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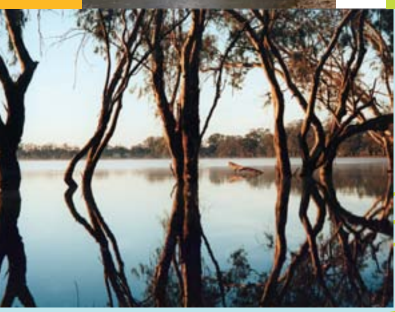

Hattah-Kulkyne Lakes

Ramsar Site

Ecological Character Description

June 2011

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

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

The *Water Act 2007* requires that in preparing the Murray-Darling Basin Plan, the Murray-Darling Basin Authority (MDBA) must take into account ECDs of declared Ramsar wetlands prepared in accordance with the National Framework.

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

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

Cover photos (left to right):
Hattah-Kulkyne Lakes – Mark Mohell, DSEWPaC; Hattah-Kulkyne Lakes sunset – Nicky Marshall, DSEWPaC; yellow rosella at Hattah-Kulkyne Lakes – Brian Furby, DSEWPaC; Hattah-Kulkyne Lakes – Mark Mohell, DSEWPaC.

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Glossary

Definitions of words associated with ECDs (DEWHA 2008 and references cited within).

Benefits	Benefits/services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	A scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc. (Ramsar Convention 2005).
Biological diversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity) and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005).
Blackwater	Tannin stained, low oxygen water as a result of the microbial breakdown of organic matter.
Change in ecological character	The human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005, Resolution IX.1 Annex A).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	All the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Conceptual model	Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003).
Contracting Parties	Countries that are Member States to the Ramsar Convention on Wetlands; 160 as at August 2010. Membership in the Convention is open to all states that are members of the United Nations, one of the United Nations specialised agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice.
Critical stage	Stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers, moulting etc.) which, if interrupted or prevented from occurring, may threaten long-term conservation of the species (Ramsar Convention 2005).
Ecological character	The combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.
Ecosystems	The complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services) (Millennium Ecosystem Assessment 2005).
Ecosystem components	The physical, chemical and biological parts of a wetland (from large scale to very small scale, for example habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	The changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the

	non-living environment that result in existing ecosystems and bring about changes in ecosystems over time.
Ecosystem services	The benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food and water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational) and supporting (e.g. nutrient cycling, ecological value) (Millennium Ecosystem Assessment 2005). See also “Benefits”.
Essential elements	A component or process that has an essential influence on the critical components, processes or services (CPS) of the wetland. Should the essential element cease, reduce or be lost, it would result in a detrimental impact on one or more critical CPS. Critical CPS may depend in part or fully on essential elements; however, an essential element is not in itself critical for defining the ecological character of the site.
Fluvial geomorphology	The study of water-shaped landforms.
Indigenous species	A species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Limits of Acceptable Change	The variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance (“Ramsar List”)	The list of wetlands which have been designated by the Ramsar Contracting Party in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties.
Ramsar	City in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention’s short title “Ramsar Convention on Wetlands”.
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values.
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names “Convention on Wetlands (Ramsar, Iran, 1971)” or “Ramsar Convention” are more commonly used.
Ramsar Information Sheet (RIS)	The form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological and socioeconomic issues (among others), ownership and jurisdictions, and conservation measures taken and needed.
Ramsar List	The List of Wetlands of International Importance.
Ramsar Sites	Wetlands designated by Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar criteria.
Waterbirds	“Birds ecologically dependent on wetlands” (Article 1.2). This definition thus includes any wetland bird species. However, at the broad level of taxonomic order, it includes especially: • penguins: *Sphenisciformes*; • divers: *Gaviiformes*; • grebes: *Podicipediformes*;

	• wetland pelicans, cormorants, darters and allies: *Pelecaniformes*; • herons, bitterns, storks, ibises and spoonbills: *Ciconiiformes*; • flamingos: *Phoenicopteriformes*; • screamers, swans, geese and ducks (wildfowl): *Anseriforme*s; • wetland related raptors: *Accipitriformes* and *Falconiformes*; • wetland related cranes, rails and allies: *Gruiformes*; • Hoatzin: *Opisthocomiformes*; • wetland related jacanas, waders (or shorebirds), gulls, skimmers and terns: *Charadriiformes*; • coucals*: Cuculiformes*; and • wetland related owls: *Strigiformes*.
Waterfowl	Waterbirds of the order Anseriformes, especially members of the family Anatidae, which includes ducks, geese and swans.
Wetlands	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland types	As defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-26-76%5E21235_4000_0__].

List of Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealar
AWSG	Australasian Waders Studies Group
CAMBA	China Australia Migratory Bird Agreement
CMA	Catchment Management Authority
CMS	The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention)
CPS	Components, processes and services
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth) (now DSEWPaC)
DSE	Department of Sustainability and Environment (Victoria)
DPI	Department of Primary Industries (Victoria)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth) (formerly DEWHA)
ECD	Ecological Character Description
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999 (Commonwealth)
EPBC Regulations	Environment Protection and Biodiversity Conservation Regulations, 2000 (Commonwealth)
GBCMA	Goulburn Broken Catchment Management Authority
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
RAOU	Royal Australasian Ornithologists Union
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
NCCMA	North Central Catchment Management Authority
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement
VWSG	Victorian Waders Studies Group

Executive Summary

This Ecological Character Description (ECD) represents the second ECD prepared for the Hattah-Kulkyne Lakes Ramsar site. The first (DSE 2010) was prepared in 2005 using the *Framework for describing the ecological character of Ramsar wetlands* (DSE 2005) which pre-dated the current *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008). This second ECD updates the description of ecological character in line with the current national framework.

The Hattah-Kulkyne Lakes Ramsar site is located in northern Victoria and consists of 12 floodplain lakes within the Hattah-Kulkyne National Park. It is part of the Hattah Lakes Icon Site, one of six icon sites under The Living Murray (TLM) program established in 2002. The lakes lie on the floodplain approximately 15 kilometres from the Murray River and are fed by Chalka Creek. The lakes include systems which hold water for several years after filling events and are important aquatic habitat in a semi-arid environment. The lakes provide habitat for a large number of bird species and native fish populations. The site was originally nominated as a Wetland of International Importance under the Ramsar Convention in 1982. The boundary of the site is the high water mark of Lakes Arawak, Bitterang, Brockie, Bulla, Cantala, Hattah, Lockie, Konardin, Kramen, Mournpall, Yerang, Yelwell and a small section of Chalka Creek between Lakes Lockie, Yerang and Mournpall. Significant areas of the floodplain are not included in the site.

The Hattah-Kulkyne Lakes Ramsar site met the following five criteria both at the time of listing and currently:

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

The Hattah-Kulkyne Lakes are the largest series of floodplain lakes along the Murray River and the site is considered representative of a good example of a series of large, hydrologically connected, permanent and intermittent floodplain lakes. The lakes are approximately 15 kilometres from the Murray River with most being fed by Chalka Creek and lie within a National Park. The lakes are the central feature of the floodplain and National Park and are representative of a large relatively intact section of Murray River floodplain.

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

Hattah-Kulkyne Lakes is considered to be an important site for three wetland dependent threatened species that are listed at the national and/or international level: the Australian painted snipe (*Rostratula australis*), regent parrot (eastern) (*Polytelis anthopeplus monarchoides*) and winged peppercress (*Lepidium monoplocoides*). There is a low degree of certainty that the site is important for other listed threatened species that are known to occur at the site, including the Australasian bittern (*Botaurus poiciloptilus*), silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii*) and flat-headed galaxias (*Galaxias rostratus*).

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

The Ramsar site and the surrounding National Park support considerable biodiversity, with flora and fauna representative of Murray River floodplain and mallee country. Species richness is high across several groups of biota including plants and waterbirds, being comparable to several other Ramsar sites in the Murray-Darling Basin. The soil seed bank from within the lakes has high species richness and is comparable to that recorded from entire floodplain systems such as Narran Lakes. Native fauna diversity is higher than some nearby floodplain forest systems, which is noteworthy given that the Ramsar boundary does not include significant areas of floodplain, just the lakes up to the high water mark.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***

The Hattah-Kulkyne Lakes Ramsar site provides habitat for 70 species of wetland birds, of which 34 have been recorded breeding within the site. In addition, the site supports a number of migratory species, notably waterbirds and fish, with 12 waterbirds listed as migratory under the EPBC Act as well as under international migratory species treaties. The site is also considered important for fish breeding.

Criteria 8: ***A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.***

This site is considered to be an important nursery area for native fish. Recruitment of juveniles back into the adult population is dependent on the water levels of the lakes being maintained, and for large bodied river specialists there needs to be reconnection to the Murray River for species to return to the riverine habitat. Small bodied wetland specialists breed in the site, with young of the year from fly-specked hardyhead (*Craterocephalus stercusmuscarum*), carp gudgeon (*Hypseleotris* spp.), flat-headed gudgeon (*Philpnodon grandiceps*) and Australian smelt (*Retropinna semoni*) recorded from the site.

* * *

An ECD identifies and describes the components, processes and services, benchmarked to the time of listing. Limits of Acceptable Change (LACs) are developed for the critical components, processes and services identified. An assessment of potential changes since listing with respect to the LACs is undertaken. Supporting components and processes are those that are not necessarily critical to the site's character but nonetheless play an important role in supporting the critical components, processes and services. At Hattah-Kulkyne Lakes, these supporting components and processes include climate, geomorphic setting, water quality, phytoplankton, fringing vegetation and invertebrates. The lakes are predominantly fresh, turbid and support high productivity, with algal blooms a common occurrence in recent years. There are some spatial differences in water quality between lakes. Fringing vegetation provides inputs of coarse woody debris and contributes to carbon cycling within the system. Woody debris and leaf litter from fringing river red gums provide important structural habitat for invertebrates and substrate for the development of biofilms. Invertebrate community structure is comparable to other lake fauna recorded elsewhere in Victoria.

Components and processes that are considered critical to the ecological character of the site include hydrology, lake bed herbland vegetation, fish and waterbirds. The site's climate, geomorphic setting and hydrological regime provide the physical template. The lakes are predominantly fed by inflows from the Murray River via Chalka Creek. Commence-to-flow occurs at 36 700 megalitres per day in the Murray River downstream of Euston. A number of modifications to flow paths and the impacts of river regulation have reduced the frequency and duration of inundation, and changed the timing of peak flows. Delivery of environmental water is possible by pumping via Chalka Creek when water levels are below the commence-to-flow level of 36 700 megalitres per day. The majority of the lakes become dry within 12 months after inflows cease, the exceptions being Lakes Mournpall and Hattah which retain water for several years post-flooding.

The lakes are dominated by one vegetation type: lake bed herbland (Ecological Vegetation Class 107). As the lakes progress from wet to dry to wet, the plant community composition changes from being dominated by aquatic and amphibious species with some terrestrial species on the edges in the wet phase, to being dominated by terrestrial species in the dry phase. The relative length of each inundation event and subsequent dry phase drives the community structure. Fish populations in the early 1990s had a higher proportion of exotic species compared to data collected in response to environmental watering which has been attributed to the water delivery mechanism (pumping). Wetland specialists are common with breeding occurring across several species. Data on large bodied fish such as Murray cod, silver perch and golden perch are limited, but this is potentially a reflection of recent drought conditions. The site supports 70 species of waterbird, 34 which have breed at the site. Many of the breeding records are for single events. Functional feeding groups are dominated by ducks and herbivores, which is a reflection of the dominant habitat of open water with submergent herbland vegetation.

The critical services identified for the Ramsar site are all supporting services. The site supports a suite of near-natural permanent and intermittent freshwater floodplain lakes that in turn provide a range of physical habitats, especially for waterbird breeding and feeding. The lakes are sequentially filled and can remain hydrologically and ecologically connected for different periods of time depending on the magnitude of the floods. On recession of floodwaters the presence of permanent water in the deeper lakes, especially Mournpall and Hattah, provides critical drought refuges and maintains populations of obligate aquatic species. The lakes, set in the National Park, support a biodiversity typical of Murray River floodplain systems and are comparable to several other Ramsar sites across the Murray-Darling Basin in terms of species richness across several groups of biota. Contributing to the biodiversity value of the site are seven nationally and internationally listed threatened species, not all of which are considered critical to the character of the site.

Threats to the ecological character of the site include water resource development, climate change, grazing and invasive species. River regulation has led to a reduced frequency and duration of inundation leading to loss of habitat and diversity of hydrological regimes. Declining rainfall and increased summer rainfall intensity exacerbates the impacts of water resource development as was evident from 2000 to 2010. Climate change may result in a decline in water quality, with a likely increase in the incidence of algal blooms. Historic grazing by native and introduced herbivores on the edges of lakes and dry lake beds has influenced plant community structure, most notably river red gum recruitment. Rabbit (*Oryctolagus cuniculus*) and kangaroo control programs have reduced but not completely removed this threat. Common carp (*Cyrpinus carpio*) and other invasive fish species were largely absent from the lakes during the period 2005 to 2010, but with recent flows have returned to the system. Carp are a particular concern in terms of contributing to turbidity and impacts on aquatic macrophytes. River red gum encroachment into the lakes occurred during the drought and has the potential to change habitat structure in the littoral zone of the lakes.

The LACs and assessment of current conditions are summarised in Table E1. Assessment of change since designation in 1982 for the Hattah-Kulkyne Ramsar site is limited by a lack of baseline data from the time of listing. This is particularly so for biotic critical components, processes and services. More recent data have become available through The Living Murray initiative with icon site condition monitoring and intervention monitoring being undertaken in response to allocation of emergency environmental water from 2005.

An assessment of current conditions with respect to LACs indicates that elements of the hydrological regime and lake bed herbland vegetation have changed. However, whether these changes are a result of sustained change or the effects of the recent (2000 to 2010) drought is unknown. It is likely due to a combination of factors that include water resource development, climate change and shorter term climatic cycles. At this point in time the ecological character of the site is not considered to have changed significantly, however if the changes in hydrology continue then this may lead to a change in character of other critical components and services.

As with most Ramsar sites, understanding of the ecological character of Hattah-Kulkyne Lakes is limited. Key knowledge gaps exist for a number of critical components, processes and services, most of which relate to a lack of data regarding conditions at the time of listing. A number of monitoring needs to address these knowledge gaps and aid assessment against LACs have been recommended.

