea and return to freshwater about five to six months later (Treadwell and Hardwick 2003; McDowall and Fulton 1996).

Reproduction

Common jollytails spawn amongst vegetation (grasses, samphire and other low vegetation) around river estuaries when under water at high tide. Most adults die after spawning. The eggs remain out of water for two weeks or more until the next spring tides, the eggs hatch on being re-inundated and the larvae migrate (or are washed out) to sea (McDowall and Fulton 1996). Eggs can tolerate and hatch in salinities ranging from fresh to seawater (Cadwallader & Backhouse 1983).

Ecological flow relationships derived from the conceptual model for common jollytail:

- provide flows to allow longitudinal connection in the channel for adult jollytail movement down to the estuary in January to March;
- provide flows to maintain open river mouth to allow downstream migration of larvae in autumn;
- provide flows to maintain open river mouth to allow juveniles to migrate upstream from sea between July and December; and
- provide flow freshes to inundate vegetation beds and instream benches to stimulate invertebrate production for fish condition.



A Freshwater flows provides longitudinal connection for common jollytail to move down to the estuary from freshwater habitats in January to March **B** Larger flows to maintain the river mouth to open **C.** Common jollytail lay their eggs in samphire and wetlands in estuary **D.** Common jollytail larvae hatch & are washed out to sea **E** by flows through the mouth in autumn to mature **F** before returning to the estuary in July to December **G**

Figure 36: Conceptual model for the common jollytail.

b) Representative Objective – Yarra Pygmy Perch (Edelia obscura) - Estuarine Dependent (Freshwater Derived)

Yarra pygmy perch (*Edelia obscura*) have a restricted distribution across southern Victoria (west of Melbourne) and in the South East of South Australia. They are a wetland specialist species and while they are generally rare, individual populations can grow quite large in the right conditions (Allen et al. 2002; Treadwell and Hardwick 2003). To a large extent, the information here also covers the life history and requirements of the southern pygmy perch which is generally more widespread. Both species are present at both Reedy Lake and Hospital Swamps. Figure 37 shows the conceptual model for the Yarra pygmy perch.

Habitat

Yarra pygmy perch are wetland specialist species, preferring slow moving and still waters which are heavily vegetated. Submerged aquatic vegetation is a critical habitat for these species required in spawning, feeding and protection for the species. They are restricted to relatively freshwater and are not known saline or estuarine habitats (Allen et al. 2002; Treadwell and Hardwick 2003).

Movement

These species do not undergo any long distance movements for reproduction or other purpose but would move in their local environment to optimise habitat and feeding opportunities. In summer, these fish would seek to move out from a drying wetland to seek refuge in permanent habitats (Allen et al. 2002; Treadwell and Hardwick 2003).

Reproduction

These fish have very low fecundity (small numbers of eggs are produced by each female) and the eggs are small and non-adhesive demersal eggs with short incubation times. Pygmy perch live a maximum of five years but are mature after their first year. Breeding is in spring (generally September to October) and eggs are laid amongst aquatic vegetation. Their eggs hatch rapidly after 2 – 4 days.

Ecological flow relationships derived from the conceptual model for Yarra pygmy perch:

- provide a water regime which results in water level rises in spring to inundate vegetation beds and shallow margins of the wetland benches to stimulate invertebrate production for fish condition;
- these flows or water level rises will also trigger spawning and subsequently allow recruitment (survival of larvae to juvenile fish);
- the water regime must support the growth of dense submerged aquatic vegetation (see vegetation section); and
- summer refuge is critical, so either some areas should retain water over summer or flows/water levels are such to allow movement into the nearby Barwon River or other wetlands.

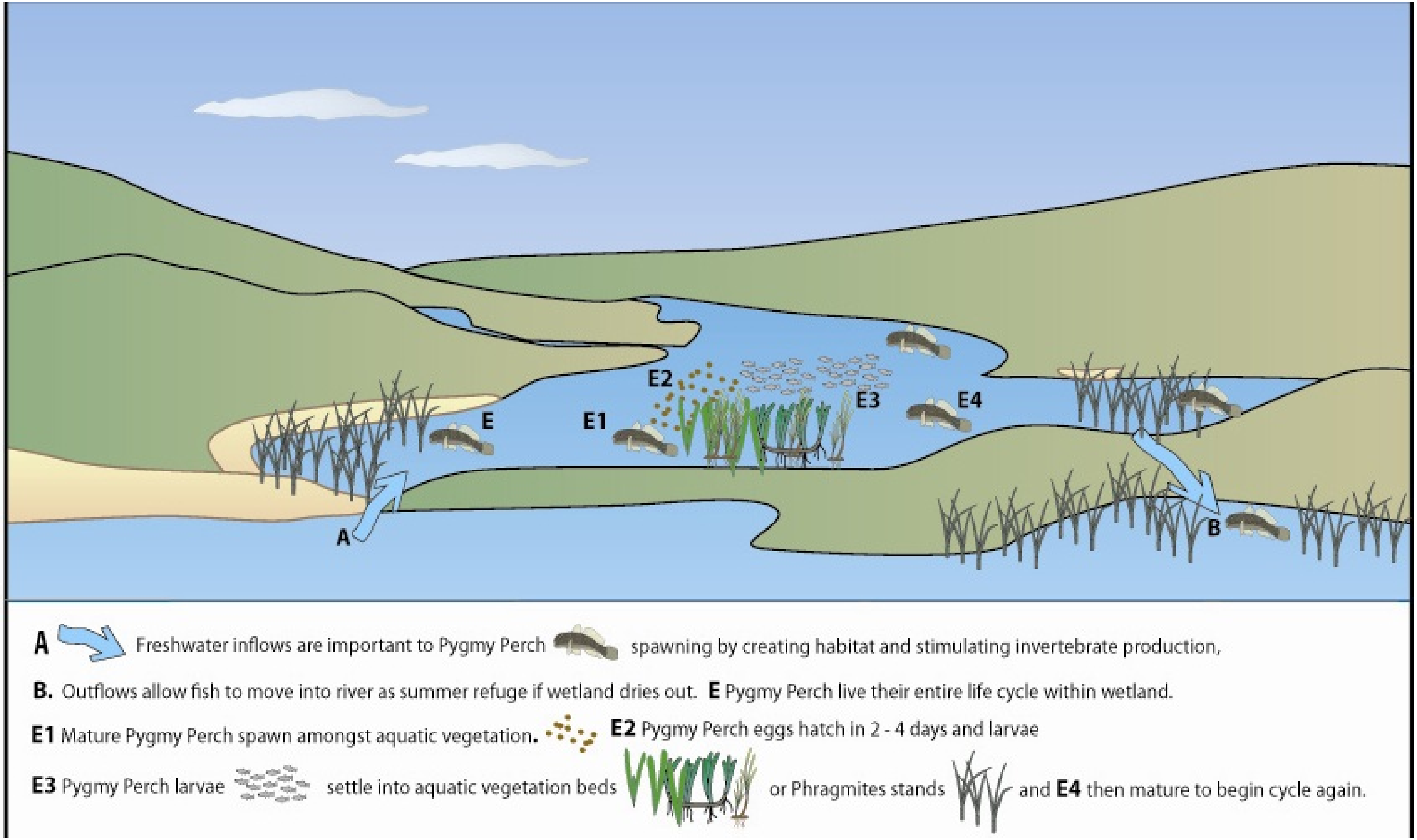


Figure 37: Conceptual model for the Yarra pygmy perch.

3.5.5 Ecological Objectives for Fish

Fish of the lower Barwon wetlands have specific habitat requirements but generally they are robust and tolerant to a broad salinity range (Koehn & O'Connor 1990, Lloyd & Balla 1986, Lloyd 1987, Lloyd 2000, McDowall 1980). Some species have quite specific flow and salinity conditions for breeding, whereas other species require healthy and extensive vegetation beds to provide cover as well as feeding and breeding habitat.

Many of these fish species will require the opportunity to migrate upstream and downstream to either complete their life-cycle or to find suitable habitats. Instream barriers such as drop-structures, road crossings, piped sections, weirs, erosion control structures, and zones of very poor habitat can all prevent fish being able to move within the system. This increases the likelihood of local extinctions of species.

In determining the environmental flow for an estuary, it is important to consider its fish community and the life history of key species, together with other organisms. These key characteristics include the life span, spawning season, incubation, duration, migration, and habitat requirements (Table 13).

Table 13: Ecological requirements of key fish species from the Lower Barwon Wetlands (Fish Categorisation shown by colours - Blue = Estuarine Resident; Green = Estuarine Dependent (Marine Derived – Anadromous); Orange = Estuarine Dependent (Freshwater Derived – Catadromous); Purple = Estuarine Opportunists (Freshwater Derived); and Brown = Freshwater).

Fish Species		**Life Span**	**Spawning Season**	**Incubation Duration***	**Migration**	**Other**
Common Name	**Scientific Name**					
Western Blue-spot Goby	*Psuedogobius olorum*	2-3 years	Oct - Jan	4 days	Local only	Need hollow in log or burrow under rock or wood as a substrate for laying eggs
Black Bream	*Acanthopagrus butcheri*	29 years	Nov – Jan	2 days	Between sea and estuary	Breeding in estuary at specific salinities. Tend to inhabit areas where rocky river beds, snags or structures provide cover but can be found in open waters over sand or mud substrates. Larvae and small juveniles require seagrass beds in shallow estuarine waters
Smallmouth Hardyhead	*Atherinosoma microstoma*	1 year	Sept - Feb	4-7 days	Local only	Breeding probably occurs in estuary or lower reaches of rivers
Tupong (Congolli)	*Pseudaphritis urvillii*	>5years	Sept - Dec	Unknown (likely to be short - 3 or so days)	Adults migrate downstream to estuary for breeding April to July. Juveniles migrate upstream Oct – Feb	Tupong are susceptible to impacts from the presence of water flow barriers. Tupong spawn at river mouth downstream of the Lower Barwon Wetlands, stimulate by riverine flows or drawdown of wetlands. Larval tupong would colonise the Wetlands as part of their upstream migration.
Australian Grayling	*Prototroctes maraena*	Males 1-2 years Females 2-3 years	Feb - May	14-21 days in freshwater <2ppt	Larvae washed to sea – May – July Juveniles migrate from sea upstream Oct - Dec	Demersal non-adhesive eggs Fry slender and buoyant Spawning occurs after high flow – full moon to last quarter Eggs develop in slow water to 5m deep Juveniles spend May to Oct in estuary Need high O_2 The species can swim up riffles at flow of 2-4m/s sustained swimming 0.6m/sec Prefer 0.2 to 0.35 m/sec

Fish Species		Life Span	Spawning Season	Incubation Duration*	Migration	Other
Common Name	**Scientific Name**					
Common Galaxias	*Galaxias maculatus*	2-3 years	April -June	Normally take 10-16 days between flow events or tides (in estuary)	Downstream to estuary in Autumn. Upstream migration Sept to Dec.	Aquatic/riparian/intertidal macrophytes required as a substrates for laying eggs
Climbing Galaxias	*Galaxias brevipinnis*	2-4 years (Uncertain)	May-June	Unknown – perhaps 5-7 days (same as *G. olidus*)	Larvae are washed downstream to the sea in Winter. Juveniles return upstream in spring and early summer.	Prefer rocky streams with flowing water and good riparian vegetation however have are also found in habitats with silt substrates
Spotted Galaxias	*Galaxias truttaceus*	2-4 years (Uncertain)	May-June	28 days at 12 degrees	Downstream to estuary in Autumn & Winter. Larvae swept to sea Juveniles return from sea upstream in spring and early summer (Oct – Jan)	LWD, undercut banks, boulders and good riparian vegetation however have are also found in habitats with silt substrates Pools are also used extensively Highly salt tolerant and occurs in turbid water – probably very tolerant of poor WQ. Can swim at 3.3m/sec for 1 hour – prefer 0.2m/sec
Short-finned Eel	*Anguilla australis*	32 years	June - Mar	Unknown as it occurs in the marine environment	Adults migrate to sea during summer and autumn and elvers return into estuaries from	Flow requirements really need to consider preservation of adult habitat – rivers and lakes. Breeding is cued by non-flow factors and occurs at sea

Fish Species		Life Span	Spawning Season	Incubation Duration*	Migration	Other
Common Name	**Scientific Name**					
					Jan – Feb and migrate upstream in subsequent years	
Australian Smelt	*Retropinna semoni*	1-2 years	Sept - Nov	9-10 days	Local only	Aquatic vegetation required as a substrate for laying eggs
Flathead Gudgeon	*Philypnodon grandiceps*	4-7 years	Oct - Feb	4-6 days	Local	Hard surfaces required as a substrate for laying eggs
Eastern Dwarf Galaxias	*Galaxiella pusilla*	1 year	Aug – Oct	10-17 days	Local	Frequently associated with aquatic vegetation and eggs are laid in separate batches on flooded vegetation, leaf litter or rocks – preferred egg site is the underside of leaves or stems Adults probably die after spawning May use yabby holes to over summer
Southern Pygmy Perch	*Nannoperca australis*	2-5yrs	Sept – Nov	2-4 days	Local	Aquatic plants for spawning and habitat Vegetation or rocks instream habitat required
Yarra Pygmy Perch	*Edelia obscura*	2-5yrs#	Sept – Oct	2-4 days#	Local	Aquatic plants for spawning and habitat Vegetation or rocks instream habitat required

* Time that eggs take to develop into larvae (eggs require inundation at least for this period)

\# Information based on requirements assuming these are similar to Southern Pygmy Perch (*Nannoperca australis*)

a) Reedy Lake

Freshwater derived fish are more dominant at Reedy Lake but several species which are also estuarine dependent are present. The fish are important for their conservation value, value in fisheries (eels) and as food for waterbirds. Many of the fish species require, or utilise, aquatic vegetation beds as critical habitat. The water regime these fish require needs to support aquatic vegetation and open water habitats as well at key stages of their biology such as feeding and growth, spawning of eggs and recruitment of juveniles. The lake has had a semi-permanent water regime in the past with long periods of inundation which has proved ideal for the species present.

Rising water levels in spring are critical as these create habitat and boost invertebrate populations for feeding, triggering spawning and allowing food resources to enhance recruitment of juveniles. Preferably this should occur in all years but at least 3 in 5 years to allow recruitment of short lived species on site (Table 13). Deep water in late spring allows creation of open water habitat required for some species and provides time for growth and maturation. Gradual recession of water level to expose shallow mudflats and vegetation communities is important to reset the system and create conditions and habitats for subsequent seasons.

The species require summer refuge or access out of the Lake. This can be provided through fishways or strategic management of the regulators to allow fish passage. Inflows, bankfull and overbank flows provide opportunities for fish migration into and out of the Lake which is critical in those periods of very low water levels or when the Lake is dried out. Recession of water level to expose entire wetland bed will restart wetland processes, allow eggbanks to be produced and laid and control carp populations. This is proposed to occur no more than once in five years, which is necessary to reduce the size of individual carp present and prevent carp populations dominating the system. The rate of recession needs to be adequate (i.e. not too fast) to provide cues for native fish to leave the Lake and then allow access to suitable habitats in the Barwon River or other nearby wetlands. More frequent drying will limit the populations of the important freshwater, aquatic vegetation dependent species (Table 14).

Table 14: Fish based ecological objectives and hydrological requirements for Reedy Lake.

Hydrological Component	Timing	Ecological Objective
Rising water levels	July to Sept, all years	• Water level peak in spring • Create habitat and invertebrate populations • Trigger spawning
Bankfull (+0.90 m AHD). Inundation of all wetland habitat types	October to November, two years in five October, All years	• Create open water habitat • Create wide range of habitats for different fish species • Allow recruitment • Provide time for growth and maturation of small-bodied fish species • Provide overflow water for fishway to operate
Overbank flows (>+0.90 m AHD)	July to December for a brief period at least once a year, three years in five	• Results in inundation of higher silled shallow wetlands which: o to create additional fish habitat and invertebrate populations o trigger spawning o provide connecting flows to the river and between wetlands
Gradual recession of water level to expose mudflats and submerged and emergent vegetation communities	December to May, two years in five November to May, two years in five	• Restart wetland processes • Allow eggbanks to be produced and laid • Provide summer refuge for smaller fish species • Create open water habitat upon refilling
Stable, low water levels in winter	May to July, four years in five	• Provide permanent fish habitat in most years but also allows margins to dry out In drying margins: • Restart wetland processes • Allow eggbanks to be produced and laid • Control carp populations
Recession of water level to expose entire wetland bed by March	November to February, one year in five	• Restart wetland processes • Allow eggbanks to be produced and laid • Control carp populations
Wetland bed dry	March to May, one year in five	• Allow nutrient re-cycling • Allow terrestrial or mudflat plants to create organic matter for habitat and processing on spring rise • Control carp populations

b) Hospital Swamps

Marine derived and estuarine dependent fish are more dominant in Hospital Swamps, but a range of species are present in this brackish to saline wetland which is intermittently connected to the Barwon River. The swamp has a temporary water regime with some semi-permanent areas.

As for Reedy Lake, rising water levels in Hospital Swamps in spring are also critical to create new habitat and boost invertebrate populations for feeding, triggering spawning and allowing sustained food resources to enhance recruitment of juveniles. Preferably this should occur in all years but at least 3 in 5 years to allow recruitment of short lived species on site (Table 13). Deeper water in late spring allows creation of open water habitat required for some species and provides time for growth and maturation. Gradual recession of water level to expose shallow mudflats and vegetation communities is important to reset the system and create conditions and habitats for subsequent seasons.

Recession of water level to expose entire wetland bed will restart wetland processes, allow eggbanks to be produced and laid and control carp populations. This has occurred annually in the past and this provides for different species to colonise and thrive at this site. It is proposed to maintain this frequency of drying, provided access to and from the Barwon River or other nearby wetlands is maintained (Table 15).

Table 15: Fish based ecological objectives and hydrological requirements for Hospital Swamps.

Hydrological Component	Timing	Ecological Objective
Rising water levels	July to Sept, all years	• Water level peak in spring • Create habitat and invertebrate populations • Trigger spawning • Provide connecting flows to River
Bankfull (+0.50 m AHD). Inundation of all wetland habitat types.	October to November, all years	• Create open water habitat • Create wide range of habitats for different fish species • Allow recruitment • Provide time for growth and maturation of small-bodied fish species • Provide overflow water to allow fish passage
Freshes raise water level to +0.70 m AHD	September to November, at least 3 years in 5	• Results in inundation of higher silled shallow wetlands: o to create additional fish habitat and invertebrate populations o trigger spawning o provide connecting flows to the river and between wetlands
Gradual recession of water level to expose mudflats and submerged and emergent vegetation communities.	December to February/March, all years	• Restart wetland processes • Allow eggbanks to be produced and laid • Provide summer refuge for smaller fish species • Create open water habitat upon refilling
Wetland bed dry.	March/April to June	• Allow nutrient re-cycling • Allow terrestrial or mudflat plants to create organic matter for habitat and processing on spring rise • Control carp populations

4 RECOMMENDED WATER REGIME

4.1 Conservation status of wetlands

Reedy Lake has been recognised as a high conservation wetland since settlement. In 1906 the site was described as being covered by rushes and water lilies during and after flooding, but dying as water disappears (PROV VPRS 5357/2365). The Yugovic (1985) vegetation survey described Reedy Lake as having a particularly rich flora. At this time, the lake featured open water in the central, deep part of the lake and at the eastern, northern and western perimeter of the lake. Large stands and smaller patches of *Phragmites, Typha, Eleocharis sphacelata* and *Bolboschoenus caldwellii* occupied the lake bed with aquatic habitat in and around the reed beds supported abundant semi-emergent aquatic macrophytes including *Myriophyllum* spp., *Potamogeton* spp., *Ruppia maritima* and *Vallisneria gigantea*. The lake supports 90 native plant species (Ecological Associates 2011).

Between 1990 and 1993 there was a rapid change in vegetation with the growth of open water and the loss of reeds in Reedy Lake. However, this trend reversed over the following seven years and reeds increased dramatically in extent (Ian MacLachlan pers comm Geelong Field and Game 2006). A survey in 2010 showed that the extent of reeds has increased from 233 to 352 ha since the Yugovic survey (Ecological Associates 2011). Hospital Swamps supports 82 native plant species including the vulnerable *Muehlenbeckia gunnii.*

Waterbird monitoring since the 1970's shows that both diversity and abundance are high within the Lower Barwon wetlands complex. Comparison between individual wetlands showed marked changes in the diversity and abundance of birds using many of the wetlands both within and between years. Few bird species use all of the wetland types within the complex, with most birds tending to associate with habitat provided by one, two or three of the wetland types. Maintenance of wetland diversity both across the wetland complex and within wetland elements is thus important in providing the range of habitat types necessary to support this varied community. The diversity and populations of birds supported by habitats within Reedy Lake have generally declined, relative to other wetlands in the complex. Such long-term trends are not evident at Hospital Swamps. The contrasting trends for the two closely linked wetlands indicate a change in ecological character in Reedy Lake over the monitoring period. The foraging conditions in Reedy Lake that in the past attracted large populations of waterbirds, particularly waders, have over the last forty years occurred less frequently. The marked decline in avian abundance suggests lower productivity levels in the lake.

The high bird diversity within the wetland complex is reflected in the large number (113) of bird species that merit significant conservation ratings under either federal and/or state legislation, of which 64 are wetland-dependent. Eighty-eight species are listed under the EPBC Act, with Hospital Swamps providing key habitat to the nationally vulnerable Australian painted snipe *Rostratula australis*. Most of the species that use Hospital Swamps and Reedy Lake are listed under international bird agreements such as: CAMBA (31 species); JAMBA (28 species), and RoKAMBA (26 species). Thirty-seven of the species recorded in the Lower Barwon wetland complex merit a significant conservation rating within Victoria – 30 of which are wetland dependent.

Fish of the Lower Barwon wetlands estuary complex are diverse and an important ecological component of the system. Fish diversity is high with Reedy Lake having 16 native species and Hospital Swamps having 19 native species which represent species with freshwater, naturally euryhaline and marine origin all co-existing. The Australian grayling (*Prototroctes maraena*) is listed under both Victorian (FFG 1988) and Australian Government (EPBC 1999) Acts as a threatened species, but there is a significant breeding population in this reach of Barwon River system. Other significant species include dwarf galaxias (*Galaxiella pusilla*) and

Yarra pygmy perch (*Edelia obscura*) are also listed under Victorian (DSE Advisory Listing) and/or Victorian (FFG 1988) and Australian Government (EPBC 1999) legislation.

The vast majority of the fish species prefer either open water or areas of dense submerged aquatic vegetation. The encroachment of reeds into open water or submerged aquatic vegetation habitat will have resulted in a decline of the population of these species and left unchecked, will lead to local extinctions.

4.2 Vegetation Relationships with Flooding and Groundwater

In Reedy Lake and Hospital Swamps the presence and extent of each vegetation type is driven by an interaction between saline groundwater and the lakes flooding regime. Saline groundwater has a strong influence at higher levels on the lakebed where flooding is less persistent and groundwater discharge occurs. This influence is reduced lower on the lakebed where surface water is present for longer, suppresses the groundwater discharge, and provides a shallow zone of low salinity under the lakebed. The seasonal cycle of flooding and then drying and salinisation support a diverse mosaic of seasonally growing macrophytes (Ecological Associates 2011) providing a diverse range of fauna foraging habitats, both when inundated and when drying. Importantly shorter flooding durations and higher salinities at the fringes of the wetlands limit the upward extent of *Phragmites australis* and *Typha domingensis*.

The lower extent of *Phragmites australis* and *Typha domingensis* in Reedy Lake is limited by deep flooding, where the depth exceeds 0.7 m in winter. The ideal depth range for these plant species in Reedy Lake is between this deeper limit and the zone subject to summer salinisation at the fringes (Ecological Associates 2011).

In Reedy Lake, it is likely that the extent of *Phragmites australis* and *Typha domingensis* beds would be reduced if the area within these upper and lower boundaries were minimised. These boundaries are not static. They vary with annual variations in flow in the Barwon River, and with factors that impact on the degree of drying of the lake over summer and autumn.

Hospital Swamps is subject to a strongly seasonal water regime, filling quickly in winter and spring and drying in summer and autumn when inflows from the Barwon River decline. Here shallow water levels prevent significant recharge to the wetland bed and maintain saline soils that are hostile to the establishment of emergent macrophytes. On the northern banks of the main basin a cycling of water into the area with winter inundation to establish a fresh groundwater lens, and a subsequent discharge from the banks in summer, limits the accumulation of salt and promotes the growth of reeds. These two limiting factors tightly confine the extent of *Phragmites australis* and *Typha domingensis* in Hospital Swamps. The diversity of vegetation types and associated fauna habitat is maintained by a complex interaction between freshwater inflows, watertable depth cycles and salinity, movement patterns in freshening groundwater, the extent of overbank flooding, and surface water flows from other sources.

4.3 Comparison to Benchmark Conditions

Since the last modifications to the hydraulics of Reedy Lake in the 1970’s, the salt and water environments have been largely stable, with an increase in water depth and permanence, and a reduction in salinity compared with previous levels. These changes to lake condition have favoured the growth of *Phragmites australis* by increasing the area of the lake that lies within the upper and lower boundaries to growth as described above (Section 4.2; Table 16).

The removal of stock in the early 1980's and the introduction of carp in the 1980's have affected the growth and extent of reeds in the lake. Grazing by stock would have pushed the reedy fringe back from the upper extent as well impacted on a range of other species from trampling, pugging and grazing of vegetative growth, flowers and seeds. The removal of stock would have acted in synergy with the last hydraulic modifications in the 1950's to allow the outer limit of the reed beds to move further up slope in Reedy Lake. The presence of carp pushed the boundary for the lower extent of reeds up higher in the wetland away from the permanent lower limits in deeper water (Ecological Associates 2006). Control of carp since the drying of the lake in 1995/96, and again in 2006, favoured an increase in extent of reed beds through expansion in the opposite direction back towards the lower boundary defined by natural conditions. It is evident that under this ongoing and relatively stable water regime the limiting factors that define the upper and lower extent of the reed beds in Reedy Lake have not yet been reached, and the reed beds are continuing to expand (Ecological Associates 2011). This represents a significant impact that has reduced the extent of other aquatic vegetation types, has degraded associated fauna habitat and decreased the abundance and diversity of fauna recorded in the wetland complex.