<u>Additional explatory notes on LACs</u>

Limits of Acceptable Change are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LACs does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LACs may require investigation to determine whether there has been a change in ecological character.

In reading the ECD and the LACs, it should be recognised that the hydrology of many catchments in the Murray-Darling Basin is highly regulated, despite many of the wetlands forming under natural hydrological regimes that were more variable and less predictable. Many of the Ramsar wetlands of the Murray-Darling Basin were listed at a time when the rivers were highly regulated and water over allocated, with the character of these sites reflecting the prevailing conditions. When listed under the Ramsar Convention, many sites were already on a long-term trend of ecological decline.

While the best available information has been used to prepare this ECD and define LACs for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The LACs may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this ECD and carefully evaluate the suitability of the information for their own purposes.

LACs can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

Table E1: Summary of critical components, process and services, LACs and current conditions.

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
Hydrology	No less than three filling events for Lakes Lockie, Hattah, Yerang and Mournpall in any 10 year period. No less than two filling events for Lakes Cantala and Bulla in any 10 year period. No less than one filling event for Lakes Arawak, Brockie, Bitterang, Konardin and Yelwell in any 10 year period No less than one filling event at Lake Kramen in any 20 year period. Note: Filling events can be achieved by above-threshold flow events in the Murray River or by delivery of environmental water via pumping.	Based on flow data from the Murray River downstream of Euston and filling events from environmental watering (S Ramamurthy, DSE, pers. comm.): Lakes Lockie, Hattah, Yerang and Mournpall Six overbank filling events (based on events of 40 000 megalitres per day of 60 days duration) in the period 1982 to 2000, no overbank filling events in the period 2000 to 2010, but Lakes Lockie, Hattah and Yerang were filled via pumping three times between 2005 to 2010. Lake Mournpall was filled twice via pumping between 2005 and 2010. **LAC has not been exceeded.** Lakes Bulla and Cantala No overbank filling events in the period 2000 to 2010, however four events occurred between 1982 and 1990 (based on events of 50 000 megalitres per day of 60 days duration). Lake Bulla had three filling events via pumping between 2005 and 2010. **LAC is considered exceeded as Lake Cantala did not have any filling events in the past 10 years; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency of filling events.** Lakes Arawak, Brockie, Bitterang, Konardin, and Yelwell One overbank filling event (based on 70 000 megalitres per day of 30 days duration) in the period 1990 to 2010. All lakes except Bitterang had one filling event in 2009 via pumping. **LAC is considered exceeded as there have been no filling events at Lake Bitterang in the past 10 years; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency of filling events.**

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
		Lake Kramen No overbank filling events (152 000 megalitres per day for 30 days duration) since listing. Single filling event in October 2010 via pumping. **LAC has not been exceeded.** **Overall, this LAC has been exceeded.**
Lake bed herbland vegetation	Extent of lake bed herbland vegetation to be no less than 776 hectares.	Not quantitatively assessed but on visual assessment of limited number of aerial photographs taken in 2009 this LAC is likely to be exceeded. Need baseline aerial photography at or near the time of listing against which to assess change. **LAC not assessed but presumed exceeded.**
Fish	Presence of the following wetland specialist species of native fish recorded over any three sampling events over a five year period in which at least three of the lakes are inundated. • Australian smelt *Retropinna semoni* • Bony herring *Nematalosa erebi* • Carp gudgeon *Hypseleotris* spp. • Western carp gudgeon *Hypseleotris klunzingeri* • Fly-specked hardyhead *Craterocephalus stercusmuscarum*	All target species have been recorded from intervention monitoring and icon site condition monitoring undertaken from 2006 to 2010 (Walters et al. 2010). **LAC has not been exceeded.**
Waterbirds – number of species	At least eight of the following species in at least 10 years of any 20 year period in which at least three of the lakes are inundated: • Australian pelican *Pelecanus conspicillatus* • Australian wood duck *Chenonetta jubata*	Ten of the 11 target species have been recorded in 10 or more years over the period 1990 to 2010 (Birds Australia, 2011b). • Australian pelican – 14 years • Australian wood duck – 15 years • Black-winged stilt – 10 years

<table>
<tr><th>Critical Components, Processes and Services</th><th>Limit of Acceptable Change</th><th>Current conditions</th></tr>
<tr><td></td><td>• Black-winged stilt Himantopus himantopus
• Australian darter Anhinga novaehollandiae
• Great cormorant Phalacrocorax carbo
• Great crested grebe Podiceps cristatus
• Little black cormorant Phalacrocorax sulcirostris
• Masked lapwing Vanellus miles
• Pacific black duck Anas superciliosa
• White-faced heron Egretta novaehollandiae
• Yellow-billed spoonbill Platalea flavipes</td><td>• Australian darter – nine years
• Great cormorant – 12 years
• Great crested grebe – 10 years
• Little black cormorant – 10 years
• Masked lapwing – 15 years
• Pacific black duck – 16 years
• White-faced heron – 13 years
• Yellow-billed spoonbill – 12 years
LAC has not been exceeded.</td></tr>
<tr><td>Threatened species – regent parrot (eastern)</td><td>Presence within Ramsar site on an annual basis.</td><td>Annual data are limited, however it is expected that this LAC is met. Regent parrots were recorded at the site in 8 of the past 10 years, including the past four (Birds Australia, 2011b).
LAC has not been exceeded.</td></tr>
<tr><td>Threatened species – winged peppercress</td><td>Presence between Lake Hattah and Lake Bulla in years when conditions are suitable.</td><td>No available data, LAC unable to be assessed.
LAC unable to be assessed.</td></tr>
<tr><td>Near natural wetland type</td><td colspan="2">This critical service is linked principally to changes in the hydrology as well as changes in extent and condition of wetland vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in herbland vegetation and frequency of flow events. See LACs for hydrology and lake bed herbland vegetation.*</td></tr>
<tr><td>Physical habitat which supports waterbird breeding</td><td colspan="2">This critical service is linked to changes in the frequency of wetland wetting and drying periods as well as changes in the extent and condition of wetland and floodplain vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through the LACs for hydrology and lake bed herbland vegetation. See LACs for hydrology and lake bed herbland vegetation.*</td></tr>
</table>

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
Biodiversity	The site is hydrologically connected with the river and on the floodplain there are interconnections between some of the lakes in which wetland dependent species establish. The wetting and drying of the lakes promotes diversity and this service is maintained by hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology. *See LAC for hydrology*. *	
Ecological connectivity	The site is hydrologically connected with the river and on the floodplain there are interconnections between some of the lakes in which fish populations and other aquatic biota establish. This service is maintained by hydrology and can also be indicated by the species richness of native fish. The key elements of connectivity are unimpeded flow and reconnection to the Murray River to allow recruitment of species into the regional population. The delivery of environmental water by pumping may affect connectivity. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and native fish populations. *See LAC for hydrology and fish. **	

* Note that the limits of acceptable change for some components (e.g. hydrology, fish) currently provide the best indication of limits of acceptable change for critical services (e.g. near natural wetland type, physical habitat which supports waterbird breeding, biodiversity and ecological connectivity) but it is not a comprehensive measure. Thus, the exceedance of LACs for relevant critical component does not necessarily indicate that critical services have unacceptably changed. The assessment of potential change in a critical service must consider all relevant information and a direct LAC should be developed if data become available.

1. Introduction

This ECD represents the second ECD prepared for the Hattah-Kulkyne Lakes Ramsar site. The first ECD (DSE 2010) was prepared in 2005 using the *Framework for describing the ecological character of Ramsar wetlands* (DSE 2005) which pre-dated the current *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (National Framework) (DEWHA 2008). This second ECD updates the first (DSE 2010) in line with the National Framework.

1.1 Site details

The Hattah-Kulkyne Lakes Ramsar site is located in northern Victoria approximately 480 kilometres north-west of Melbourne, 80 kilometres south south-east of Mildura and 40 kilometres north north-east of Ouyen. The site comprises 12 floodplain lakes subject to flooding from the Murray River with flows entering the site predominantly via Chalka Creek. The surrounding floodplain and dryland areas and several additional lakes comprise the Hattah Lakes National Park; however, the Ramsar site boundary mainly extends to the high water mark of each of the 12 lakes and includes only small areas of mallee and interconnecting floodplain. The lakes are in near-natural condition and represent a significant complex of Murray River permanent and intermittent floodplain wetlands.

The Hattah-Kulkyne Lakes site was originally nominated as a Wetland of International Importance under the Ramsar Convention in 1982. Site details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for Hattah-Kulkyne Lakes Ramsar site.

Site Name	Hattah-Kulkyne Lakes.
Location in coordinates	Latitude (GDA94): (approx) 34º 39' to 34º 47'S; Longitude (GDA94): (approx) 142º 20'E to 142º 30'E
General location of the site	The Hattah-Kulkyne Lakes Ramsar site is located on the Murray River floodplain in Victoria, approximately 480 kilometres north-west of Melbourne. Bioregion – Drainage Division 4: Murray-Darling (Australia's River Basins Australian Water Resources Council 1987).
Area	955 hectares.
Date of Ramsar site designation	Designated on 15/12/1982.
Ramsar/DIWA Criteria met by wetland	Ramsar criteria 1, 2, 3, 4 and 8.
Management authority for the site	Parks Victoria.
Date the ECD applies	1982.
Status of Description	This represents the second ECD for the site, updating DSE 2010.
Date of Compilation	May 2011.

Name(s) of compiler(s)	Rhonda Butcher and Jennifer Hale on behalf of the Australian Government Department of Sustainability, Environment, Water, Population and Communities.
References to the Ramsar Information Sheet (RIS)	RIS compiled by Parks Victoria in 1999. Updated by Marcus Cooling in 2005 on behalf of DSE.
References to Management Plan(s)	DSE (2003), Hattah-Kulkyne Lakes Ramsar Site Strategic Management Plan, DSE, Victoria. http://parkweb.vic.gov.au/__data/assets/pdf_file/0004/313285/hattah-kulkyne-lakes-ramsar-site-mp.PDF

1.2 Statement of purpose

As a contracting party to the Ramsar Convention, Australia is obliged to promote the conservation of listed sites, promote the wise use of wetlands and report any changes to the ecological character of those sites. Wise use is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development" (Ramsar 2005). Thus understanding and describing the 'ecological character' of a Ramsar site is fundamental to promoting the conservation of Ramsar wetlands and being able to detect changes.

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

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

and

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

The EPBC Act lists Ramsar wetlands as matters of national environmental significance. Actions which have or are likely to have a significant impact on the ecological character of a Ramsar wetland are required to be referred, assessed and approved under the Act (Figure 1). The EPBC Act also provides for Ramsar management principles which guide the development of management plans by site managers.

In order to detect change it is necessary to establish a benchmark for management and planning purposes. An ECD forms the foundation on which a site management plan and associated monitoring and evaluation activities are based. It also forms the basis for the assessment of actions which are likely to impact on the Ramsar site.

The ECD provides details on the interactions between ecological components, processes and services to give a comprehensive description of ecological character. This information supplements the RIS which is prepared at the time of designation. The ECD conforms to the National Framework (DEWHA 2008), which was developed by Australian and state/territory governments.

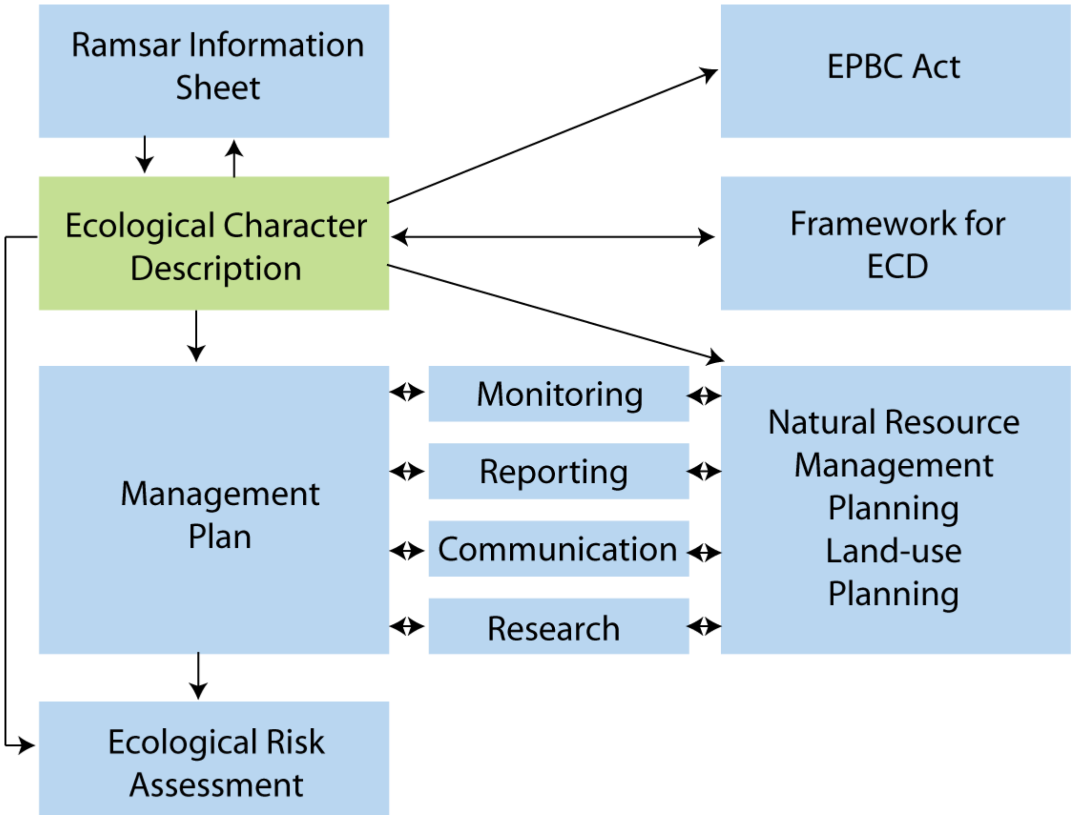


Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008).

<u>The National Framework</u>

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

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

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing Wetlands of International Importance) of the *Environment Protection and Biodiversity Conservation Regulations 2000* (EPBC Regulations) (Commonwealth):

    a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and

    b) To formulate and implement planning that promotes:

        i) Conservation of the wetland; and

        ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.