Within Reedy Lake the existing habitat diversity for waterbirds includes deep and open water, a range of emergent and fringing vegetation types, regions of annual zones of inundation and drying, extensive shallow water (<0.3 m) regions, mudflat areas and saltmarsh. This habitat diversity within Reedy Lake and in turn the diversity and abundance of waterbirds that can use the lake is threatened by habitat simplification brought about by the ongoing spread of a *Phragmites* dominated community across the Lake and by habitat engineering by an overabundant carp population, both of which have probably resulted in reduced lake productivity.

As a consequence of relative stability in water regime in Hospital Swamps there has been little change in the plant communities and the associated diversity and abundance of fauna using the wetland complex since the 1980's.

Table 16: Ecological changes at Reedy Lake since 1983.

Change from 1983 to 2011	Reason
Reed beds have increased from 233 to 352 ha	The earlier extent of reeds was controlled by grazing that was removed shortly before the 1983 study. Reeds have since increased in the absence of grazing. Reeds have been promoted by works to raise the outlet sill and provide inflows in late spring and summer. Reeds have benefited from the lower lake salinities and shallow flooding during their summer growth period. In the past carp have destabilised reeds and reduced their extent. Two drying events in the past 20 years appear to have controlled carp to a level where they do not significantly degrade reeds.
Aquatic vegetation was extensive in both 1983 and 2011, but has been degraded for periods in between.	Submerged aquatic vegetation was abundant in 1983 and was most likely largely unaffected by grazing because vegetation grew in flooded areas that would not be accessed by stock. Submerged aquatic vegetation declined dramatically in the early 1990s most likely because of an increasing carp population. Vegetation has recovered since drying events have been used to control carp numbers.
The carp population in 1983 and 2011 is probably similar in terms of its impact on vegetation.	Carp were introduced to the Barwon River in 1979 and arrived in Reedy Lake soon after. They were not noted in 1983 as impacting on vegetation. Carp were present in 2011 but were not noted as impacting on vegetation. Carp have the potential to increase in abundance and impact dramatically on vegetation.
Lake surface water and soil water salinity in 1983 and 2011 is probably similar.	The hydraulics of Reedy Lake were last changed significantly in the 1950s when the outlet sill was raised and an outlet channel was constructed. It is most likely that the overall salinity environment had reached a steady state by the time of the 1983 survey and that this has continued to 2011. The removal of grazing prior to 1983 allowed reeds to benefit in subsequent years from a salinity environment that was most likely already in place.

4.4 Management and Ecological Objective for Reedy Lake

The Steering Committee and Scientific Panel reviewed the available information and decided the most appropriate objective for Reedy Lake was:

> **To achieve the extent and proportions of plant communities mapped in 1983 within a reasonable (say 20%) variation.**

This objective seeks to maintain the diversity and populations of waterbirds, fish and other fauna dependent upon the site and its plant communities. Achieving this implies a specific water regime is required.

4.4.1 Desired Water Regime for Reedy Lakes

A balance between the marshland, reed bed and sedgeland components of Reedy Lake is important to the value of the wetland for aquatic fauna. While all three components contribute to the habitat requirements of various birds and fishes, the excess growth of one component threatens the habitat value of the lake as a whole. The extent of reeds and open water in 1983 is considered more appropriate to promote the fish and waterbird breeding and feeding potential of the lake than the current extent.

A decrease in the current extent of *Phragmites australis* from the current extent to the 1983 extent (a reduction of 33%) could be achieved by a change in the salinity and surface flooding regimes of Reedy Lake. At present the lake provides ideal habitat for reed beds. *Phragmites australis* is very tolerant of variation in salt and flooding conditions and, without dramatic intervention, responses to management could only be expected over the long term (in the order of decades).

Reed beds could be suppressed by targeting the components of the current water regime that favour *Phragmites australis* and suppress other plant species. The critical component of the water regime in this respect is shallow summer flooding, which supports *Phragmites australis* by supporting stems through buoyancy, providing moisture for growth and reducing soil salinities. A water regime that achieved a maximum depth in spring and exposed most of the wetland bed in early summer would favour seasonally growing submerged macrophytes and emergent macrophytes with an earlier growing season, such as *Schoenoplectus validus*. Higher salinities would also develop over summer, as a lower hydraulic head in the wetland would promote groundwater discharge. Higher salinities would promote plants more salt-tolerant than *Phragmites australis*.

Lower water levels in summer might introduce reeds to the lower levels of the wetland bed, but would induce a retreat from the outer stands, where groundwater discharge would be promoted. The effectiveness of this approach is limited by the overbank flows, which occur from the Barwon River with a median frequency of three per year (Table 5). Overbank flows create high water levels that would persist unless they could be rapidly drained.

A flooding pattern that involved drying over late spring / early summer would more closely match the seasonal pattern of Barwon River inflows. The water regime would also be similar to Hospital Swamps. However, the high salinities of Hospital Swamps would not be achieved in Reedy Lake because the salinity of groundwater beneath the lake is lower.

Effective management of the wetland for birds and fish must ensure that a diversity of habitat types is maintained in proportion as a mosaic across the wetland and that carp populations are effectively controlled. The hydrological objectives required to achieve these outcomes may periodically result in a lower abundance and diversity of waterbird and fish species able to utilise the wetland. Over the long-term the benefits to the waterbird and fish community of a productive and diverse wetland outweigh this short-term loss of habitat.

The water regime in Reedy Lake needs to change from the present regime because:

- the existing regime favours the spread of *Phragmites australis* and *Typha domingensis* across extensive areas of the lake bed;
- this spread of reeds is simplifying the diversity of vegetation types and reducing their area across the wetland;
- as a consequence of the loss of habitat complexity there appears to be a concomitant reduction in the diversity and abundance of waterbirds that are using the wetland;
- these changes have occurred since the last modifications to the hydraulics of Reedy Lake in the 1950's;
- reed beds could be suppressed by targeting the components of the current water regime that favour *Phragmites australis* and suppress other plant species; and
- the provision of permanent water has favoured the introduced carp, which have brought about significant changes to habitat that have probably been detrimental to vegetation community composition and faunal diversity and abundance.

4.4.2 How to achieve the desired water regime for Reedy Lake

The desired water regime would involve filling and draining Reedy Lake following the patterns of Barwon River flows. The wetland would be filled as river flows increase and be allowed to drain as river levels fall. The operations to achieve this regime are presented in Table 17 below. Regulator operations are assigned to seasons, but these are indicative only, and actual operations should respond to river flows.

The key requirement of the proposed water regime is that the wetland can be drained from a full supply level of 0.9 to 0.3 m AHD over six to eight weeks in order to drain water from the reed beds in late spring before the summer growing period for *Phragmites australis*.

Hydraulic modelling indicates that the existing structures allow the water level to be drawn down from 0.7 to 0.3 m AHD over six weeks in early summer in the absence of over bank flows. This drawdown rate would allow a suitable draw-down period to commence on November 1, to reach an early summer target level of 0.3 m by December 15. However the outlet channel is subject to choking by reeds and silt and its capacity would need to be confirmed for practical operation.

It is likely that the established reed beds will be resilient to summer drying. Conditions which are stressful may retard reed growth, but may allow reeds to recover when a season with favourable conditions occurs. It is important to apply stressful conditions for as consistently as possible to minimise the possibility of recovery: a frequency of 9 in 10 years is recommended for the spring drawdown (Table 17). Low water levels in summer are recommended in all years, however complete drying is recommended 2 in 10 years to control carp and to further dry and stress reed beds.

Further alteration may be required to the water regime to effectively control the reed beds. Increasing the salinity of the lake water would intensify the stress to the reeds. Lake salinities could be increased by opening the outlet regulator when lake levels are low to allow estuarine water from Lake Connewarre to enter. A further, but more intrusive, option would be to lower the level of the sill between Reedy Lake and Lake Connewarre. This would reduce the full supply level of the lake so that the potential for summer flooding is further reduced. It would also increase the potential for saline water from Lake Connewarre to enter the wetland and would provide intermittent saline events. This regime would represent a return to early 20th century conditions, prior to the time when the outlet sill was first raised to increase freshwater storage for irrigation and waterfowl hunting. It would more closely replicate conditions in Hospital Swamps where there is a degree of exchange of saline water between the wetland and the estuary (Table 4).

The recommended water regime for the control of reeds is presented in Table 17.

Table 17: Water Regime Recommended for Reedy Lake to address Reed Management Objectives. The whole water regime is required to meet the overall ecological outcomes and it is not possible to separate out which objective has priority.

Season	Typical Hydrological Environment	Hydrological Objective	Frequency	Environmental Objective
Early Winter (June to July)	Moderate to high flows in the Barwon with the possibility of minor freshes.	Allow wetland to fill with moderate and high flows in Barwon River. - inlet regulator open - outlet regulator closed	9 years in 10	• Initiate decomposition of organic matter on wetland bed • Initiate growth of submerged aquatic macrophytes • Initiate macroinvertebrate productivity • Dilute accumulated soil and surface water salts • Stimulate fish and waterbird breeding • Allow fish to colonise wetland from the river
Winter-spring High Flow Period (August to October)	High flows in the Barwon River. Overbank flows occur intermittently.	Fill Reedy Lake and allow overbank flows to surcharge and flush the wetland. - inlet regulator open - outlet regulator closed	9 years in 10 High flows to extend through to November 4 years in 10 years (no more than 3 years between November flooding)	• Growth of submerged aquatic macrophytes • Growth of *Schoenoplectus validus* and other emergent aquatic macrophytes • Persistent waterlogging and intermittent inundation of *Muehlenbeckia*, *Sarcocornia* and *Distichlis* vegetation communities • Stimulate fish and waterbird breeding • Stimulate increase in invertebrate populations and biomass • Create nesting habitat colonial and other waterbirds • Trigger fish spawning and sustain juvenile fish • Provide connecting flows to the river

Season	Typical Hydrological Environment	Hydrological Objective	Frequency	Environmental Objective
Late Spring – Early Summer Drawdown Period (November to December)	Moderate flows in the Barwon. Overbank flows less frequent.	Drain Reedy Lake to a level of less than 0.3 m AHD before the end of December. - inlet regulator closed - outlet regulator open	Every year; No more than one year in 10 without drawdown (in very wet years)	• Reed beds exposed before growing season commences • Aquatic habitat retained in big hole and deep channels • *Bolboschoenus* and herbland plants grow on exposed mudflats • Submerged aquatic macrophytes set seed and retreat to resting stages • Saline groundwater discharge to wetland bed • Restart wetland processes • Allow eggbanks to be produced and laid • Provide waterbird food supply from access to tubers, seeds and invertebrates in shallow water • Reduce carp habitat and control carp populations
Late Summer – Autumn (January to May)	Low flows in the Barwon. Overbank flows rare.	Maintain water level at or below 0.3 m AHD. Drain overbank flows at normal rate - inlet regulator closed - outlet regulator open	8 years in 10	• Salt accumulation in wetland soils • Expose some mudflats for waterbird feeding • Allow nutrient re-cycling • Control carp populations
Late Summer – Autumn (January to May)	Low flows in the Barwon. Overbank flows rare.	Allow water level to drop below 0.3 m AHD and dry. Drain overbank flows as rapidly as possible. - inlet regulator closed - outlet regulator open	2 years in 10; Wetland dry - March to May	• Salt accumulation in wetland soils • Expose mudflats for waterbird feeding • Allow extensive nutrient re-cycling • Eliminate carp populations

The proposed water regime has placed the highest priority on restoring vegetation types in Reedy Lake to the composition and extent recorded in 1983 (the stakeholder agreed ecological and management objective). As such, it puts in place conditions necessary to control the spread of *Phragmites australis* across the lake. To achieve this outcome the water regime focuses on relatively frequent annual drawdown in early summer, and periodic drying of the lake in late summer and autumn.

The recommended water regime has placed a lower priority, in the short term, on waterbird and fish ecological objectives. In particular, hydrological objectives that do not align with the proposed water regime include:

1. gradual drawdown between November and May three years in five, to expose the entire wetland bed by March, to provide some summer waterbird refuge while providing foraging habitat on tubers and other water vegetation and on mudflats through summer with trapped and exposed fish providing food for piscivores and carnivores (**Table 7**).
2. summer flooding three years in five, with the lake very shallow or dry by the end of May. Such a scenario provided important summer and drought refuge for waterbirds, while providing avian foraging habitat along the wetland fringe, in association with reed beds and in shallows for many shorebirds and waterbird species from all guides. Foraging success for piscivores would also increase in the shallow areas (**Table 7**).
3. bankfull flooding until November two years in five to provide extensive open water habitats, allow time for fish recruitment, growth and maturation and allow greater time of fishway operation (Table 14).
4. stable low water levels four years in five to provide relatively permanent fish habitat and allow populations, and longer lived individuals, to grow (Table 14).

The recommended water regime is likely to re-set the lake to provide the desired ecological and biodiversity outcomes in the longer term, based on our current level of information and system understanding.

The key messages from the science and our understanding of the Lower Barwon system are that summer drying and higher lake salinities in summer will help to control reeds and that a reduction of reeds, in the longer term is necessary to protect the biodiversity of Reedy Lakes. There may be short term reductions in populations of some species, but these species will recolonise, following reed reduction and habitat improvements over time.

However, effective drying cannot occur when there are overbank flows in summer and should be planned in years when effective drying is likely to be achieved. Overbank flows result from heavy rainfall events and cannot be predicted specifically. They are more likely following winter-spring periods with high rainfall that has wet the catchment.

In the longer term, once reeds are controlled, a water regime could be adopted that balances the water requirements of all the flora and fauna (Table 18). The recommended future water regime sets environmental objectives in wet, typical and dry years which are assigned to the 25th, interquartile and 75th percentile years, respectively. These recommendations allow for sustained high water levels and summer inundation to occur in the wettest 25% of years to meet the requirements of breeding and visiting waterbirds and to provide sustained deep water habitat for fish. Summer flooding is avoided in 75% of years by drawdown of the wetland after spring. This balances the habitat requirements of fish and waterbirds while preventing the re-establishment of extensive reed beds. The driest 25% of years allows for more intensive disturbance to reeds and assists in the control of carp.

Table 18: Future Water Regime for Reedy Lake to Balance all Ecological Objectives.

Scenario	Typical Hydrological Environment	Hydrological Objective	Frequency	Environmental Objective
Wettest 25% of years	High flows in in the Barwon with multiple overbank flow events in winter, spring and summer	Maintain high lake level (at or near 0.8 m AHD) throughout the year.	1 year in 4	• Major waterbird breeding events • Summer feeding by waterbirds in flooded vegetation and wetland fringe • Major fish breeding and recruitment • Growth of fish • Migration and dispersal of fish between river, lake and estuary
Typical (interquartile) years	Moderate flows in the Barwon with frequent freshes and overbank flow events in winter and spring	Allow wetland to fill in winter and spring to 0.8 m AHD. Gradually reduce water levels to 0.3 m (below the reed beds) at an approximate rate of 7 cm per week, starting December 1. Restart drawdown following overbank flows in summer, if any.	2 years in 4	• Moderate waterbird breeding events • Wading bird habitat over summer • Spring feeding by waterbirds in flooded vegetation and wetland fringe • Moderate fish breeding and recruitment events
Driest 25% of years	Low flows in the Barwon with infrequent freshes	Allow wetland to fill in winter Gradually reduce water levels to 0.0 m at an approximate rate of 7 cm per week, starting November 1. Restart drawdown following overbank flows in summer, if any	1 year in 4	• Recruitment of aquatic macrophytes at wetland fringes • Retard or reverse reed colonisation of low-lying areas • Control carp • Wading bird habitat over summer • Decay of organic matter on wetland bed, which will increase lake productivity when reflooded

4.5 Management and Ecological Objective for Hospital Swamps

The Steering Committee and Scientific Panel reviewed the available information and decided the most appropriate objective for Hospital Swamps was:

> **To achieve the extent and proportions of plant communities mapped in 1983 (and currently) within a reasonable (say 20%) variation.**

Inherent in this objective is the maintenance of the diversity and populations of waterbirds, fish and other fauna dependent upon the site. Achieving this implies a maintaining the previous water regime and future changes or other impacts are avoided.

4.5.1 Desired Water Regime for Hospital Swamps

Hospital Swamps ecosystem has remained unchanged since the 1970s in terms of waterbird populations and since the 1980s in terms of vegetation (and one would assume fish populations as well). The water regime of Hospital Swamps was seen as currently beneficial to the ecosystem values of the site. The management objectives established for this site are to maintain the current water regime (see Section 2.4.2) and prevent changes and potential threats into the future.

4.5.1 How to achieve the desired water regime for Hospital Swamps

The current water regime and the species requirements have been considered and a water regime is recommended in Table 19. In addition, it will be necessary to prevent changes to water regime from the several potential threats into the future.

The threats to Hospital Swamps are mainly derived through potential future changes to water regime. These may come about from:

- stormwater inflows from Armstrong Creek (developments upstream are likely to produce increasing amounts of run-off);
- changes to inflows from Barwon River (these need to be secured through the bulk entitlement and access rights across the land to the Swamp through ownership or management agreements); and/or
- additional environmental flows from upstream (these would need to be managed to prevent additional inflows).

Hospital Swamps are vulnerable to a water regime that increases inflows over summer and autumn. Low flows or no flows in this period are important in creating saline conditions in the wetland bed which exclude emergent macrophytes and maintain a diverse community of plants that tolerate a variety of saline environments. Summer inflows will suppress groundwater discharge to the wetland and dilute surface water salinities. They may lead to an increase in the extent of reeds and a loss of a variety of salt-tolerant herbs, sedges and shrubs.

In addition, nutrient run-off from stormwater, recreational ovals and irrigation upstream may change the nutrient status of the Swamp and therefore the vegetation community and the rest of the ecosystem through trophic cascades.

While the recommended regime will protect the values of Hospital Swamps provided the inflows are not overwhelmed by stormwater inflows or changes in river flow.

Table 19: Water Regime Recommended for Hospital Swamps to meet Ecological and Management Objectives. While the whole water regime is required to meet the overall ecological outcomes, the coloured highlighting indicates the priority of each objective: Orange indicates the highest priority hydrological objectives, Green the second priority objectives and Blue indicates the third priority objectives.

Season	Typical Hydrological Environment	Hydrological Objective	Frequency	Environmental Objective
Early Winter (May to September)	Moderate to High flows in the Barwon with the possibility of minor freshes. Minor inflows from Armstrong Creek	Allow wetland to fill with moderate and high flows in Barwon River. - inlet regulator open - outlet regulator closed	9 years in 10	• Initiate *Stuckenia* and *Chara* growth • Initiate decomposition of organic matter on wetland bed • Dilute accumulated soil and surface water salts • Create habitat and invertebrate populations • Stimulate fish and waterbird breeding • Allow fish to colonise wetland from the river
Spring High Flow Period (September to November)	High flows in the Barwon River. Overbank flows occur intermittently. Storm flows from Armstrong Creek	Fill Hospital Swamps with main wetland filled to 0.5m AHD. - inlet regulator open - outlet regulator closed	9 years in 10	• Continuous flushing of salt from deep wetland basins • Inundation of reedbeds and *Bolboschoenus* beds fringing the main basin • Sustain growth of *Stuckenia* and *Chara* • Promote growth of *Myriophyllum* in southern part of main basin • Waterlog *Gahnia filum* sedgelands • Stimulate fish and waterbird breeding • Stimulate increase in invertebrate populations and biomass • Create nesting habitat colonial and other waterbirds
Spring High Flow Period (September to November)	Flow freshes in the Barwon River. Storm flows from Armstrong Creek	Flow freshes used to surcharge (to 0.7m AHD) and flush the wetland. - inlet regulator open - outlet regulator closed	9 years in 10	• Continuous flushing of salt from deep wetland basins • Inundate shallow wetland basins and promote growth of *Ruppia* • Inundate *Gahnia filum* sedgelands • Create additional fish and waterbird habitat and

Season	Typical Hydrological Environment	Hydrological Objective	Frequency	Environmental Objective
				invertebrate populations • Trigger fish spawning • Provide connecting flows to the river and between wetlands
Early Summer Drawdown Period (December to January)	Moderate flows in the Barwon. Overbank flows less frequent. Intermittent minor flows from Armstrong Creek.	Drain Hospital Swamps to a level of less than 0.3 m AHD by the end of January. - inlet regulator closed - outlet regulator open	9 years in 10	• Increase wetland salinity as groundwater discharge increases in proportion to surface water • Shallow wetland basins exposed (creates open water habitat upon refilling) • Restart wetland processes • Allow eggbanks to be produced and laid • Provide waterbird food supply from access to tubers, seeds and invertebrates in shallow water
Late Summer – Autumn (February to March/April)	Low flows in the Barwon. Overbank flows rare. Inflows from Armstrong Creek rare.	Allow wetland bed to dry. - inlet regulator closed - outlet regulator open	9 years in 10	• Soil salinity increases in shallow wetland basins and deep wetland basin • *Chara* and *Stuckenia* die back • Limited colonisation of wetland bed by annual herbland plants • Reeds and other emergent macrophytes become dormant • High soil salinity excludes reeds • Expose mudflats for waterbird feeding • Allow nutrient re-cycling • Control carp populations
All year	Very low flows in Barwon and Armstrong Creek	Wetland bed dry or shallow flooding Salinisation of the wetland bed and limit extent of flushed soil conditions	1 year in 10	• Maintain vegetation structure

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Flow-ecology relationships for the key components of the Reedy Lake and Hospital Swamps are used as the basis for water regime recommendations for these systems.

Reedy Lake has been becoming dominated by reedbeds of *Phragmites australis* and *Typha domingensis*. The potential for Carp and other exotic fish to proliferate are significant threats which are being driven by the past water regime (permanent high water levels). This regime has led to a decline in overall biodiversity of the values. A modified water level regime is proposed to support biodiversity as well as one which will retard or hamper the growth of reed beds and control Carp populations.

Hospital Swamps have displayed little ecological change over the last 30 years and this is most likely due to the water regime the system has been maintained over that time. A water regime derived from the flow-ecology relationships aligns well with the existing water regime. However, Hospital Swamps face threats from additional inflows from more stormwater which threaten to drive the system to become more like Reedy, loosing overall biodiversity. Management of these threats into the future will be necessary to ensure the conservation values of Hospital Swamps are not lost.

5.2 Knowledge Gaps and Recommendations

This document recommends a water regime for both Reedy Lake and Hospital Swamps however there are some knowledge gaps, investigations and other management actions necessary to secure the future of these sites to help support the new water regime as it is implemented (Table 20). Further, the ecological response should be monitored and a specific study (following the VEFMAP strategies, such as Chee et al 2009) may be necessary to design a monitoring program.

Table 20: Knowledge Gaps and Recommendations to Support the Proposed Water Regimes for the Lower Barwon Wetlands (in priority order)

Knowledge Gap and Priority	Recommendation	Key Assets Addressed
1. Wetland planning should be guided by the responses of the wetlands to water management decisions	An adaptive management regime is required to implement and understand the responses of each action and refine the strategy over time (Figure 38; see also VEFMAP strategies, such as Chee et al 2009).	Geomorphology; Vegetation; Waterbirds and Fish
2. The scale and rate of change in reed beds in response to the proposed water regime is uncertain. As previously stated, *Phragmites* and *Typha* are resilient to disturbance and may respond slowly.	A monitoring program is required to measure leading indicators of vegetation change. Particularly important will be measures of ramet recruitment and new ramet density. These may indicate that reeds are responding as planned to the proposed water regime long before gross measures, such as reed bed extent. Longer-term measuring is required to confirm that the leading indicators correspond to a change in reed bed extent. This could be achieved using aerial photography interpretation.	Vegetation
3. The water regime recommended in this report draws heavily on qualitative descriptions of lake behaviour and uncalibrated lake modelling. This results in some uncertainty in the water regime recommendations.	A formal water level monitoring regime is required in Reedy Lake and Hospital Swamps. Weekly automated water level records, or monthly manual staff gauging records is essential to verify the interpreted current water regime, to measure compliance with the proposed water regime and to evaluate ecological responses to future hydrological events.	Geomorphology; Vegetation; Waterbirds and Fish
4. The role of spring tides in affecting the salinity and ecology of both systems but in particular, Hospital Swamps.	Monitor the height and extent of spring high tides and their entry into Hospital Swamps. Evaluate the potential to use saline inflows to Reedy Lake to assist in control of reed bed extent.	Geomorphology; Vegetation; Waterbirds and Fish

Knowledge Gap and Priority	**Recommendation**	**Key Assets Addressed**
5a. Salinity impacts of Reedy Lake and Hospital Swamps operations on salinities in Lake Connewarre. These wetlands are not managed in isolation from the Barwon River and Lake Connewarre. The hydraulic study conducted in parallel to this project (Water Technology 2011) indicates that “wet” and “maximum variation” scenarios can result in changes to salinity of Lake Connewarre. It is unlikely the level of these changes will have ecological effects at Lake Connewarre, however, monitoring the responses of Lake Connewarre salinity to water regime changes in Reedy Lake and Hospital Swamps will allow this risk to be evaluated and confirmed as low (or managed if not).	A water and salt balance model of Reedy Lake, Hospital Swamps and Lake Connewarre is required to fully understand and refine the water level management of the system into the future. Incorporation of an urban stormwater runoff model would assist in planning for changes to wetland inflows from urban development. The modelling will allow water-sensitive urban design principles to be applied to upstream land developments (especially within the Armstrong Creek catchment) and these will assist the process of protecting the quality and volumes of water entering these wetlands.	Geomorphology; Vegetation; Waterbirds and Fish
5b. The choice of the 2008-2009 stream flow sequence on which the hydraulic modelling is based is limiting. It contains no over bank flows into Reedy Lake, and this seriously impacts on the wet scenario, but also makes the dry scenario somewhat predictable. The existing model is informative on the time taken for Reedy Lake to dry, however, a water balance model over a range of years and flow would be more informative.		