2. To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.

3. To supplement the description of the ecological character contained in the RIS submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.

4. To assist the administration of the EPBC Act, particularly:

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

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

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

6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

1.3 Relevant treaties, legislation and regulations

The Hattah-Kulkyne Lakes Ramsar site falls within the jurisdiction of the Rural City of Mildura Shire Council and is affected by a number of conventions and legislation. The following provides a brief listing of the legislation and policy that is relevant to the description of the ecological character of the Ramsar site.

International

<u>Ramsar Convention</u>

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

<u>Migratory bird bilateral agreements and conventions</u>

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds, which are relevant to Hattah-Kulkyne Lakes Ramsar site as various migratory bird species covered in these agreements utilise the site. The bilateral agreements are:

- *Japan Australia Migratory Bird Agreement (JAMBA)* – the agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

- *China Australia Migratory Bird Agreement (CAMBA)* – the agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986;

- *Republic of Korea Australia Migratory Bird Agreement (ROKAMBA)* – the agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006; and

- *The Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention)* – the convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species cooperate to prevent migratory species from becoming endangered. For Australian purposes, many of the species are migratory birds.

National

EPBC Act 1999

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

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

The Living Murray (TLM) Initiative, 2002

TLM instigated one of Australia's most significant river restoration programs. It aims to achieve a healthy working River Murray system for the benefit of all Australians, which includes returning water to the river's environment. The Living Murray program was established in response to strong evidence showing the declining health of the River Murray system. It is a partnership of the Australian, New South Wales, Victorian, South Australian and Australian Capital Territory governments.

Water Act 2007

The Water Act provides for the management of the water resources of the Murray-Darling Basin, and to make provision for other matters of national interest in relation to water and water information, and for related purposes.

The [Murray-Darling] Basin Plan

The Basin Plan is a strategic plan for the integrated and sustainable management of water resources in the Murray-Darling Basin. It provides a framework for setting environmentally sustainable limits on the amount of surface water and groundwater that can be taken from the Basin. In addition it identifies, and seeks to protect and restore, key environmental assets which are essential to the life of the rivers, their surrounding landscapes and the cultural values of the communities which depend on those water resources. The Basin Plan takes into account the impact of this protection and restoration on individual communities, industries, regions and the wider economy (http://www.mdba.gov.au/what-we-do/basin-plan).

Native Title Act 1993

This Act provides for the recognition and protection of native title. It establishes ways in which future dealing affecting native title may proceed and sets standards for such dealing. It establishes a mechanism for determining claims to native title. It provides for, or permits, the validation of past acts, and intermediate period acts, invalidated because of the existence of native title.

Victorian

Environment Protection Act 1970

This Act establishes the Environment Protection Authority and makes provision for the Authority's powers, duties and functions. These relate to improving the air, land and water environments by managing waters, control of noise and control of pollution. State Environment Protection Policies (SEPPs) are subordinate legislation made under the provisions of the Act. SEPP (Waters of Victoria) sets water quality objectives to protect the beneficial uses of inland waters.

National Parks Act 1975

This Act makes provision for the preservation and protection of the natural environment including wilderness areas and remote and natural areas. This includes the protection and preservation of indigenous flora and fauna and of features of scenic or archaeological, ecological, geological, historic or other scientific interest in those parks. It allows for the study of ecology, geology, botany, zoology and other sciences relating to the conservation of the natural environment in those parks; and for the responsible management of the land in those parks.

Wildlife Act 1975

This Act ensures procedures are in place to protect and conserve Victoria's wildlife and prevent any taxa of wildlife from becoming extinct. The Act also provides for the establishment of State Game Reserves. Regulations under the Act ensures that the consumptive use or other interactions with flora and fauna in Victoria does not threaten the sustainability of wild populations, while facilitating cultural and recreational pursuits in a humane, safe, ethical and sustainable manner.

Flora and Fauna Guarantee Act 1988

This Act provides a legislative and administrative framework for the conservation of biodiversity in Victoria. The Act provides for the listing of threatened taxa, communities and potentially threatening processes. It requires the preparation of action statements for listed species, communities and potentially threatening processes and sets out the process for implementing interim conservation orders to protect critical habitats. The Act also seeks to provide programs for community education in the conservation of flora and fauna and to encourage co-operative management of flora and fauna.

Water Act 1989

This Act establishes rights and obligations in relation to water resources and provides mechanisms for the allocation of water resources. This includes the consideration of environmental water needs of rivers and wetlands as well as for human uses such as urban water supply and irrigation.

Victorian Water Amendment (Victorian Environmental Water Holder) Act 2010

This Act amends the *Water Act 1989* to establish the Victorian Environmental Water Holder as a body corporate responsible for managing the State's environmental water holdings. In addition it provides for the role of waterway managers in environmental water management; improves the management of environmental water in the State; and makes further provision as to rights and entitlements to water under that Act.

Catchment and Land Protection Act 1994

This Act establishes a framework for the integrated management and protection of catchments. It establishes processes to encourage and support community participation in the management of land and water resources and provides for a system of controls on noxious weeds and pest animals.

Fisheries Act 1995

This Act provides a framework for the regulation, management and conservation of Victorian fisheries. It deals with commercial and recreational licences, fish culture, noxious aquatic species, research and development, the declaration and management of fisheries reserves; and the preparation of management plans for individual fisheries, declared noxious aquatic species and fisheries reserves.

Aboriginal Heritage Act 2006

This Act provides for the protection and management of Victoria's Aboriginal heritage. It establishes the Victorian Aboriginal Heritage Council to advise the Minister in the management of cultural heritage and registered Aboriginal parties. The Act also deals with cultural heritage management plans, cultural heritage permits and agreements. The Act also includes enforcement provisions and processes for handling dispute resolution. This includes the review of certain decisions through the Victorian Civil and Administrative Tribunal (VCAT).

Securing our natural future: A white paper for land and biodiversity at a time of climate change (November 2009)

The Land and Biodiversity White Paper is a long-term, strategic framework to secure the health of Victoria's land, water and biodiversity in the face of ongoing pressures and a changing climate over the next fifty years. The framework for action is based on three inter-related elements:

- Building ecosystem resilience across Victoria;
- Managing flagship areas to maintain ecosystem services; and
- Improving connectivity in areas identified as biolinks.

The Northern Region Sustainable Water Strategy (Northern Region SWS) 2010

The Northern Region SWS aims to identify and understand threats to water availability and quality over the next 50 years, and outlines policies and actions to manage the consequences of prolonged drought and climate change.

1.4 Preparing the ECD

The method used to develop the ECD for the Hattah-Kulkyne Lakes Ramsar site is based on the twelve-step approach provided in the National Framework (DEWHA 2008), illustrated in Figure 2. A more detailed description of each of the steps and outputs required is provided in the source document.

This ECD was developed primarily through a desktop assessment and is based on existing data and information. A stakeholder advisory group was formed to provide input and comment on the ECD. Details of members of this group and more details of the method are provided in Appendix A.

1. Introduction to the description
Site details, purpose of the description, relevant legislation

2. Describe the site
Site location, climate, maps and images, tenure, criteria and wetland types

3. Identify and describe the critical components, processes, benefits and services
3.1 Identify all possible components, processes, benefits and services
3.2 Identify the critical components, processes benefits and services responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes, benefits & services

4. Develop a conceptual model of the wetland
Depict the critical components & processes of the wetland and their interactions

5. Set limits of acceptable change (LAC)
Determine LAC for critical components, processes and services

6. Identify threats to the ecological character of the site
Identify the actual or likely threats to the site

7. Describe changes to ecological character
Describe changes to the ecological character since the time of listing
Include information on the current condition of the site

8. Summarise knowledge gaps
Use information from Steps 3 - 7 to identify knowledge gaps

9. Identify site monitoring needs
Use information from Steps 3 - 8 to identify monitoring needs

10. Identify communication and education messages
Identify any communication & education messages highlighted during the development process

11. Compile the description of ecological character

12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure 2: Twelve step process for developing an ECD (adapted from DEWHA 2008).

2. General Description of Hattah-Kulkyne Lakes Ramsar Site

2.1 Location and regional context

The Hattah-Kulkyne Lakes Ramsar site is located in northern Victoria, within the Murray-Darling Drainage Division. This Drainage Division covers over one million square kilometres and comprises 14 percent of the continent. The Ramsar site is located on the floodplain of the Murray River south east of Mildura and is part of the Hattah Lakes Icon Site, one of six icon sites under The Living Murray program established in 2002. The site includes 12 lakes which lie within the Hattah-Kulkyne National Park (Figure 3). The site is 480 kilometres north-west of Melbourne between Mildura and Ouyen (population 1100, in 2011) in the Rural City of Mildura municipality.

The lakes are subject to flooding from the Murray River with flows entering the site predominantly via Chalka Creek. The lakes are in near natural condition and represent a significant complex of Murray River permanent and intermittent floodplain wetlands. Hattah-Kulkyne Lakes was originally nominated as a Wetland of International Importance under the Ramsar Convention in December 1982.

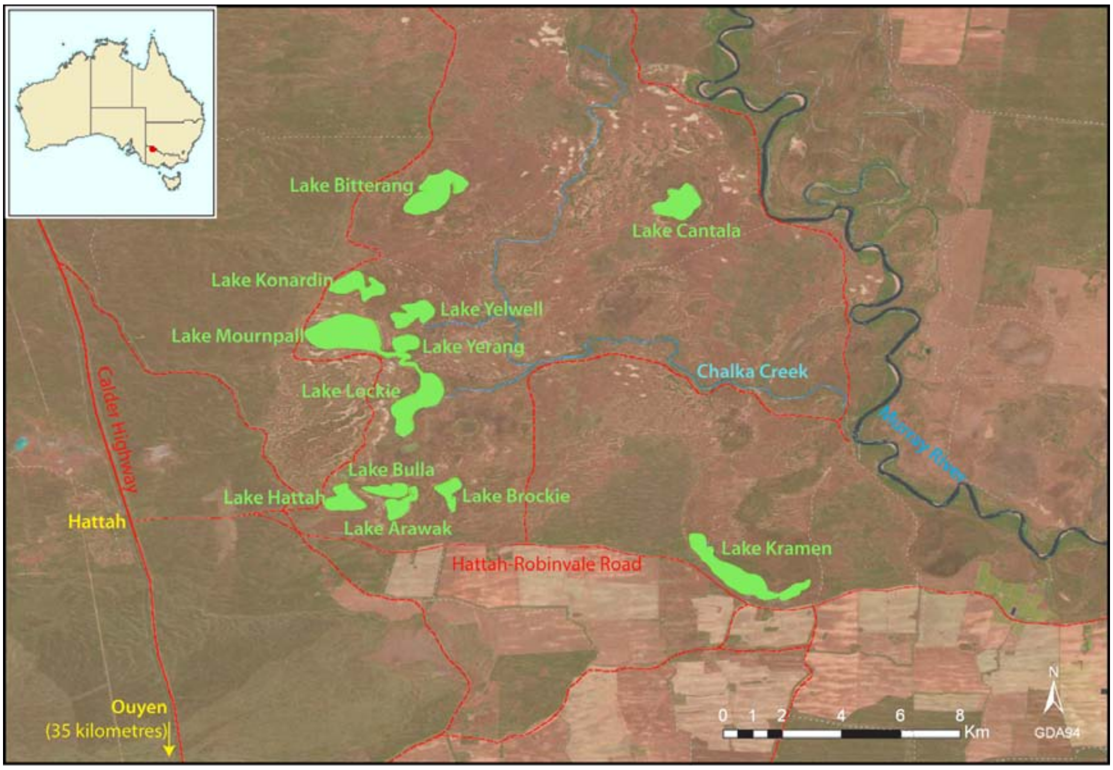


Figure 3: Location of the Hattah-Kulkyne Lakes Ramsar site (from Australian Government 2011).

2.2 Land tenure and land use

Hattah Lakes, an area of 17 820 hectares, was declared as National Park in 1960. This was later incorporated into the Hattah-Kulkyne National Park, which was declared in 1980, and covers 48 000 hectares including the 12 lakes of the Ramsar site. The National Park is surrounded by private land, most of which has been cleared for agriculture. The National Park is also part of the network of international Biosphere Reserves coordinated by the UNESCO Man and the Biosphere Program (MDBA 2005).

2.3 Wetland types

Three classification systems have been applied to the wetlands of the Ramsar site: the Ramsar classification, Victorian classification and one developed by Ecological Associates (2007) based on water regime. The Hattah-Kulkyne Lakes have only three Ramsar wetland types – intermittent creeks (Ramsar type N), seasonal intermittent freshwater lakes over eight hectares (Ramsar type P) and permanent freshwater lakes over eight hectares (Ramsar type O), with Ramsar type P being the dominant type. Type N is represented by a small section of Chalka Creek connecting Lakes Lockie, Yerang and Mournpall, and is not considered a major wetland type within the site. The classification of Lakes Mournpall and Hattah as permanent freshwater lakes reflects their status at the time of listing, not currently.

In Victoria, wetlands have been mapped and classified according to the system developed by Corrick and Norman (1980) and defines "permanent" as wetlands that hold water for at least 12 months, although they can have periods of drying, especially during prolonged drought. Ecological Associates (2007) classified the lakes of the Ramsar site into water regimes based on a spell analysis of natural conditions. They assigned three water regimes to the lakes within the Ramsar site: persistent temporary wetlands, semi-permanent wetlands and Lake Kramen as episodic.

This classification classes those wetlands which are greater than 50 percent full more than 76 percent of the time as being semi-permanent wetlands. These wetlands are described as relatively deep and dry events are rare, occurring less than 13 percent of the time. Dry periods are described as typically lasting less than 12 months. Once full, these wetlands typically retain water for up to 30 weeks (Ecological Associates 2007).

Persistent temporary wetlands are shallower and only reach 50 percent capacity approximately 60 percent of the time. This group of wetlands are classed as being dry approximately one year in four with dry events having a median duration of approximately six to 12 months (Ecological Associates 2007). Frequency of inundation varies according to the position in the landscape. Lake Kramen is classed as an episodic wetland. It has a relatively high sill (42.6 m AHD) and is only inundated rarely (Ecological Associates 2007).