Knowledge Gap and Priority	Recommendation	Key Assets Addressed
6. The volume, timing and quality of future urban stormwater run-off into Armstrong Creek in unknown. However, upstream catchments are being developed and urbanised which is likely to result in further run-off into Armstrong Creek and therefore into Hospital Swamps.	The volume, timing and quality of future urban stormwater run-off into Armstrong Creek needs to be estimated using a catchment runoff model. Strategies should be planned to divert, detail and/or treat stormwater before it enters Hospital Swamps (or the Barwon River if volumes are large enough to influence its flow). These strategies might include water sensitive urban design within the new urban areas, constructed wetlands downstream of urban areas or before Hospital Swamps.	Geomorphology; Vegetation; Waterbirds and Fish
7. Further work is required to characterise the role of salinity in the structure of plant communities in Reedy Lake and Hospital Swamps. Existing groundwater monitoring has confirmed that the wetlands are underlain by saline groundwater and has characterised the hydraulic gradients in the vicinity of the lakes. However the salinity thresholds that corresponds to the distribution of plant communities is not clear, and would be valuable in setting targets for water level management.	These investigations would comprise quarterly soil salinity sampling at a range of bed elevations (where exposed) over a 24 month period. This information would be particularly helpful in distinguishing the effects of salt and flooding on plant communities.	Vegetation
8. Fish population dynamics within the wetlands are unknown. This will be especially important if management compromises are made to the proposed water level regime.	A study of the population dynamics of the fish will help formulate strategies to optimise these populations and understand the likely responses of water regime changes.	Fish

Knowledge Gap and Priority	Recommendation	Key Assets Addressed
9. The wetlands in the Lower Barwon complex all provide habitat for a range of flora and fauna. The more mobile animals, birds and fish for instance, may use one or more wetland for different purposes or life stages, moving within or between wetlands over the seasons or years. There is very limited and poor quality data on the role of the wetland complex and individual components in waterbird breeding. How important are these wetlands to regional populations, and for which species? Are the wetlands more important as summer and drought refuge for some species, with breeding taking place elsewhere?	A study to determine the extent of movement and use between wetlands of birds and fish will help understand how each wetland supports these fauna populations. This knowledge will help understand whether the components of the system need to be operated in concert or separately.	Waterbirds and Fish

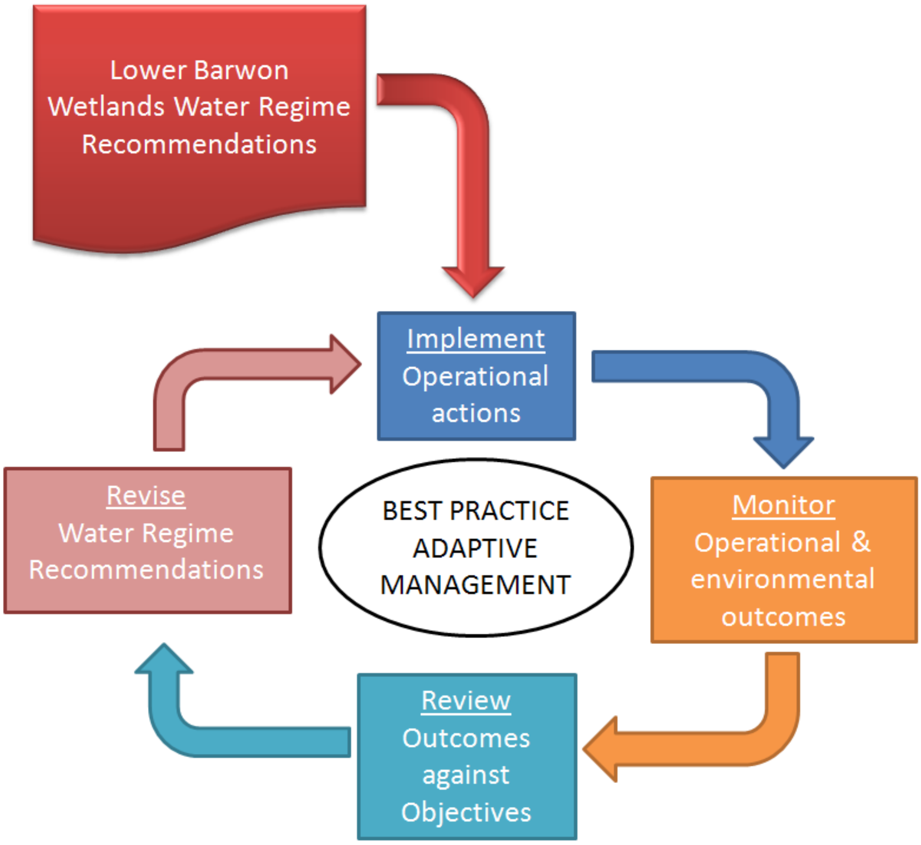


Figure 38: Adaptive management cycle applicable to the Lower Barwon Wetlands Water Regime Recommendations.

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7 APPENDIX A: LOWER BARWON WETLANDS COMPLEX FAUNA DATA

Class FAMILY *Genus species*	Common Name	Wetland: Reedy Lake Records	Reedy Lake Mean Count	Hospital Swamps Records	Hospital Swamps Mean Count	Connewarre Lake Records	Connewarre Lake Mean Count	Barwon Estuary Records	Barwon Estuary Mean Count	Salt Swamp Records	Salt Swamp Mean Count	Murtnaghurt Swamp Records	Murtnaghurt Swamp Mean Count	Conservation Significance: EPBC†	Victoria§ Rating	Victoria§ Listing FFGA
Amphibians																
HYLIDAE																
Litoria ewingii	Southern Brown Tree Frog	3	7.0													
Litoria raniformis	Growling Grass Frog	3	3.7											VU	EN	L
MYOBATRACHIDAE																
Crinia signifera	Common Froglet	5	450	2	2.5											
Limnodynastes dumerilii	Eastern Banjo Frog															
Limnodynastes tasmaniensis	Spotted Marsh Frog															
Number of Species		**3**	**3**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**
Aves																
ACANTHIZIDAE																
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	28	5.7	20	0.0	12	1.6	26	0.9			1	1.0			
Acanthiza lineata	Striated Thornbill							1	10.0							
Acanthiza nana	Yellow Thornbill					1										
Acanthiza pusilla	Brown Thornbill	1		1		3	0.0	42	0.5	1		2	4.0			
Acanthiza reguloides	Buff-rumped Thornbill							1								
Calamanthus fuliginosus	Striated Fieldwren	24		12		18		22		1		2				
Sericornis frontalis	White-browed Scrubwren	8	1.3	2	0.0	4	0.0	16	3.3	3	1.0	2	2.0			
ACCIPITRIDAE																
Accipiter fasciatus	Brown Goshawk	7	0.3	4	0.0	1	0.0	3	1.0			1	1.0	m		
Accipiter novaehollandiae novaehollandiae	Grey Goshawk			1				1	1.0						VU	L
Aquila audax	Wedge-tailed Eagle	2	1.0	2	0.0	4		1								
Circus approximans **(W)**	Swamp Harrier	94	2.0	43	0.5	34	0.9	22	0.7	3	0.0			m		
Circus assimilis	Spotted Harrier							1	0.0						NT	
Elanus axillaris	Black-shouldered Kite	37	0.9	10	0.0	17	0.9	11	1.3	2	1.0	1				
Haliaeetus leucogaster **(W)**	White-bellied Sea-Eagle	4	1.0	3	0.0	17	1.0	4	1.0					C m	VU	L
Haliastur sphenurus	Whistling Kite	28	2.1	20	0.0	26	1.1	14	0.5					m		

Class FAMILY *Genus species*	Common Name	Wetland												Conservation Significance		
		Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		EPBC†	Victoria§	
		Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
Hieraaetus morphnoides	Little Eagle	11	1.0	2		15	2.0	5		1		1	1.0			
ACROCEPHALIDAE																
Acrocephalus australis **(W)**	Australian Reed Warbler	50	4.5	21	0.0	3	0.0	2	0.0			1		m		
ALAUDIDAE																
Alauda arvensis	European Skylark *****	67	1.7	22	0.0	26	1.8	10	0.5	1	11.0	3	12.0			
Mirafra javanica	Horsfield's Bushlark	3	0.0			2	0.0	1		1	0.0					
ANATIDAE																
Anas castanea **(W)**	Chestnut Teal	45	95.2	35	96.1	26	181	7	10.0			2	44.0			
Anas gracilis **(W)**	Grey Teal	30	436	25	437	18	79.8	3	40.0			2	355			
Anas platyrhynchos **(W)**	Northern Mallard			1		1	0.0									
Anas rhynchotis **(W)**	Australasian Shoveler	41	91.8	25	51.1	24	6.4	4				1	25.0		VU	
Anas superciliosa **(W)**	Pacific Black Duck	93	318	45	140	37	37.1	25	12.2			4	71.7			
Aythya australis **(W)**	Hardhead	26	32.3	13	12.2	9	22.2								VU	
Biziura lobata **(W)**	Musk Duck	31	1.9	2	2.0	13	2.0	3						m	VU	
Cereopsis novaehollandiae **(W)**	Cape Barren Goose	2	1.0											m	NT	
Chenonetta jubata **(W)**	Australian Wood Duck	1		2	2.0	2										
Cygnus atratus **(W)**	Black Swan	110	93.8	66	169	96	768	47	223	2	0.0	7	20.2			
Malacorhynchus membranaceus **(W)**	Pink-eared Duck	6	19.8	1		5	2.0	1								
Oxyura australis **(W)**	Blue-billed Duck	13	1.8			1	8.0								EN	L
Stictonetta naevosa **(W)**	Freckled Duck	5	3.5	1	1.0	1	1.0								EN	L
Tadorna tadornoides **(W)**	Australian Shelduck	63	122	45	158	54	37.1	9	0.0	1	2.0	4	34.3			
ANHINGIDAE																
Anhinga novaehollandiae **(W)**	Darter	9	0.5	1	1.0			1	1.0							
ANSERANATIDAE																
Anseranas semipalmata **(W)**	Magpie Goose	37	3.8	5	5.0	1								m	NT	L
APODIDAE																
Apus pacificus	Fork-tailed Swift	1												m		
Hirundapus caudacutus	White-throated Needletail					1								m		
ARDEIDAE																
Ardea ibis **(W)**	Cattle Egret	3	9.0	1				5	0.0					C J m		
Ardea intermedia **(W)**	Intermediate Egret	5	0.5	1		1	1.0	1						m	CR	L
Ardea modesta **(W)**	Eastern Great Egret	63	3.7	28	2.9	49	4.2	31	0.6	2	0.0			C J m	VU	L
Ardea pacifica **(W)**	White-necked Heron	15	0.7	1				5	10.0	1	0.0					

Class FAMILY *Genus species*	Common Name	Wetland												Conservation Significance		
		Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		EPBC†	Victoria§	
		Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
Botaurus poiciloptilus **(W)**	Australasian Bittern	46	0.9	5	1.8	6	2.0	1	1.0						EN	L
Egretta garzetta nigripes **(W)**	Little Egret	4	0.0	2	0.0	26	2.8	9	0.8					m	EN	L
Egretta novaehollandiae **(W)**	White-faced Heron	64	5.4	36	0.5	60	7.3	64	1.8	4	0.0	4	3.3			
Ixobrychus minutus dubius **(W)**	Australian Little Bittern	1	2.0												EN	L
Nycticorax caledonicus hillii **(W)**	Nankeen Night Heron	3	3.0			1	0.0	2	0.0	1	0.0			m	NT	
ARTAMIDAE																
Artamus cyanopterus	Dusky Woodswallow							1								
Artamus personatus	Masked Woodswallow	1	100													
Artamus superciliosus	White-browed Woodswallow	1	100													
Cracticus tibicen	Australian Magpie	68	2.9	37	0.0	35	0.8	93	0.0	2	0.0	3	3.0			
Cracticus torquatus	Grey Butcherbird	5		21	0.0	5		42	0.0			1	1.0			
Strepera graculina	Pied Currawong							2	10.0							
Strepera versicolor	Grey Currawong							4	0.0							
CACATUIDAE																
Cacatua galerita	Sulphur-crested Cockatoo							14	0.0							
Cacatua tenuirostris	Long-billed Corella							1		1	15.0					
Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo	6	0.0	5	0.0	2	0.0	15	0.3			1	38.0			
Eolophus roseicapilla	Galah	6		4	0.0	4	3.0	35	0.3	1	6.0					
CAMPEPHAGIDAE																
Coracina novaehollandiae	Black-faced Cuckoo-shrike	8	0.0	9	0.0	1	0.0	1						m		
CHARADRIIDAE																
Charadrius bicinctus **(W)**	Double-banded Plover	2	2.0	3	1.0	21	39.1	4								
Charadrius dubius **(W)**	Little Ringed Plover					1	1.0							C R		
Charadrius mongolus **(W)**	Lesser Sand Plover			1										C J R	VU	
Charadrius ruficapillus **(W)**	Red-capped Plover	1	3.0	8	0.0	43	6.6	18	0.9	1	0.0	3	4.0			
Elseyornis melanops **(W)**	Black-fronted Dotterel	19	4.7	25	1.8	3	15.0			1						
Erythrogonys cinctus **(W)**	Red-kneed Dotterel	36	10.3	25	2.1	3	29.0									
Pluvialis fulva **(W)**	Pacific Golden Plover			1		4	1.0	3	30.0			1	100	C J R	NT	
Pluvialis squatarola **(W)**	Grey Plover							1						C J R	NT	
Thinornis rubricollis rubricollis **(W)**	Hooded Plover							3	2.0			7	4.0		VU	L

Class		Wetland												Conservation Significance		
		Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		EPBC†	Victoria§	
FAMILY *Genus species*	Common Name	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
Vanellus miles **(W)**	Masked Lapwing	78	6.4	45	0.5	63	9.2	88	2.9	4	0.0	11	6.7			
Vanellus tricolor	Banded Lapwing	1				6	0.0					1	1.0			
CISTICOLIDAE																
Cisticola exilis **(W)**	Golden-headed Cisticola	80	6.8	29	0.0	26	2.9	7	1.0	1	10.0	4	6.0			
COLUMBIDAE																
Columba livia	Rock Dove *****	4	0.0	1		4	0.0	7	1.0	1						
Ocyphaps lophotes	Crested Pigeon			5		2				1	0.0					
Stigmatopelia (Streptopelia) chinensis	Spotted Turtle-Dove *****	10		9	0.0	5	0.0	60	0.4							
CORVIDAE																
Corvus coronoides	Australian Raven							1								
Corvus mellori	Little Raven	56	5.7	26	0.0	26	0.5	58	0.4	2	3.0	4	4.0	m		
CUCULIDAE																
Cacomantis flabelliformis	Fan-tailed Cuckoo	1		2	0.0	1		4	0.0					m		
Chalcites basalis	Horsfield's Bronze-Cuckoo	6	0.7	11	0.0	3	0.0	9	1.0					m		
Chalcites lucidus	Shining Bronze-Cuckoo			1				4	0.0					m		
Cuculus pallidus	Pallid Cuckoo	1	0.0	2	0.0			1	1.0			1		m		
DIOMEDEIDAE																
Diomedea exulans	Wandering Albatross									1	0.0			J, VU, m	EN	L
Diomedea (Thalassarche) cauta cauta	Shy Albatross			1										m		
ESTRILDIDAE																
Neochmia temporalis	Red-browed Finch	2	4.0					3		2	0.0	1				
Stagonopleura bella	Beautiful Firetail							1	100							
FALCONIDAE																
Falco berigora	Brown Falcon	30	0.8	16	0.0	13	0.9	7	0.0			1	2.0			
Falco cenchroides	Nankeen Kestrel	10	0.5	6	0.0	6	0.0	9	0.0					m		
Falco longipennis	Australian Hobby	14	0.6	1	0.0	2		3	0.0	1	1.0					
Falco peregrinus	Peregrine Falcon	1		1		4	0.0	2								
Falco subniger	Black Falcon			1				1	0.0						VU	
FRINGILLIDAE																
Carduelis carduelis	European Goldfinch *****	42	8.3	20	0.0	13	1.5	34	0.2	2	30.0	2	20.0			
Chloris chloris	European Greenfinch *****	25	38.3	11	0.0	1	0.0	3								
GRUIDAE																
Grus rubicunda **(W)**	Brolga	20	2.0	6	1.0	3				2	2.0				VU	L

Class		Wetland												Conservation Significance		
		Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		EPBC†	Victoria§	
FAMILY *Genus species*	Common Name	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
HAEMATOPODIDAE																
Haematopus fuliginosus **(W)**	Sooty Oystercatcher							3	1.0						NT	
Haematopus longirostris **(W)**	Pied Oystercatcher					15	1.7	9	0.5							
HALCYONIDAE																
Dacelo novaeguineae	Laughing Kookaburra							4	0.0							
Todiramphus sanctus	Sacred Kingfisher							1	0.0					m		
HIRUNDINIDAE																
Hirundo neoxena	Welcome Swallow	75	57.0	41	2.1	39	2.1	74	0.4	2		3	20.0	m		
Petrochelidon (Hirundo) ariel	Fairy Martin	1	20.0	7	0.0	1		2	0.0							
Petrochelidon (Hirundo) nigricans	Tree Martin	9	0.0	9	0.0	3	0.0	1						m		
LARIDAE																
Chlidonias hybridus javanicus **(W)**	Whiskered Tern	43	64.6	17	157	19	34.1	10	6.0	4	0.0			m	NT	
Chlidonias leucopterus **(W)**	White-winged Black Tern	5	2.5	3	8.0	2	30.0							C J R m	NT	
Chroicocephalus novaehollandiae **(W)**	Silver Gull	25	37.7	21	16.5	65	27.3	65	7.0	1	0.0	2	10.5	m		
Gelochelidon nilotica macrotarsa **(W)**	Gull-billed Tern	1	1.0			6	0.8	2	12.0					m	EN	L
Hydroprogne caspia **(W)**	Caspian Tern	10	1.6	4	15.0	58	3.3	23	1.9					C J m	NT	L
Larus pacificus pacificus **(W)**	Pacific Gull	2	0.5			20	1.2	54	0.6			1	2.0	m	NT	
Sternula albifrons sinensis **(W)**	Little Tern	1	20.0	3	10.7	3	0.0	1						C J R m	VU	L
Sternula nereis nereis **(W)**	Fairy Tern			1	3.0	13	5.1	8	0.3					m	EN	L
Thalasseus bergii **(W)**	Crested Tern	1	1.0			23	1.6	39	3.1					m		
MALURIDAE																
Malurus cyaneus	Superb Fairy-wren	81	4.6	42	0.1	33	1.3	38	0.6	3	0.0	2				
Stipiturus malachurus	Southern Emu-wren					3	1.7	13		1	0.0					
MEGALURIDAE																
Cincloramphus cruralis	Brown Songlark	2	2.0			1	1.0									
Megalurus gramineus **(W)**	Little Grassbird	75	4.1	23	0.0	34	1.5	23	2.0	2	0.0	4	4.5			
MELIPHAGIDAE																
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	1		9	0.0	3	0.0	33	0.7			2	3.0			
Acanthorhynchus tenuirostris	Eastern Spinebill	1	1.0					13	0.0							
Anthochaera carunculata	Red Wattlebird	15	0.0	21	0.0	7	0.0	82	0.4	2	0.0	1				

Class FAMILY *Genus species*	Common Name	Wetland: Reedy Lake Records	Reedy Lake Mean Count	Hospital Swamps Records	Hospital Swamps Mean Count	Connewarre Lake Records	Connewarre Lake Mean Count	Barwon Estuary Records	Barwon Estuary Mean Count	Salt Swamp Records	Salt Swamp Mean Count	Murtnaghurt Swamp Records	Murtnaghurt Swamp Mean Count	Conservation Significance: EPBC†	Victoria§ Rating	Victoria§ Listing FFGA
Anthochaera chrysoptera	Little Wattlebird							7				1	1.0			
Epthianura albifrons	White-fronted Chat	73	13.6	35	0.0	35	1.7	32	1.4	4	3.7	6	12.3			
Glyciphila (Phylidonyris) melanops	Tawny-crowned Honeyeater					1	0.0									
Lichenostomus chrysops	Yellow-faced Honeyeater	1	1.0	1	0.0			4	0.0							
Lichenostomus leucotis	White-eared Honeyeater									1	0.0					
Lichenostomus penicillatus	White-plumed Honeyeater	13	1.3	29	0.0	2	1.5	12	0.0	1						
Lichenostomus virescens	Singing Honeyeater							12	0.0			2	4.0			
Manorina melanocephala	Noisy Miner			17	0.0	13	1.0	9	0.0							
Melithreptus brevirostris	Brown-headed Honeyeater									1	0.0					
Melithreptus lunatus	White-naped Honeyeater							1								
Phylidonyris novaehollandiae	New Holland Honeyeater	20	0.5	11	0.0	9	0.0	70	0.4	2	0.0					
MONARCHIDAE																
Grallina cyanoleuca	Magpie-lark	62	1.0	28	0.4	17	2.0	59	0.3	1				m		
Myiagra inquieta	Restless Flycatcher	1	2.0	1				1	0.0							
MOTACILLIDAE																
Anthus novaeseelandiae	Australasian Pipit	12	10.0	3		7	0.0	10	1.3					m		
NECTARINIIDAE																
Dicaeum hirundinaceum	Mistletoebird							3	5.0	1						
OCEANITIDAE																
Oceanites oceanicus	Wilson's Storm-Petrel									1	0.0			J		
Pelagodroma marina	White-faced Storm-Petrel									1	0.0	1			VU	
PACHYCEPHALIDAE																
Pachycephala pectoralis	Golden Whistler					1	0.0									
Pachycephala rufiventris	Rufous Whistler	1														
PARDALOTIDAE																
Pardalotus punctatus	Spotted Pardalote					1	0.0	7	2.5							
Pardalotus striatus	Striated Pardalote			1	0.0											
PASSERIDAE																
Passer domesticus	House Sparrow *	33	4.7	18	0.0	18	0.0	47	0.0	2	0.0					
Passer montanus	Eurasian Tree							5	10.0							

Class FAMILY *Genus species*	**Common Name**	**Wetland** Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		**Conservation Significance** EPBC†	Victoria§	
		Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
	Sparrow*															
PEDIONOMIDAE																
Pedionomus torquatus	Plains-wanderer							1	0.0					VU	CR	L
PELECANIDAE																
Pelecanus conspicillatus **(W)**	Australian Pelican	74	18.4	30	8.1	73	10.3	43	2.4	1				m		
PETROICIDAE																
Microeca fascinans	Jacky Winter							1								
Petroica phoenicea	Flame Robin	18	0.7	4	0.0	1	0.0	12	0.0	1		1	1.0	m		
Petroica rodinogaster	Pink Robin							2	0.0	1	0.0			m		
Petroica rosea	Rose Robin									2	0.0					
PHALACROCORACIDAE																
Microcarbo melanoleucos **(W)**	Little Pied Cormorant	45	4.0	21	2.5	64	5.1	49	2.0	1						
Phalacrocorax carbo **(W)**	Great Cormorant	38	9.0	16	1.3	49	3.2	44	2.1							
Phalacrocorax fuscescens **(W)**	Black-faced Cormorant							1							NT	
Phalacrocorax sulcirostris **(W)**	Little Black Cormorant	35	9.0	14	1.3	35	18.4	28	2.8			1				
Phalacrocorax varius **(W)**	Pied Cormorant	7	3.0	2	4.0	44	2.9	31	1.9						NT	
PHASIANIDAE																
Coturnix pectoralis	Stubble Quail	1	2.0	1	0.0	3	1.3	1	0.0							
Coturnix ypsilophora australis ***(W?)***	Brown Quail	9		1		3	1.0	1							NT	
PODICIPEDIDAE																
Podiceps cristatus **(W)**	Great Crested Grebe	16	1.4	3	0.0	21	2.6	1	0.0							
Poliocephalus poliocephalus **(W)**	Hoary-headed Grebe	28	71.0	24	7.6	33	8.5	11	102.5	2	0.0	1	5.0			
Tachybaptus novaehollandiae **(W)**	Australasian Grebe	14	12.3	7	13.7	7	8.0					1	1.0			
POMATOSTOMIDAE																
Pomatostomus temporalis temporalis	Grey-crowned Babbler					1	0.0								EN	L
PROCELLARIIDAE																
Pachyptila belcheri	Slender-billed Prion							3						m		
Pachyptila desolata	Antarctic Prion							1	1.0					m		
Pachyptila turtur	Fairy Prion							5						m	VU	
Pelecanoides urinatrix	Common Diving-Petrel							2						m	NT	
Procellaria westlandica	Westland Petrel							1						m		