Surface area and a summary of the different wetland classifications for each wetland in the Ramsar site is presented in Table 2. Throughout the ECD, the Ramsar type and water regime of Ecological Associates will be used to describe the wetlands.

According to the Victorian classification each of the lakes has small fringing areas of river red gum (Figure 4). Lakes Kramen and Brockie each have a small area classified as 'island'. The Ramsar classification for the time of listing is represented in Figure 5.

Table 2: Surface area, depth and wetland type (from SKM 2003b; Ecological Associates 2007; MDBA 2010).

Wetland	Surface area (hectares)	Depth (metres)	Victorian Wetland type	Water regime (Ecological Associates 2007)	Ramsar Wetland type
Arawak	40	2.4	POW – shallow <5m, river red gum	SPW	P
Bitterang	73	2.4	DFM – open water, river red gum	PTW	P
Brockie	28	2.3	POW – shallow <5m, river red gum	SPW	P
Bulla	40	2.5	POW – shallow <5m, river red gum	SPW	P
Cantala	101	2.2	DFM – open water, river red gum	PTW	P
Hattah	61	3.1	POW – shallow <5m, river red gum	SPW	O
Konardin	121	1.7	DFM – open water, river red gum	PTW	P
Kramen	124	2.9	POW – shallow <5m, river red gum	Episodic	P
Lockie	141	1.0	POW – shallow <5m, river red gum	PTW	P
Mournpall	195	3.2	POW – shallow <5m, river red gum	SPW	O
Yelwell	81	1.3	DFM – open water, river red gum	PTW	P
Yerang	65	1.5	POW – shallow <5m, river red gum	PTW	P
Chalka Creek	-	-	-	-	N

POW = Permanent open freshwater, DFM = Deep freshwater marshes; SPW = semi-permanent wetlands; PTW = persistent temporary wetlands; P = seasonal/intermittent freshwater lakes over eight hectares, including floodplain lakes; O = permanent freshwater lakes over eight hectares including large oxbow lakes, N = intermittent creek.

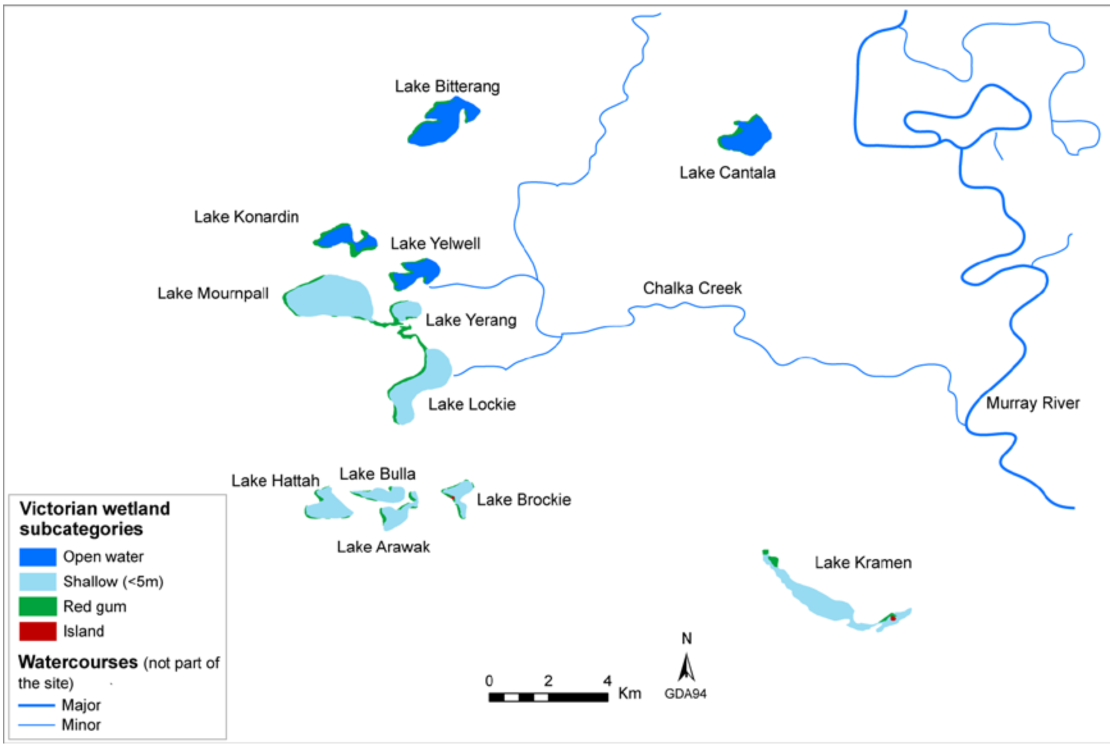


Figure 4: Wetland subcategories, Victorian Classification (data supplied DSE).

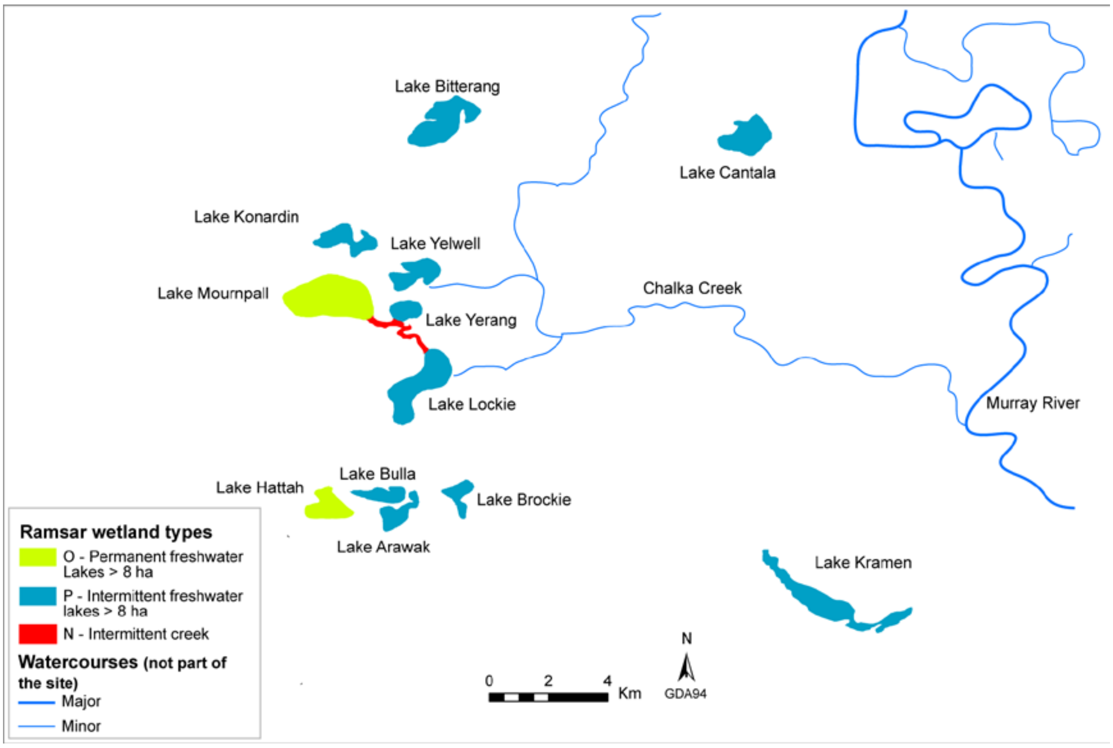


Figure 5: Ramsar wetland types.

Lake Mournpall (Ramsar type O) in the 2006 to 2007 period and Lake Yerang (Ramsar type P) are represented in Figures 6 – 9). A notable feature is the band of regenerating river red gum within the lakes (Figure 9).

Figure 6: Lake Mournpall with fringing river red gum (image courtesy of Victorian EPA).

Figure 7: Lake Yerang January 2011 (Samantha Walters, MDFRC Mildura).

Figure 8: Lake Yerang September 2006 (image courtesy of Parks Victoria).

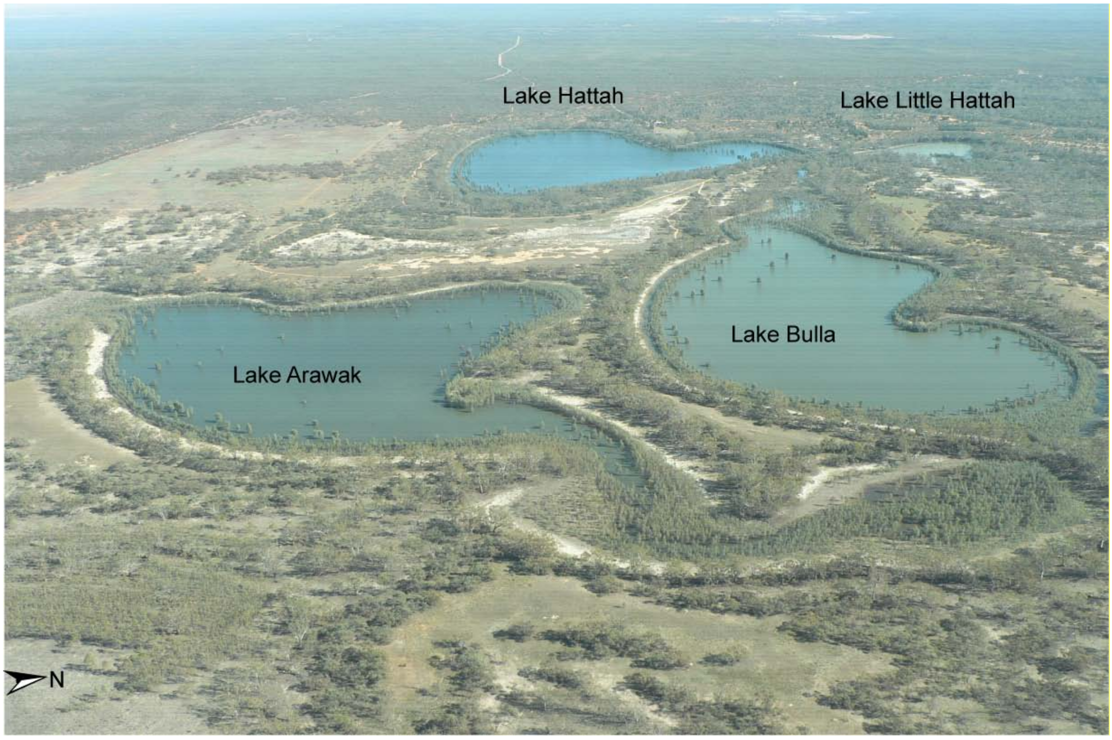


Figure 9: Aerial of Lakes Hattah, Bulla and Arawak September 2006. Lake Little Hattah is not part of the Ramsar site (image courtesy of Parks Victoria).

2.4 Ramsar criteria

2.4.1 Criteria under which the site was designated

When the Hattah-Kulkyne Lakes site was first designated as a Wetland of International Importance (1982), the criteria for identifying Wetlands of International Importance were the "Cagliari criteria", adopted at the first conference of contracting parties in Cagliari in 1980. The original nomination documentation for the Ramsar site considered that the site met two of these criteria as shown in (Table 3), although no justification was provided in the original RIS.

Table 3: Criteria originally used to identify the Hattah-Kulkyne Lakes Ramsar site as a Wetland of International Importance in 1982.

Basis	Number	Description	Criterion met
Criteria for waterfowl.	1a	It regularly supports 10,000 ducks, geese and swans; or 10,000 coots or 20,000 waders.	Not met.
	1b	It regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.	Not met.
	1c	It regularly supports 1% of the breeding pairs in a population of one species or subspecies of waterfowl.	Not met.
Criteria based on plants and animals.	2a	It supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal.	Not met.
	2b	It is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna.	Met.
	2c	It is of special value as the habitat of plants or animals at a critical stage of their biological cycle.	Not met.
	2d	it is of special value for one or more endemic plant or animal species or communities.	Not met.
Criterion based on representative wetlands.	3	it is a particularly good example of a specific type of wetland characteristic of its region.	Met.

The original listing criteria were reassessed in 1999. This assessment claimed the site no longer met the representative wetland criterion but included claims that the site met two additional criteria relating to waterfowl. Specifically, that the site supported large numbers of certain groups of waterfowl and supported one percent of a population of a waterbird species. A further update of the RIS occurred in 2005 which disputed these claims and supported the original listing (Cooling 2005). The justification for the site meeting each criterion as assessed in 2005 are provided in Table 4 against the current criteria met by Hattah-Kulkyne Lakes Ramsar site. Details of the current assessment are presented in Section 2.4.2 below.

Table 4: Current Ramsar listing criteria showing justification for listing as per Cooling (2005) and current assessment.

Number	Criterion	Justification (Cooling 2005)	Current assessment
Group A. Sites containing representative, rare or unique wetland types			
1	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.	The site supports representative wetland and floodplain ecological vegetation classes that are depleted in the Robinvale Plains Bioregion. The site supports three wetland or floodplain ecological vegetation classes (EVCs) (Arthur Rylah Institute 2003). The site mainly comprises Lake Bed Herbland and Intermittent Swampy Woodland and includes a small area of Riverine Grassy Woodland. All three EVCs are reported as 'depleted' in the Robinvale Plains bioregion. The site supports wetlands representative of two of Victoria's six natural wetland types and of the Robinvale Plains bioregion, including a depleted wetland type. The 955 hectare site supports 899 hectares of freshwater wetlands. The Ramsar site includes two of the freshwater wetland types; deep freshwater marsh and permanent open freshwater.	Met.
Group B. Sites of international importance for conserving biological diversity			
2	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	Not met.	Met.
3	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.	The site maintains the ecological diversity of the Robinvale Plains bioregion by supporting a large number and variety of waterbirds, including breeding habitat for many species. A total of 53 waterbird species have been reported at the site since annual waterbird counts began in 1983.	Met.
4	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.	Not met.	Met.

Number	Criterion	Justification (Cooling 2005)	Current assessment
5	A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.	Not met.	Not met.
6	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.	Not met.	Not met.
7	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.	Not met.	Not met.
8	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.	Not met.	Met.
9	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.	Not assessed as no equivalent criteria.	Not met.

2.4.2 Assessment based on current information and Ramsar criteria

There have been factors since the site was listed in 1999 that influence the application of the Ramsar criteria to wetland sites which are outlined below.

- Refinements and revisions of the Ramsar criteria: a ninth criterion was added at the ninth Conference of the Contracting Parties to the Ramsar Conference in Uganda in 2005.

- Revision of population estimates for waterbirds (Wetlands International 2006; Bamford et al. 2008), which influences the application of Criterion 6.

- A decision with respect to the appropriate bioregionalisation for aquatic systems in Australia, which for inland systems are now based on drainage divisions and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). This affects the application of Criteria 1 and 3.

- Updating of threatened species listings, which affects Criterion 2.

An assessment against each of the criteria for the Hattah-Kulkyne Lakes Ramsar site is provided below:

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

The application of this criterion must be considered in the context of the Bioregion within which the site is located. The Hattah-Kulkyne Lakes Ramsar site is located within the Murray-Darling Drainage Division. At listing and in subsequent reviews (Parks Victoria 1999; Cooling 2005; DSE 2010) of this criterion, a different bioregional system than the current Australian Water Drainage Divisions was used. Assessment against this criterion at the scale of the Victorian Robinvale Plains Bioregion clearly indicates the Hattah-Kulkyne Lakes are representative of two important wetland types.

Applying this criterion at the scale of the Murray-Darling Drainage Division is more difficult as a complete census of Ramsar wetland types within the bioregion is lacking. Despite this, the Hattah-Kulkyne Lakes are considered representative of a good example of a series of large, hydrologically connected, permanent and intermittent floodplain lakes on the Murray River floodplain. The lakes are approximately 15 kilometres from the Murray River with most being fed by Chalka Creek and lie within a National Park. The site clearly meets the sub criterion of hydrological importance as the wetlands of the Ramsar site are the key feature of the floodplain and National Park. The lakes, combined with a range of other wetland types in the National Park, are representative of a large relatively intact section of Murray River floodplain.

This criterion was met at the time of listing, in 1999 and currently.

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

In the Australian context, it is recommended that this criterion should only be applied with respect to nationally and/or internationally threatened wetland dependent species/communities, listed under the EPBC Act or the International Union for Conservation of Nature Red List. This criterion was not considered met by DSE (2010) or Cooling (2005), however there are several nationally and internationally listed species recorded from the site (Table 5). Of these, based on current species data, the site is considered to be important for the Australian painted snipe, regent parrot (eastern) and winged peppercress. For the other species in Table 5, there is a very low degree of certainty that the site is important.

Whilst not considered to have been met at the time of listing or in subsequent revisions, based on current species data the site is deemed to meet this criterion.

Table 5: Threatened species recorded in Hattah-Kulkyne Lakes Ramsar site post 1960 (CE = critically endangered; E = endangered; V = vulnerable).

Species	IUCN	EPBC	Records	Strength of evidence
Australasian bittern - *Botaurus poiciloptilus*	E	E	Listed as occurring at the site in DSE (2010), recorded at Lake Yerang in 1994 (Birds Australia 2011b) and 2010 (DSE unpublished).	The preferred habitat of this species is not common at the site and it is unlikely that the site supports this species.
Australian painted snipe - *Rostratula australis*	E	E	Two birds at Lake Yerang in 2007 (Birds Australia 2011a). Unknown number of birds recorded in 2009 (GHD 2009 cited in Goulburn-Murray Water 2010).	Despite the cryptic nature of this species there are a number of records from within the site. There is a reasonable degree of certainty that the site is important for this species.
Regent parrot (eastern) - *Polytelis anthopeplus monarchoides*		V	Listed as occurring at the site in DSE (2010). Baker-Gabb and Hurley (2010) state that birds usually move away from riverine breeding areas, but at Hattah the species is found all year round.	Reliable sightings exist of flocks of regent parrots feeding within the site along Chalka Creek between Lake Lockie and Yerang. The species probably uses the site for roosting, feeding and possibly breeding. There is strong evidence this site is used by the species.
Murray cod - *Maccullochella peelii*	CE	V	Walters et al. (2010) report a single cod from Lake Little Hattah in 2010. Three individual were recorded in Chalka Creek in 2006.	Fish data is limited and the relative importance of the site for the species is unknown, but use of the site is considered likely on an irregular basis linked to flooding events.
Silver perch - *Bidyanus bidyanus*	V		Found in Lake Little Hattah in May 2010 and in Lake Yerang in 2011 (Walters et al. 2010; MDFRC in prep). Recorded in Chalka Creek in 2006 and 2010 (Walters et al. 2010). Recorded in 1981 location unknown (DSE unpub).	Fish data is limited and the relative importance of the site for the species is unknown, but use of the site is considered likely on an irregular basis linked to flooding events.
Flat-headed galaxias - *Galaxias rostratus*	V		One record from 1963 (DSE unpublished). No recent records could be found. It is possible this species does not occur at the site.	There is a low degree of certainty that the site is important for this species.
Winged peppercress - *Lepidium monoplocoides*		E	Listed as occurring at the site in DSE (2010). DSE (unpublished) has records for 1985-1987, 1991, 1993 & 2007. Mavromihalis (2010) provides population estimates for 1991 & 2003.	Only occurs in a small area between Lake Hattah and Lake Bulla (Mavromihalis 2010). High degree of certainty that the site supports this species.

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

As with criterion one, application of this criterion must be taken in the context of the appropriate bioregion, in this instance the Murray-Darling Drainage Division. Guidance from the Convention indicates that this criteria should be applied to "hotspots" of biological diversity, centres of endemism, sites that contain the range of biological diversity (including habitat types) occurring in a region; and/or support particular elements of biological diversity that are rare or particularly characteristic of the biogeographic region.

The Hattah-Kulkyne Lakes Ramsar site and the surrounding National Park in general are considered to support considerable biodiversity at the local scale, with flora and fauna representative of Murray River floodplain and mallee country. Soil seed bank species richness is high and comparable to other major floodplain systems in the Murray-Darling, such as Narran Lakes. The site supports over 200 native species of flora (DSE unpublished; EPA and MDFRC 2008) with the lakes supporting upwards of 114 species on the lake beds from five lakes (EPA and MDFRC 2008). Over 183 species of native fauna, excluding invertebrates have been recorded from the site (DSE unpublished) which is more than recorded at nearby Gunbower Forest Ramsar site (150). This is noteworthy as the Ramsar boundary at Hattah-Kulkyne does not include significant areas of floodplain, just the lakes up to the high water mark.

This criterion was met at the time of listing and currently.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***

The intention of this criterion is to ensure wetlands within the Ramsar estate include those which are vital for providing habitat during critical life stages and or in period of adverse conditions (Ramsar 2009). The current assessment indicates that Hattah-Kulkyne Lakes Ramsar site supports a number of migratory bird species including 12 species listed under international migratory species treaties and as migratory under the EPBC Act (Appendix B). The site supports breeding of waterbirds (34 species listed as breeding at the site since listing (Appendix B)) and native fish (at least five species recorded breeding (Walters et al. 2010)).

The site acts as a drought refuge as water can remain in the lakes for several years after filling, thus providing habitat in adverse times for waterbirds and other aquatic species (MDBC 2006; DSE 2010). Records at Hattah Lake indicate that between 1908 and 1982 the lake only dried out on nine occasions, with a maximum dry period of 36 months (DSE 2010). Data specific to the role of the lakes as drought refuges are lacking for individual species.

This criterion was met at the time of listing and currently.

Criterion 5: ***A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.***

Regular waterbird count data are available from 1983 to present, allowing the application of the requirement of ‘regularly supports’ for this criterion (see Text box 1 below). Data indicate that rarely, not regularly, does the site support 20 000 or more waterbirds. Only twice have total numbers exceeded 20 000, with the highest total of 23 923 birds recorded in 2001 (Figure 10) and 20 188 in 2007. The remainder of years, for which data is available, have fewer birds, typically less than 5000. However the majority of counts are for mid to late summer and may not represent the highest abundance and diversity of waterbirds at the site (DSE 2010); nonetheless it is still unlikely that this criterion would be met.

This criterion was not met at the time of listing or currently.

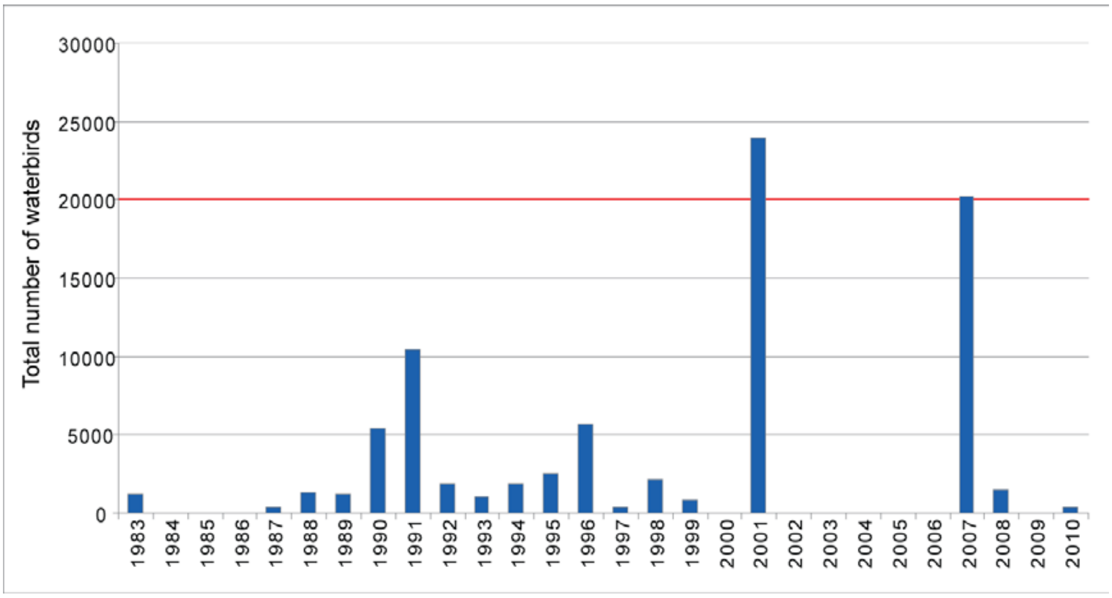


Figure 10: Total waterbird counts for 1983 to 2010 (data supplied DSE and from Kingsford and Porter 2009).

Criterion 6: ***A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.***

The 1999 assessment for this criterion used Victorian populations as a benchmark, claiming the site met the criterion for freckled duck (*Stictonetta naevosa*). However, the correct benchmark is the national or international populations as provided in Wetlands International (2006). DSE (2010) present the data for this species from 1983 to 2002 for which one percent of the estimated population was only exceeded in one year. The one percent population threshold for freckled duck is 250 (Wetlands International 2006) and there is little or no evidence that the site regularly supports greater than one percent of the population of this or any other individual species.

This criterion was not met at the time of listing or currently.

Criterion 7: ***A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.***

Guidance from the Ramsar Convention (Ramsar Convention 2009) on the application of this criterion indicates that in order to meet this criterion, a site should have a high degree of endemism or biodisparity in fish communities. A site can potentially qualify based on the proportion of fish species present that are endemic to the site (must be greater than 10 per cent) or by having a high degree of biodisparity in the fish community.

This criterion was not met at the time of listing or currently.

Text Box 1: Definition of regularly supports (Ramsar 2009).

Regularly (Criteria 5 & 6) – as in supports regularly – a wetland regularly supports a population of a given size if:

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

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

In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

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

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

Criterion 8: ***A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.***

This criterion relates to the importance of wetlands for providing food sources, spawning grounds, nursery grounds and or migratory routes for fish, thus supporting fish stocks. Whilst information is limited this site is considered to be an important nursery area for native fish. The larvae and juveniles of large bodied native fish such as golden perch (*Macquaria ambigua*), silver perch and even Murray cod, move into the floodplain lakes in floodwaters. Recruitment of juveniles back into the adult population is dependent on the water levels of the lakes being maintained but more importantly there needs to be reconnection to the Murray River for species to return to the riverine habitat. Small-bodied natives also breed in the site, with young of the fly-specked hardyhead (*Craterocephalus stercusmuscarum*), carp gudgeons (*Hypseleotris* spp.), flat-headed gudgeon (*Philpnodon grandiceps*) and Australian smelt (*Retropinna semoni*) recorded from the site. The site provides migratory routes between habitat in the Murray River and the floodplain, with Chalka Creek and possibly Cantala Creek being important passageways for native fish. Native fish typically move into off-stream areas on rising flows, and make refuge movements into deeper waters during low flow periods.

This criterion was met at the time of listing and currently.

Criterion 9: ***A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.***

The application of this criterion relies on estimates of the total population of non-avian wetland dependent species.

This criterion was not met at the time of listing or currently.

3. Ecosystem components and processes

3.1 Identifying critical components and processes

Ecological Character Descriptions identify, describe and where possible, quantify the critical components, processes and services of the site which determine the wetland's character and ultimately allow detection and monitoring of change in that character. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would result in a significant change in the system.

DEWHA (2008) suggest the minimum components, processes, benefits and services, which should be included in an ECD are those:

- that are important determinants of the sites unique character;
- that are important for supporting the Ramsar or Directory of Important Wetlands Australia criteria under which the site was listed;
- for which change is reasonably likely to occur over short to medium time scales (less than 100 years); and/or
- that will cause significant negative consequences if change occurs.

The role that components and processes play in the provision of critical ecosystem services should also be considered in the selection of critical components and processes. The linkages between components, processes, benefits and services and the criteria under which the site was listed are illustrated conceptually in Figure 11. This simple conceptual model for Hattah-Kulkyne Lakes Ramsar site shows not only the components, processes and services that are critical to the ecological character of the site, but also those which are important in supporting the critical components, processes and services of the site.

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

Each of the identified critical components and processes meet the four criteria provided by DEWHA (2008) in that they are central to the character of the site, are directly linked to the Ramsar criteria for which the site was listed, could potentially change in the next 100 years and for which change would result in negative consequences and a change in the ecological character of the site.

The critical components and processes for the Hattah-Kulkyne Lakes Ramsar site are:

- hydrology;
- fish;
- lake bed vegetation; and
- waterbirds.