Class FAMILY *Genus species*	Common Name	Wetland												Conservation Significance		
		Reedy Lake		Hospital Swamps		Connewarre Lake		Barwon Estuary		Salt Swamp		Murtnaghurt Swamp		EPBC†	Victoria§	
		Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count	Records	Mean Count		Rating	Listing FFGA
Puffinus gavia	Fluttering Shearwater							11						m		
Puffinus huttoni	Hutton's Shearwater							1						m		
PSITTACIDAE																
Glossopsitta concinna	Musk Lorikeet			3	0.0			3	0.0	1	0.0					
Glossopsitta porphyrocephala	Purple-crowned Lorikeet			4	0.0											
Neophema chrysogaster	Orange-bellied Parrot					66	24.0	1		1	0.0			CE m	CR	L
Neophema chrysostoma	Blue-winged Parrot	12	35.0			34	38.1	7	0.0	1	75.0			m		
Platycercus elegans	Crimson Rosella	1		4	0.0	2	0.0	9	0.0							
Platycercus eximius	Eastern Rosella	3	2.0	16	0.0	6	0.0	40	0.5							
Psephotus haematonotus	Red-rumped Parrot			12	0.0	5	9.0	1	0.0	1	0.0					
Psephotus varius	Mulga Parrot									1	0.0					
Trichoglossus haematodus	Rainbow Lorikeet							1	2.0							
RALLIDAE																
Fulica atra **(W)**	Eurasian Coot	45	723	13	245	23	576	1	0.0	1	0.0	2	13.0			
Gallinula tenebrosa **(W)**	Dusky Moorhen	3	0.3	6	14.3	2	0.0	1	0.0	1	0.0					
Gallirallus philippensis **(W)**	Buff-banded Rail	2		1	0.0			2								
Porphyrio porphyrio **(W)**	Purple Swamphen	85	35.0	43	17.9	5	3.8	1	0.0	1	0.0			m		
Porzana fluminea **(W)**	Australian Spotted Crake	19	4.5	7	8.3	4		4	0.0							
Porzana pusilla palustris **(W)**	Baillon's Crake	14	1.1	1		1	1.0			1	0.0			m	VU	L
Porzana tabuensis **(W)**	Spotless Crake	1	2.0	1	0.0									m		
Tribonyx ventralis **(W)**	Black-tailed Native-hen			6	0.0	1	1.0	1	1.0							
RECURVIROSTRIDAE																
Cladorhynchus leucocephalus **(W)**	Banded Stilt	1	0.0	2	13.5	7	0.0	4	0.0							
Himantopus himantopus **(W)**	Black-winged Stilt	50	25.4	31	12.4	16	41.5	5	0.0	1		2	10.0	m		
Recurvirostra novaehollandiae **(W)**	Red-necked Avocet	2	0.5	5	27.3	15	33.1	2	0.0					m		
RHIPIDURIDAE																
Rhipidura albiscarpa	Grey Fantail	1		1				22	0.7			1				
Rhipidura leucophrys	Willie Wagtail	56	2.2	34	0.0	21	0.1	68	0.4	2	2.0	2	10.0			
ROSTRATULIDAE																
Rostratula australis **(W)**	Australian Painted Snipe			2	0.5					2	0.0			C VU m	CR	L
SCOLOPACIDAE																
Actitis hypoleucos **(W)**	Common Sandpiper					1	2.0	10	0.4					C J R m	VU	
Calidris acuminata **(W)**	Sharp-tailed Sandpiper	28	43.6	22	89.1	25	29.6	17	134	2	0.0	3	10.0	C J R m		

Class FAMILY *Genus species*	Common Name	Wetland: Reedy Lake Records	Reedy Lake Mean Count	Hospital Swamps Records	Hospital Swamps Mean Count	Connewarre Lake Records	Connewarre Lake Mean Count	Barwon Estuary Records	Barwon Estuary Mean Count	Salt Swamp Records	Salt Swamp Mean Count	Murtnaghurt Swamp Records	Murtnaghurt Swamp Mean Count	Conservation Significance: EPBC†	Victoria§ Rating	Victoria§ Listing FFGA
Calidris canutus **(W)**	Red Knot					7	6.5	4	2.0			1	40.0	C J R m	NT	
Calidris ferruginea **(W)**	Curlew Sandpiper	12	66.7	22	214	30	47.1	15	560	1	0.0	3	0.0	C J R m		
Calidris melanotos **(W)**	Pectoral Sandpiper	3	0.5	5	1.0	3	1.0			2	0.0			J R m	NT	
Calidris ruficollis **(W)**	Red-necked Stint	8	0.0	23	0.6	47	192	22	158	1		3	37.5	C J R m		
Calidris subminuta **(W)**	Long-toed Stint			1	1.0	1	1.0							C J R m	NT	
Calidris tenuirostris **(W)**	Great Knot					2	5.5	1	2.0			1	45.0	C J R m	EN	L
Gallinago hardwickii **(W)**	Latham's Snipe	22	2.7	2		2	150							C J R m	NT	
Limicola falcinellus **(W)**	Broad-billed Sandpiper					1	1.0							C J R m		
Limosa lapponica **(W)**	Bar-tailed Godwit			1	0.0	7	0.8	6	18.0			2	19.5	C J R m		
Limosa limosa **(W)**	Black-tailed Godwit	4	14.0	7	10.0	2	2.0	1						C J R m	VU	
Numenius madagascariensis **(W)**	Eastern Curlew					32	2.1	22	1.0					C J R m	NT	
Numenius phaeopus **(W)**	Whimbrel							3						C J R m	VU	
Philomachus pugnax **(W)**	Ruff	3		1	1.0									C J R m		
Tringa (Heteroscelus) brevipes **(W)**	Grey-tailed Tattler	1	0.0											C J R m	CR	L
Tringa glareola **(W)**	Wood Sandpiper	4	1.0	2	1.0									C J R m	VU	
Tringa nebularia **(W)**	Common Greenshank	38	8.3	24	6.7	47	8.3	33	13.1	1		4	64.0	C J R m		
Tringa stagnatilis **(W)**	Marsh Sandpiper	17	0.0	15	53.0	2	4.5			1				C J R m		
Xenus cinereus **(W)**	Terek Sandpiper			1		1	2.0							C J R m	EN	L
SPHENISCIDAE																
Eudyptula minor	Little Penguin							20	0.0	1	0.0			m		
STRIGIDAE																
Ninox boobook (novaeseelandiae)	Southern Boobook									1	0.0			m		
STURNIDAE																
Acridotheres tristis	Common Myna *****	2		10	0.0	3	0.0	46	0.5	1						
Sturnus vulgaris	Common Starling *****	46	24.0	26	0.0	17	0.0	76	0.4	1		2				
SULIDAE																
Morus serrator **(W)**	Australasian Gannet							1	0.0					m		
THRESKIORNITHIDAE																
Platalea flavipes **(W)**	Yellow-billed Spoonbill	40	3.9	28	0.4	27	3.8	10								
Platalea regia **(W)**	Royal Spoonbill	59	13.1	29	3.8	35	8.9	32	1.2			1	1.0		VU	
Plegadis falcinellus **(W)**	Glossy Ibis	16	9.8	15	9.6					1				C m	NT	
Threskiornis molucca **(W)**	Australian White Ibis	85	44.1	42	5.0	59	15.3	59	5.3	3	0.0	1		m		
Threskiornis spinicollis **(W)**	Straw-necked Ibis	66	157	30	6.7	26	15.1	35	10.0	1		2	6.0	m		
TIMALIIDAE																
Zosterops lateralis	Silvereye	6	3.0	2	0.0	2		51	3.9	1	0.0	2	1.0			

Class FAMILY *Genus species*	**Common Name**	**Wetland**												**Conservation Significance**		
		Reedy Lake		**Hospital Swamps**		**Connewarre Lake**		**Barwon Estuary**		**Salt Swamp**		**Murtnaghurt Swamp**		**EPBC†**	**Victoria§**	
		Records	**Mean Count**	**Records**	**Mean Count**	**Records**	**Mean Count**	**Records**	**Mean Count**	**Records**	**Mean Count**	**Records**	**Mean Count**		**Rating**	**Listing FFGA**
TURDIDAE																
Turdus merula	Common Blackbird	13	1.0	9	0.0	3	0.0	68	0.4	1		3	3.0			
TURNICIDAE																
Turnix velox	Little Button-quail							1	0.0						NT	
TYTONIDAE																
Tyto delicatula (javanica)	Australian Barn Owl					1	1.0			1	0.0					
Number of Species	**219**	**139**		**139**		**144**		**166**		**80**		**62**		**88**	**53**	**25**
Wetland Dependent Species (W)		**76**		**67**		**76**		**60**		**25**		**25**				
Mammalia																
TACHYGLOSSIDAE																
Tachyglossus aculeatus	Short-beaked Echidna							1	1.0							
CANIDAE																
Vulpes vulpes	Red Fox *****	4	1.3			1	3.0					1	2.0			
CERVIDAE																
Cervus dama	Fallow Deer *	1		1												
DELPHINIDAE																
Tursiops truncatus	Common Bottlenose Dolphin							1								
LEPORIDAE																
Lepus europas	European Hare *	1		1												
Oryctolagus cuniculus	European Rabbit *****	1	10.0			1	2.0									
MACROPODIDAE																
Macropus giganteus	Eastern Grey Kangaroo					1										
Wallabia bicolor	Black Wallaby							1	1.0							
MURIDAE																
Hydromys chrysogaster	Water Rat	1	1.0													
Mus musculus	House Mouse *****							1	1.0							
Rattus norvegicus	Brown Rat *							1								
OTARIIDAE																
Arctocephalus pusillus doriferus	Australian Fur Seal							1								
PHASCOLARCTIDAE																
Phascolarctos cinereus	Koala					1	1.0									
PTEROPODIDAE																
Pteropus poliocephalus	Grey-headed Flying-fox	1	2											VU	VU	L

Class FAMILY *Genus species*	Common Name	Wetland: Reedy Lake Records	Reedy Lake Mean Count	Hospital Swamps Records	Hospital Swamps Mean Count	Connewarre Lake Records	Connewarre Lake Mean Count	Barwon Estuary Records	Barwon Estuary Mean Count	Salt Swamp Records	Salt Swamp Mean Count	Murtnaghurt Swamp Records	Murtnaghurt Swamp Mean Count	Conservation Significance: EPBC†	Victoria§ Rating	Victoria§ Listing FFGA
Number of Species		**3**		**0**		**3**		**3**		**0**		**1**		**1**	**1**	**1**
Reptilia																
ELAPIDAE																
Austrelaps superbus	Lowland Copperhead			1	1.0											
SCINCIDAE																
Bassiana duperreyi	Eastern Three-lined Skink					1										
Ctenotus robustus	Large Striped Skink			1	2.0											
Number of Species		**0**	**0**	**2**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Invertebrates																
Hesperilla flavescens flavescens	Yellow Sedge-skipper									1	0.0	1	0.0		VU	L
Paratya australiensis	Common Freshwater Shrimp	1	150													

Data Source: Department for Sustainability and Environment VBA Flora and Fauna Dataset (inclusive to October 2010).

†EPBC: National conservation rating: *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

CE Critically Endangered: A taxon is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.

EN Endangered: A taxon is endangered when it is not critically endangered but is facing a very high risk of extinction in the wild in the near future.

VU Vulnerable: A taxon is vulnerable when it is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium-term future.

C: CAMBA China-Australia Migratory Bird Agreement. J: JAMBA Japan-Australia Migratory Bird Agreement. R: RoKAMBA Republic of Korea- Australia Migratory Bird Agreement.

m: migratory

§Victoria: State Conservation rating (DSE Advisory List)

CE Critically Endangered: it is considered to be facing an extremely high risk of extinction in the wild.

EN Endangered: it is considered to be facing a very high risk of extinction in the wild.

VU Vulnerable: it is considered to be facing a high risk of extinction in the wild.