The remaining components and process identified in Figure 11 are important in supporting the critical components, processes, benefits and services but are not considered critical, as a change in these components and process in isolation (that is, without a corresponding biological response) would be unlikely to result in a change in the ecological character of the site. Nevertheless, these supporting components and processes are important in managing the site to maintain ecological character and some may provide early warning indicators of change. As such, this ECD includes a description of the following components and processes that are important in supporting the ecological character of the site:

- climate;
- water quality;
- geomorphic setting;
- phytoplankton;
- fringing woody vegetation;
- invertebrates; and
- amphibians, reptiles and mammals.

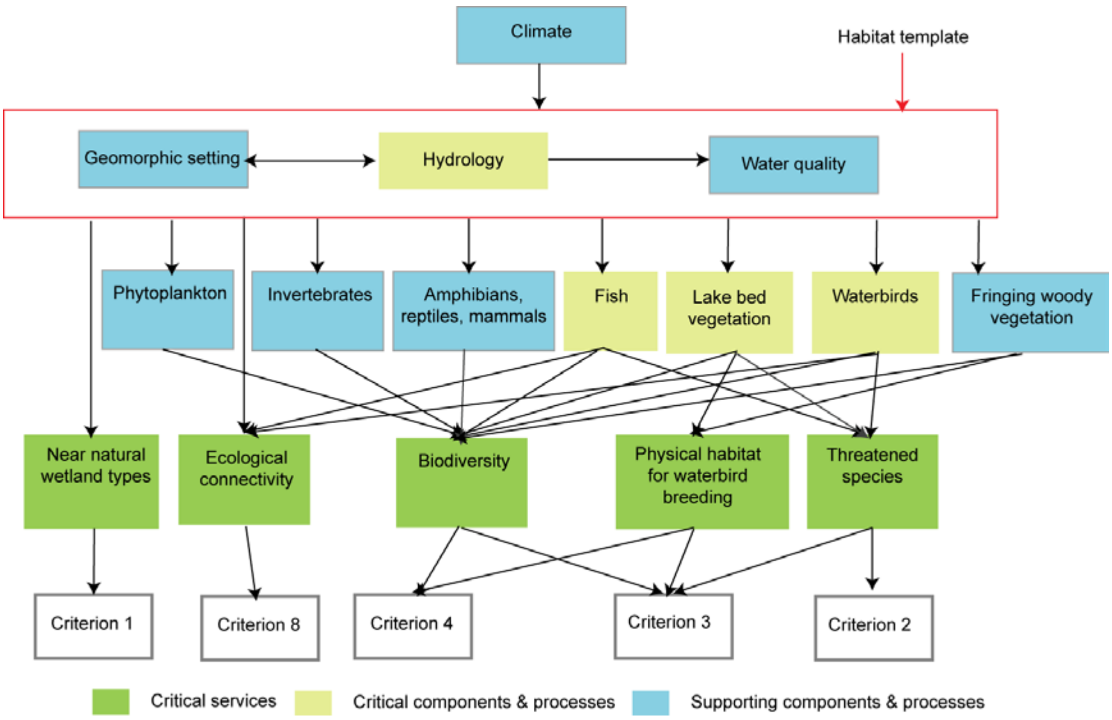


Figure 11: Simple conceptual model showing the key relationships between components and processes; benefits and services and the Ramsar criteria for which the site was listed as a Wetland of International Importance.

3.2 Supporting components and processes

The components and processes that are considered important in supporting the critical components, processes and services of the Hattah-Kulkyne Lakes Ramsar site are described briefly below and summarised in Table 6. The attributes and characteristics of each of the supporting components and processes of the Ramsar site are described below (Sections 3.2.1–3.2.6) with critical components and processes summarised in Section 3.3. Ecosystem services are described in Section 4.

Table 6: Summary of supporting components and processes within the Hattah-Kulkyne Lakes Ramsar site.

Component / process	Description
Climate	Located in semi-arid climatic zone with hot dry summers and cold winters. Average rainfall is 334 millimetres with rainfall higher in the winter months, but occurs all year. On average evaporation exceeds rainfall. There is high variability in rainfall which can include long periods of low rainfall.
Geomorphic setting	Most extensive series of floodplain lakes along the Murray River. Several of the lakes lie in a former large palaeo-lake which was fresh. Lunette formation and composition indicates that deposition of lunettes occurred in a much more saline environment (Joyce et al. 2003).
Water quality	Variable between lakes and over time. Drying of lakes leads to concentration of salts and increasing salinity. Turbidity and oxygen levels are affected by phytoplankton blooms. Comprehensive data for all lakes is lacking and this remains a knowledge gap.
Phytoplankton	Species richness of algal in the lakes is high with 20 to 30 species recorded (EPA and MDFRC 2008). Algal blooms are common; with multiple species of blue green algae present and dominating the algal counts. Nutrients are not limiting.
Fringing woody vegetation	The dominant vegetation type is Lake Bed Herbland. The proportion of aquatic species, amphibious and terrestrial species is related to the inundation stage and history for each lake. Each of the lakes has a small fringe of river red gum (Riverine Grassy Woodlands) and there is a small amount of Intermittent Swampy Woodland lining connecting channels, particularly between Lake Lockie, Yerang and Mournpall. The input of organic carbon from the fringing vegetation is considered important as a nutrient source for the lakes as well as in the provision of structural habitat.
Invertebrates	Reasonably diverse invertebrate assemblage typical of freshwater lakes. Comparable to other Victorian lakes in terms of number of taxa.
Amphibians, reptiles and mammals and terrestrial birds	Species within the actual boundary of the site are limited. However, a number of bats, water rat, and frogs all are recorded from within the site. The surrounding floodplain supports a high terrestrial diversity, particularly bush birds.

3.2.1 Climate

The climate of the Hattah-Kulkyne Lakes Ramsar site and the surrounding area is considered semi-arid. The annual rainfall averages about 334 millimetres, with August usually the wettest month (Bureau of Meteorology 2011). The aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and evaporation as these all fundamentally affect wetland hydrology and the water budget. Data from the weather station at Ouyen, approximately 34 kilometres south east of the Ramsar site, is presented as representative of the site. Note that the climate as described here is relevant to the time of listing and current. The issue of climate change is dealt with under threats (see Section 5).

Rainfall occurs year round, with highest monthly average rainfall in August (32 millimetres) and lowest in January (11 millimetres). There is some degree of variability in rainfall as evidenced by the 10^{th} and 90^{th} percentiles, which range from less than five millimetres per month to greater than 74 millimetres per month (Figure 12).

As stated above, annual average rainfall at Ouyen is 334 millimetres per year. However, there is some degree of variability in annual rainfall with the lowest on record of 110 millimetres in 1967 and 1983 and the wettest in 1973 with 682 millimetres (1950–2010 record) (Figure 13) Heavy rainfall was also recorded in 2010, being the second wettest year on record, which followed a sustained period of below average rainfall (except for 2007) since 2000, this being of high significance to the ecology of the system.

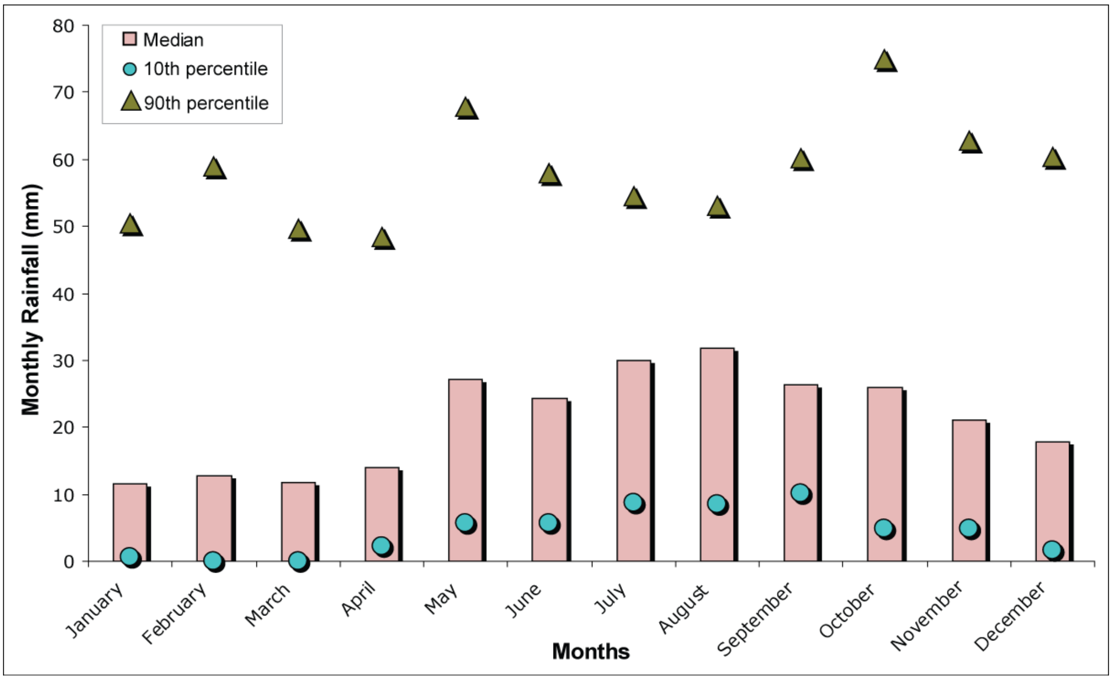


Figure 12: Median, 10th and 90th percentile monthly rainfall at Ouyen (1911 – 2011; Bureau of Meteorology).

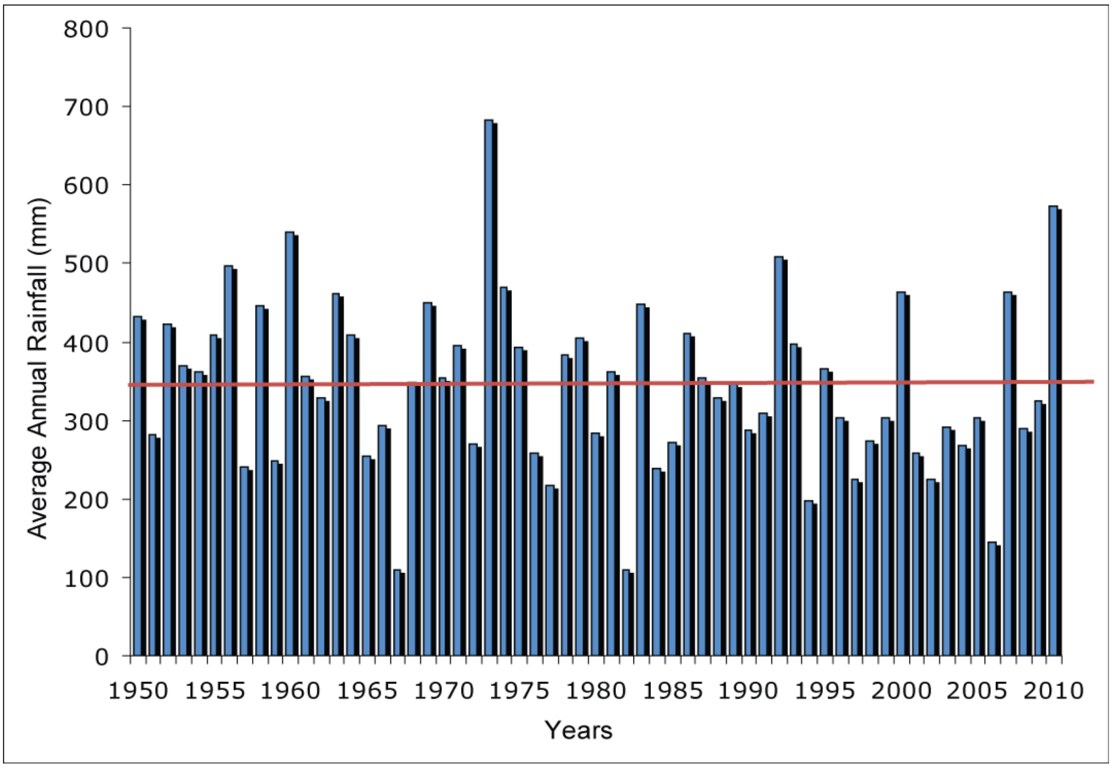


Figure 13: Average annual rainfall at Ouyen (1950 – 2010; Bureau of Meteorology 2011). Horizontal line shows long term average.

Temperatures range from mild to hot, with average summer maximum temperatures around 31 degrees Celsius and average minimum summer temperatures around 15 degrees Celsius. During winter average maximum temperatures are milder (15 to 17 degrees Celsius) as are average minimum temperatures (four to five degrees Celsius) (Figure 14).

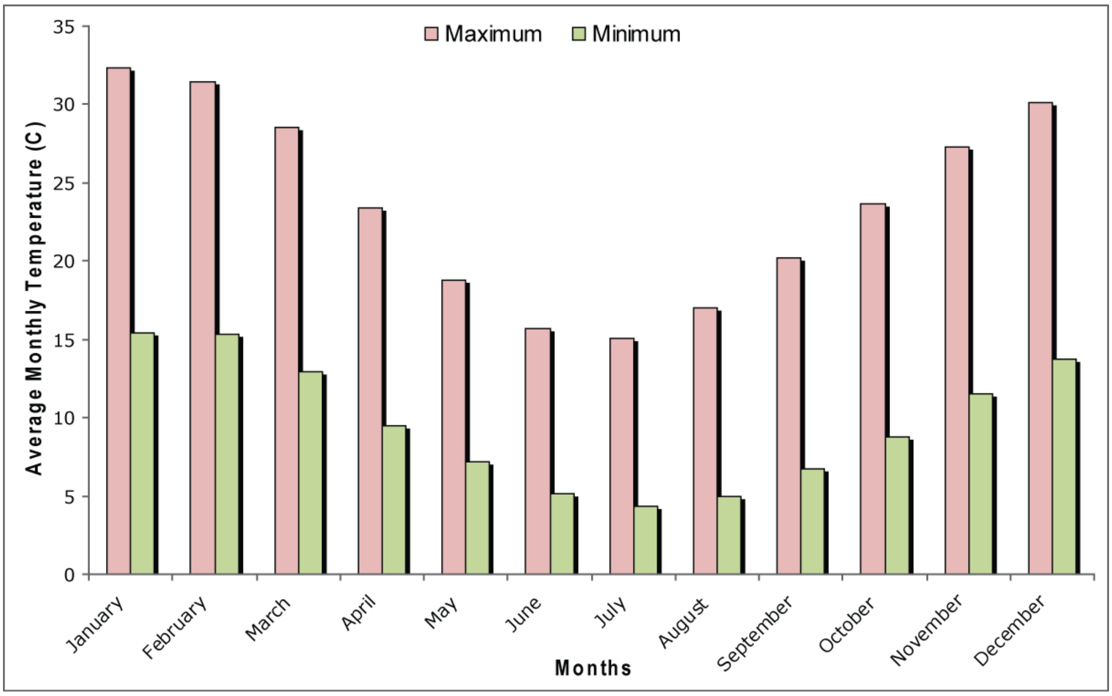


Figure 14: Average monthly temperature at Ouyen (1937-2011; Bureau of Meteorology 2011).