NT Near Threatened: it does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

FFGA: Victorian Flora and Fauna Guarantee Act

W: Wetland dependent species

* feral animal

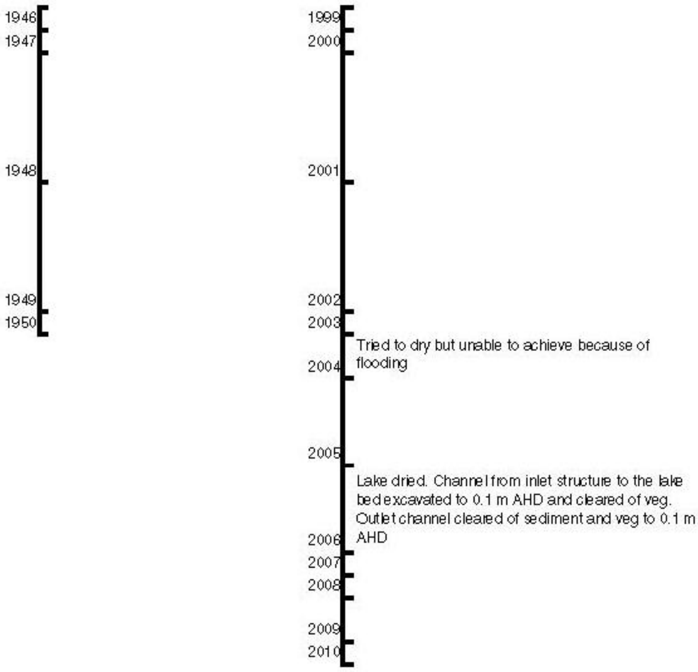
8 APPENDIX B: LOWER BARWON WETLANDS HISTORICAL WATER REGIMES

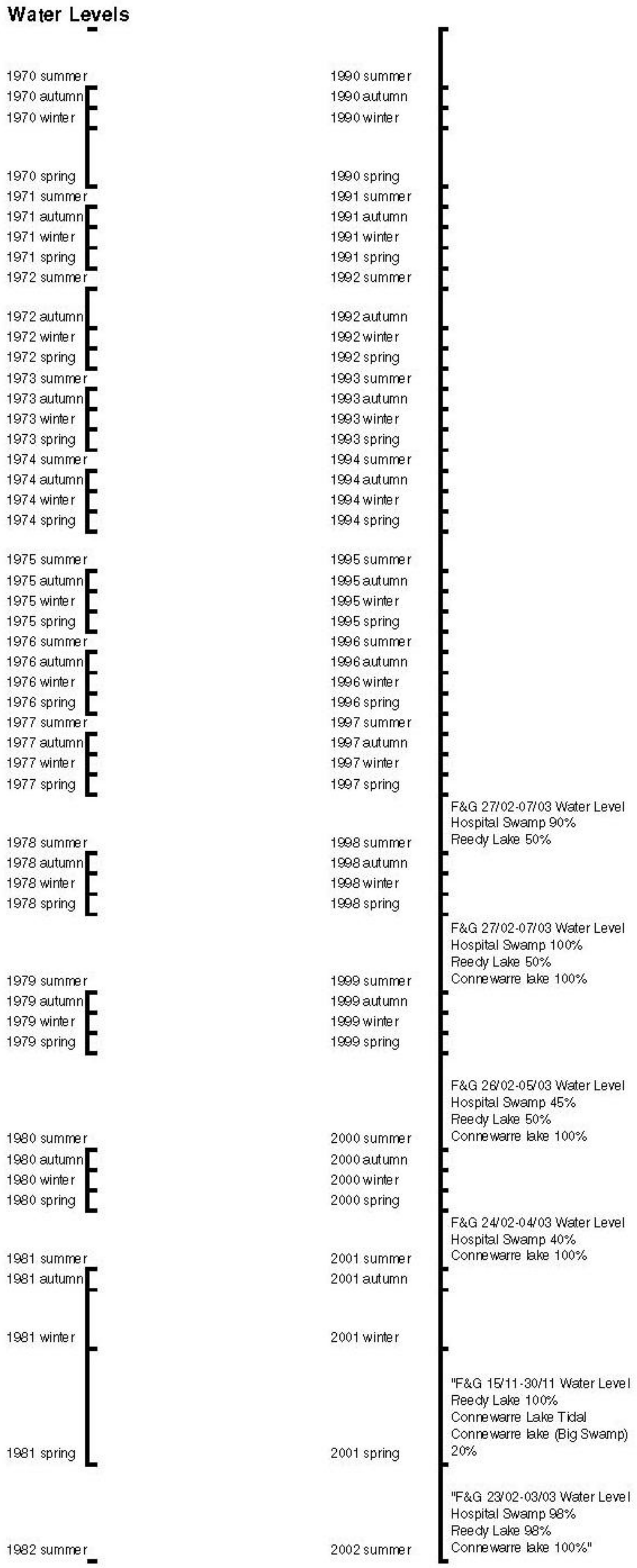
The historical water regimes are shown in the following series of diagrams.

Reedy Lake - Management History

Pre 1898	Ephemeral Wetland
1898	Lower Breakwater Constructed
1899	
1900	
1901	
1902	
1903	
1904	
1905	
1906	Dry lake with prolonged dry weather
1907	
1908	
1909	
1910	
1911	
1912	
1913	
1914	
1915	
1916	
1917	
1918	
1919	
1920	
1921	
1922	
1923	
1924	
1925	
1926	
1927	
1928	
1929	
1930	
1931	
1932	
1933	
1934	
1935	
1936	
1937	
1938	
1939	
1940	
1941	
1942	
1943	
1944	
1945	

1950	Floating gate structure replaces lower breakwater. Water level 0.3 m lower than historical	
1951		
1952		
1953	Channel cut to Reedy from regulator to aid inflows. Water entering the lake rapidly drained to estuary.	
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961	1961 Reed declared a State Game reserve	
1962		
1963	Typical water regime in 1960's: flooding in central lake 3 to 4 times/year. Water retained between floods. Mostly dry by February	
1964		
1965		
1966		
1967	Drought. Bank at outlet raised to 0.7 to 0.8 m AHD.	
1968	Inlet structure sabotaged to fill lake	
1969		
1970	Outlet regulated by raising the sill to 0.2 m (AHD?), and flap gate regulator installed.	
1971		
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979	Carp arrived in Barwon River	
1980		
1981		
1982		Reedy Lake full winter / spring (0.8 m AHD). Level in high flows up to 1.2 m AHD. Drying to average 0.3 m AHD by late summer. Refilling in response to autumn breaks, usually April/May.
1983		
1984		
1985	Grazing and irrigation licences terminated	
1986		
1987		
1988		
1989		
1990	Cessation of supplementation by brackish (~4,500 EC) water discharged to the Moorabool from a dewatering quarry which maintained weir pool upstream of lower breakwater	
1991		
1992		
1993		
1994	F & G drained lake by cutting a new outlet	
1995		
1996	Lake dry for first time since 1970's. Sill of drain at 0.1 m AHD. Regulator on outlet channel installed	
1997	Regulator from Barwon upgraded. Two box culverts closed and flap gate on third replaced with a penstock regulator and fish screen	Lake Dried completely summer 1997/98
1998	First Brolgas recorded	


1946
1947
1948
1949
1950
1999
2000
2001
2002
2003
Tried to dry but unable to achieve because of flooding
2004
2005
Lake dried. Channel from inlet structure to the lake bed excavated to 0.1 m AHD and cleared of veg. Outlet channel cleared of sediment and veg to 0.1 m AHD
2006
2007
2008
2009
2010


Water Levels
1970 summer
1970 autumn
1970 winter
1970 spring
1971 summer
1971 autumn
1971 winter
1971 spring
1972 summer
1972 autumn
1972 winter
1972 spring
1973 summer
1973 autumn
1973 winter
1973 spring
1974 summer
1974 autumn
1974 winter
1974 spring
1975 summer
1975 autumn
1975 winter
1975 spring
1976 summer
1976 autumn
1976 winter
1976 spring
1977 summer
1977 autumn
1977 winter
1977 spring
1978 summer
1978 autumn
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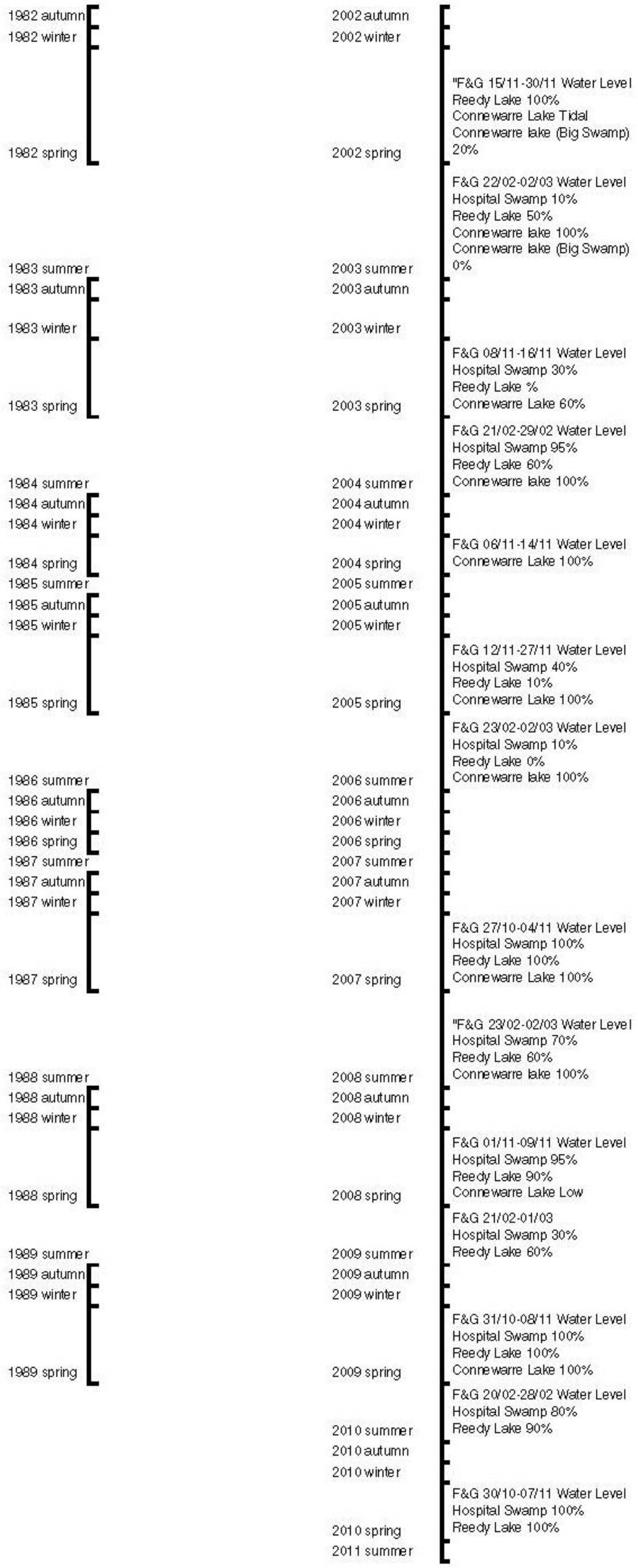
1991 spring
1992 summer
1992 autumn
1992 winter
1992 spring
1993 summer
1993 autumn
1993 winter
1993 spring
1994 summer
1994 autumn
1994 winter
1994 spring
1995 summer
1995 autumn
1995 winter
1995 spring
1996 summer
1996 autumn
1996 winter
1996 spring
1997 summer
1997 autumn
1997 winter
1997 spring
F&G 27/02-07/03 Water Level
Hospital Swamp 90%
Reedy Lake 50%
1998 summer
1998 autumn
1998 winter
1998 spring
F&G 27/02-07/03 Water Level
Hospital Swamp 100%
Reedy Lake 50%
Connewarre lake 100%
1999 summer
1999 autumn
1999 winter
1999 spring
F&G 26/02-05/03 Water Level
Hospital Swamp 45%
Reedy Lake 50%
Connewarre lake 100%
2000 summer
2000 autumn
2000 winter
2000 spring
F&G 24/02-04/03 Water Level
Hospital Swamp 40%
Connewarre lake 100%
2001 summer
2001 autumn
2001 winter
"F&G 15/11-30/11 Water Level
Reedy Lake 100%
Connewarre Lake Tidal
Connewarre lake (Big Swamp)
20%
2001 spring
"F&G 23/02-03/03 Water Level
Hospital Swamp 98%
Reedy Lake 98%
Connewarre lake 100%"
2002 summer


1982 autumn
1982 winter
1982 spring
1983 summer
1983 autumn
1983 winter
1983 spring
1984 summer
1984 autumn
1984 winter
1984 spring
1985 summer
1985 autumn
1985 winter
1985 spring
1986 summer
1986 autumn
1986 winter
1986 spring
1987 summer
1987 autumn
1987 winter
1987 spring
1988 summer
1988 autumn
1988 winter
1988 spring
1989 summer
1989 autumn
1989 winter
1989 spring
2002 autumn
2002 winter
"F&G 15/11-30/11 Water Level
Reedy Lake 100%
Connewarre Lake Tidal
Connewarre lake (Big Swamp)
20%
2002 spring
F&G 22/02-02/03 Water Level
Hospital Swamp 10%
Reedy Lake 50%
Connewarre lake 100%
Connewarre lake (Big Swamp)
0%
2003 summer
2003 autumn
2003 winter
F&G 08/11-16/11 Water Level
Hospital Swamp 30%
Reedy Lake %
Connewarre Lake 60%
2003 spring
F&G 21/02-29/02 Water Level
Hospital Swamp 95%
Reedy Lake 60%
Connewarre lake 100%
2004 summer
2004 autumn
2004 winter
F&G 06/11-14/11 Water Level
Connewarre Lake 100%
2004 spring
2005 summer
2005 autumn
2005 winter
F&G 12/11-27/11 Water Level
Hospital Swamp 40%
Reedy Lake 10%
Connewarre Lake 100%
2005 spring
F&G 23/02-02/03 Water Level
Hospital Swamp 10%
Reedy Lake 0%
Connewarre lake 100%
2006 summer
2006 autumn
2006 winter
2006 spring
2007 summer
2007 autumn
2007 winter
F&G 27/10-04/11 Water Level
Hospital Swamp 100%
Reedy Lake 100%
Connewarre Lake 100%
2007 spring
"F&G 23/02-02/03 Water Level
Hospital Swamp 70%
Reedy Lake 60%
Connewarre lake 100%
2008 summer
2008 autumn
2008 winter
F&G 01/11-09/11 Water Level
Hospital Swamp 95%
Reedy Lake 90%
Connewarre Lake Low
2008 spring
F&G 21/02-01/03
Hospital Swamp 30%
Reedy Lake 60%
2009 summer
2009 autumn
2009 winter
F&G 31/10-08/11 Water Level
Hospital Swamp 100%
Reedy Lake 100%
Connewarre Lake 100%
2009 spring
F&G 20/02-28/02 Water Level
Hospital Swamp 80%
Reedy Lake 90%
2010 summer
2010 autumn
2010 winter
F&G 30/10-07/11 Water Level
Hospital Swamp 100%
Reedy Lake 100%
2010 spring
2011 summer