Average relative humidity ranges from 50 percent during summer to 80 percent during the winter months, which, combined with the warm temperatures means evaporation exceeds rainfall all year (Figure 15).

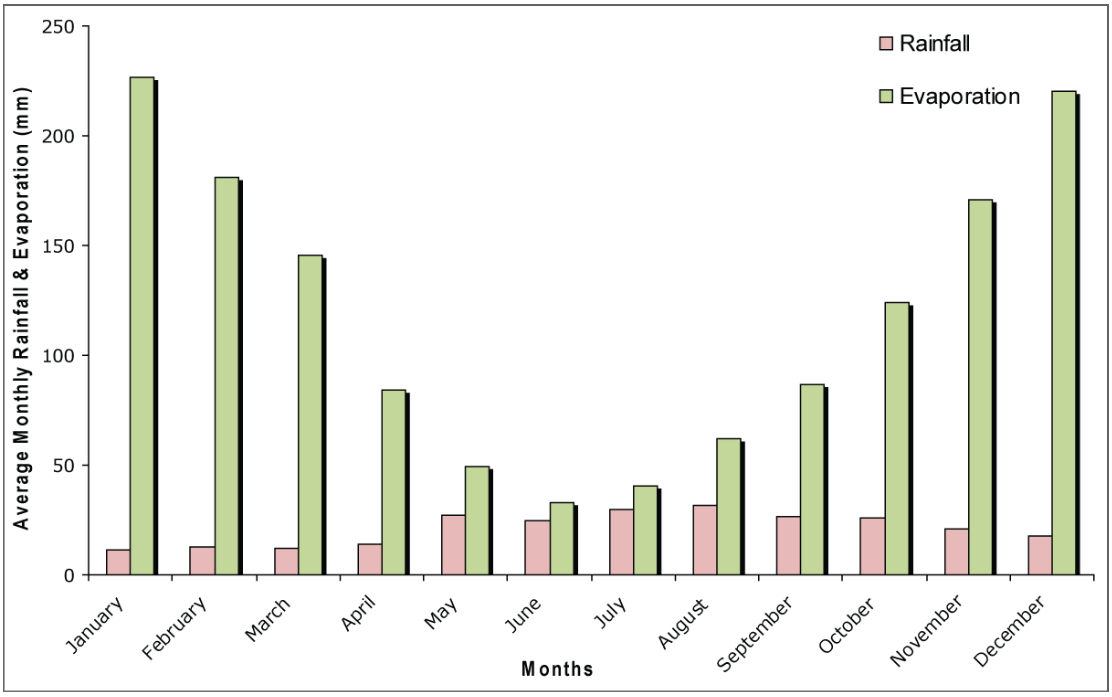


Figure 15: Average monthly evaporation against rainfall at Ouyen (1911-2011; Bureau of Meteorology 2011).

3.2.2 Geomorphological setting

The Hattah Lakes system comprises a series of interconnected lakes which is the most extensive lake system along the Murray River (Joyce et al. 2003). The Hattah Lakes are part of the extensive and complex alluvial Riverine Plain of the Murray River and its tributaries. The Riverine Plain developed following the Pliocene sea retreating. Several of the Hattah Lakes lie on the floor of a former larger lake which covered over 50 square kilometres (Joyce et al. 2003) (Figure 16). The palaeo-lake probably developed from an old meander cut-off with the other lakes east and south of this 'mega lake' also located on terraced floodplain sediments of the ancestral Murray River. The lakes are surrounded by the longitudinal dunes of the Woorinen Formation and subparabolic dunes of the Lowan Sand (Joyce et al. 2003).

Lake Kramen lies on a lower floodplain terrace and is also located in a large arcuate abandoned channel with source-bordering dunes on the inner (eastern) side of meanders. Several of the lakes are bordered with small vegetated lunettes on their eastern sides. These lunettes consist of pelletal clay, as well as occasional Wüstenquarz derived from aeolian dunes (Joyce et al. 2003), and are overlain by self-mulching clay soils with fine disseminated carbonate and lenticular gypsum. This profile indicates that the lunettes developed under conditions of high salinity during the glacial maximum (Joyce et al. 2003). The remains of Aboriginal middens which contain evidence of freshwater species such as mussels, on the top of some of the lunettes, suggest that freshwater conditions returned to the floodplain after the lunette building had ceased (Joyce et al. 2003). There is evidence that dune encroachment occurred at the same time that lunette formation occurred, both occurring after the palaeo-lake dried (Joyce et al. 2003).

Alluvium deposits from the Cainozoic period have produced red brown earths, cracking clays and texture contrast soils (Dermosols, Vertosols, Chromosols and Sodosols) that support dominant Ecological Vegetation Classes (EVCs) of the area such as Riverine Grassy Forest and Riverine Chenopod Woodland EVCs (DSE 2010).

In contemporary times, the majority of the lakes are interconnected with inflows from the Murray River via Chalka Creek, an anabranch of the river. Flow paths are discussed in more detail in Section 3.3.1. Lake Kramen is filled with overland flows in large flood events, with flows originating in part from Chalka Creek, but it is not directly connected to Chalka Creek. Lake Cantala receives inflows from Cantala Creek a distributary of the Murray River, located downstream from Chalka Creek (MDBC 2005).

3.2.3 Water Quality

Water quality data for the time of listing are not available. There are a number of water quality data sets, but not for all lakes within the Ramsar site. The former Department of Natural Resources and Environment (DNRE, now DSE) undertook a sampling program between 1994 and 1997 including pre and post flooding in 1996 (EPA and MDFRC 2008). Water quality data were analysed and related to fish and invertebrate communities (EPA and MDFRC 2008). Data consisted of instantaneous measurements of DO, EC, pH and water temperature in two to three key littoral habitats types per lake over eight sampling events from October 1994 until May 1997 (EPA and MDFRC 2008). In addition, limited nutrient data were also collected in five lakes in 2005 (EPA and MDFRC 2008). For the purpose of this ECD, this DNRE data set is considered to be representative of conditions at the time of listing (Table 7).

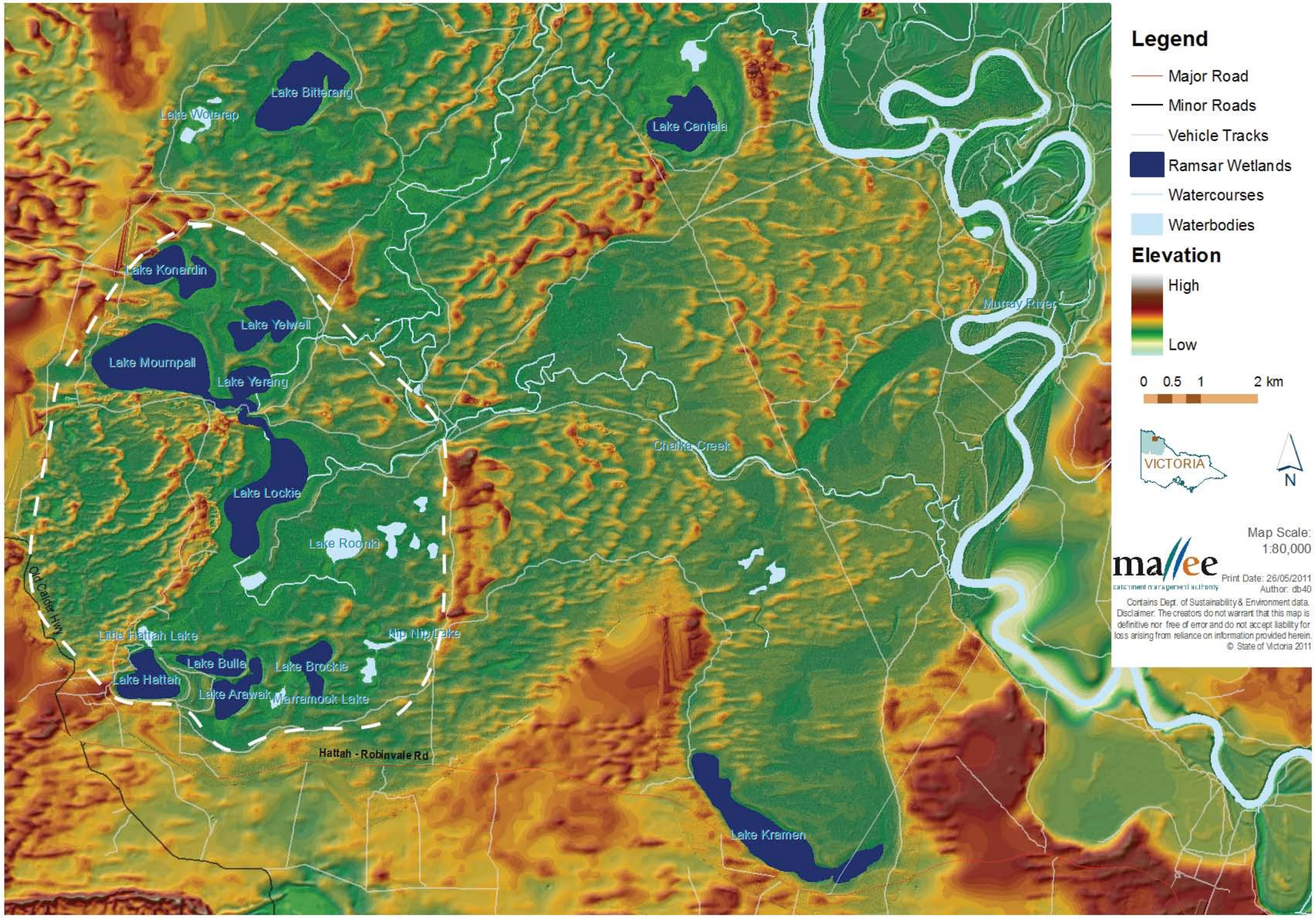


Figure 16: Digital elevation model showing Ramsar site and 'mega-lake' (white dashed line) (image courtesy Mallee CMA).

Table 7: Mean water quality data in seven of the 12 Ramsar site lakes from 1994-1997 (modified from EPA and MDFRC 2008).

Lake	No of samples*	Mean DO (milligrams per litre)	EC @ 25 (micro Siemens per centimetre)	Mean pH	Mean water temp. (degrees Celsius)	Mean turbidity (NTU)	Mean secchi depth (centimetres)	Mean Total Phosphate (milligrams per litre)	Nitrate (milligrams per litre)	Nitrite (milligrams per litre)
Arawak	74	8.0	679	7.8	21.1	80.0	12.1	0.35	0.61	0.056
Bitterang	66	8.5	641	8.1	22.3	141.3	18.1	0.26	1.93	0.031
Hattah	80	7.8	561	7.9	23.1	74.6	10.5	0.41	2.03	0.059
Konardin	75	7.4	753	7.8	23.0	124.5	5.4	0.97	0.58	0.064
Kramen	65	9.6	422	7.9	23.8	40.0	71.8	0.1	2.45	0.003
Mournpall	79	8.7	412	7.8	19.4	94.8	13.0	0.59	3.4	0.012
Lockie	15	6.7	336	7.2	18.3	126.5	-	-	-	-

* Measures are from several sites per water body and represent eight sampling events.

Intervention monitoring in response to emergency environmental watering

Due to a lack of overbank flows into the Hattah Lakes since 2000 and a decline in vegetation (notably river red gum communities), delivery of environmental water commenced in April 2005 as an emergency measure to maintain the existing river red gum communities of the floodplain. Water was pumped from the Murray River and ponded in Chalka Creek and nine of the floodplain lakes (EPA and MDFRC 2008). Environmental monitoring was instigated to assess whether the pumping was a viable option to meet the requirements of TLM objectives. Subsequent to the first release in 2005, three more pumping events took place; see Section 7 for further details. Data presented below relate to the water quality observed in response to these pumping events.

Data are presented for four lakes – Mournpall, Hattah, Bulla and Arawak – as these lakes retained water into 2008. Lakes Yerang, Brockie and Little Hattah had all dried by January 2008 (McCarthy et al. 2009). The water regime of each of Lakes Mournpall, Hattah, Bulla and Arawak were similar with change in depth and level dropping at similar rates across all sites. As would be expected as water levels dropped, salinity increased (especially as water levels became very low prior to complete drying) but remained below 1500 micro Siemens per centimetre (McCarthy et al. 2009); again this pattern of increase was relatively similar across all lakes (Figure 17). pH values varied between the lakes and over time. High readings from Lakes Arawak and Mournpall were attributed to large algal blooms. At Lake Bulla the high readings were attributed to the photosynthesis of large stands of *Myriophyllum verrucosum* (McCarthy et al. 2009) (Figure 18).

High oxygen readings at Lake Arawak were also attributed to algal blooms in March 2008. Lower levels of dissolved oxygen at Lakes Mournpall and Hattah corresponded to lower phytoplankton biomass (McCarthy et al. 2009) (Figure 19). Turbidity became more variable over time as the lakes dried and the likelihood of resuspension of lake sediments increased. Also the high algal biomass in the water column at several lakes could be a contributing factor (McCarthy et al. 2009) (Figure 20). These results suggest water quality is highly variable between the lakes despite the fact that they are hydrologically connected.

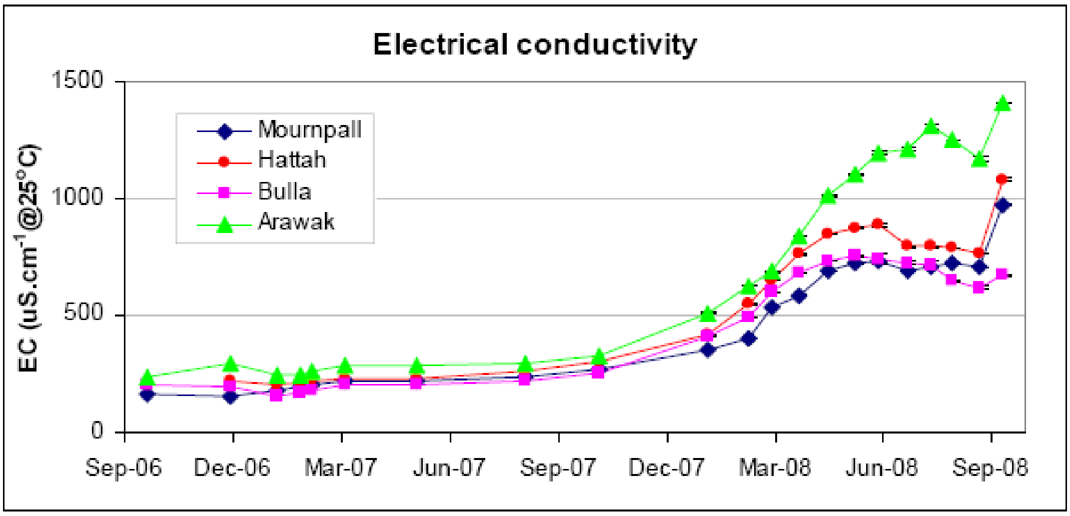


Figure 17: Surface water electrical conductivity micro Siemens per centimetre at 25 degrees Celsius at Lakes Mournpall, Hattah, Bulla and Arawak for the period September 2006 to September 2008 (from McCarthy et al. 2009).

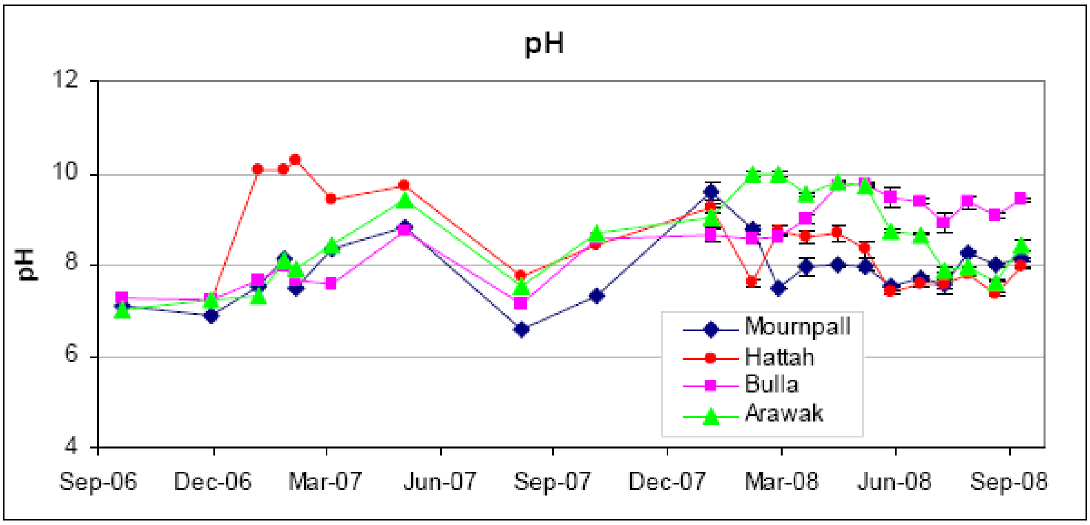


Figure 18: Surface water pH at Lakes Mournpall, Hattah, Bulla and Arawak for the period September 2006 to September 2008 (from McCarthy et al. 2009).

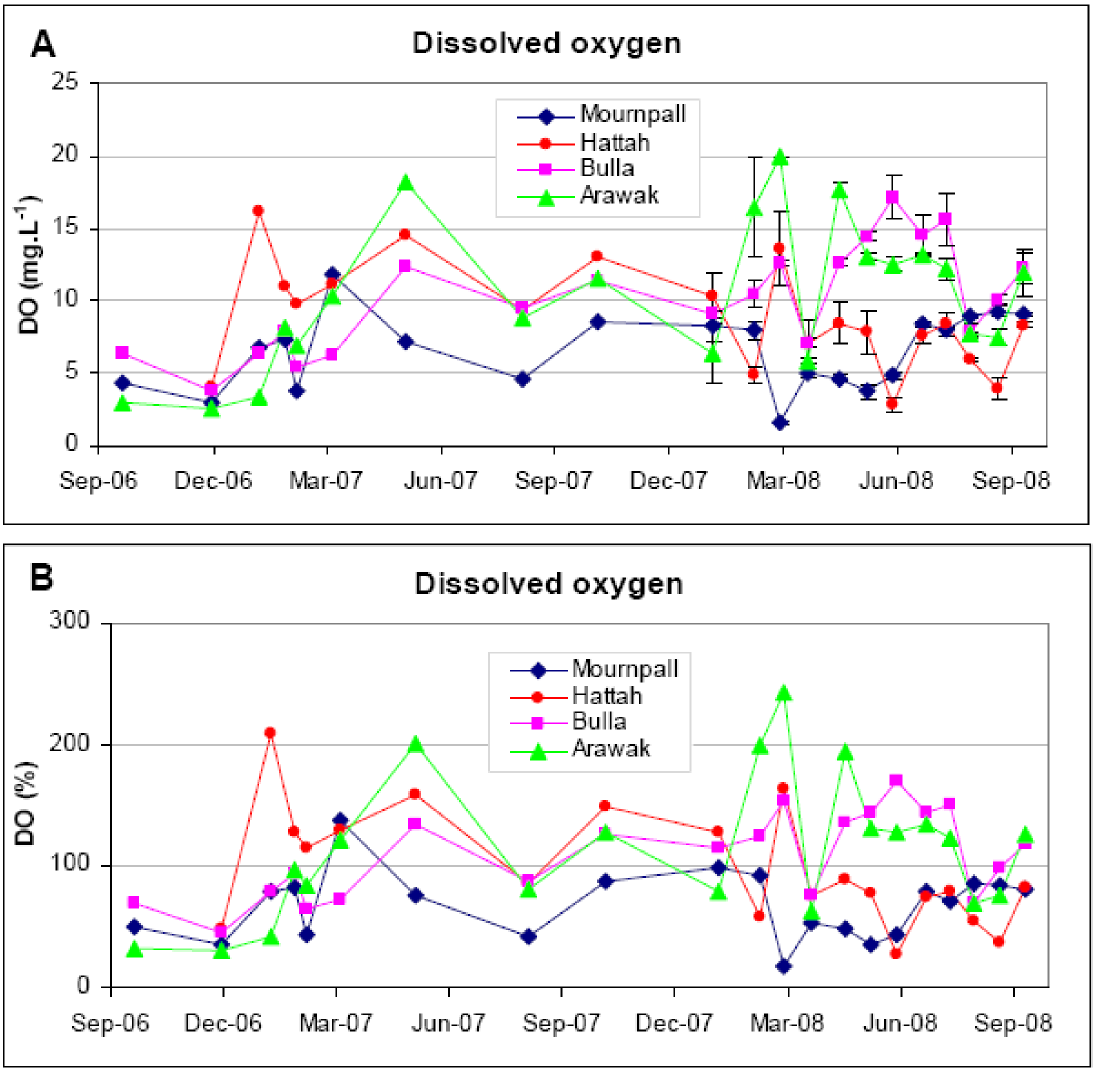


Figure 19: Surface water dissolved oxygen shown as (A) milligrams per litre and (B) percent saturation at Lakes Mournpall, Hattah, Bulla and Arawak for the period September 2006 to September 2008 (from McCarthy et al. 2009).

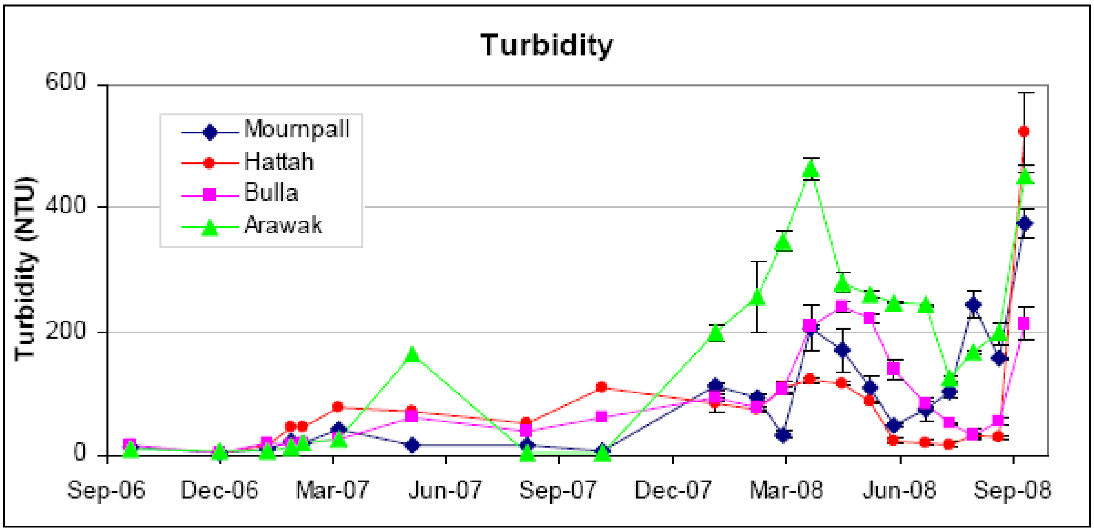


Figure 20: Surface water turbidity (NTU) at Lakes Mournpall, Hattah, Bulla and Arawak for the period September 2006 to September 2008 (from McCarthy et al. 2009).

Nutrient levels measured during the intervention monitoring were high in most lakes assessed with Lake Arawak recording very high dissolved and total levels of phosphorous and high available nitrogen in December 2007 (Figure 21). Lake Hattah, Yerang and Lockie all had lower phosphorous levels which was attributed to clay dominated substrates (EPA and MDFRC 2008). Strong correlations between algae and nutrients were not found suggesting that algal growth is not limited by nutrients in this floodplain system (EPA and MDFRC 2008).

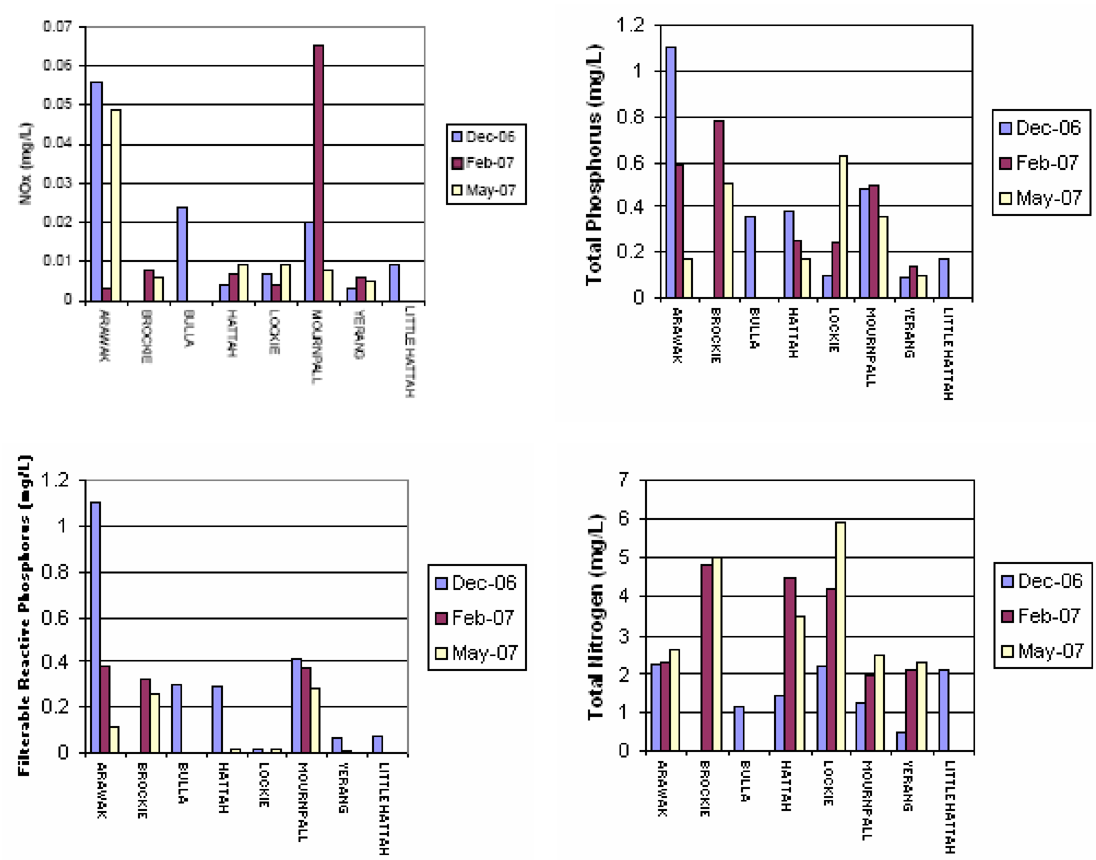


Figure 21: Nutrient concentrations at Hattah Lakes in December 2006, February and May 2007 (from EPA and MDFRC 2008; McCarthy et al. 2009).

3.2.4 Phytoplankton

Algal blooms can pose a significant threat to the water quality of the Hattah-Kulkyne Lakes. Cyanobacteria, or blue-green algae, were recorded in the period 1994 to 1997 and were likely to be present at the time of listing as they are a natural component of aquatic ecosystems (EPA and MDFRC 2007). The intervention monitoring showed that algal species richness is high in the lakes with 20 to 30 species of algae per sample (EPA and MDFRC 2008; McCarthy et al. 2009). Community composition varied between lakes and algal levels differed significantly between seasons. Lakes Arawak, Lockie, Hattah, Brockie and Bulla all had algal blooms during the intervention monitoring (Figure 22). Dominant species were all blue green species including *Anabaena circinalis* and *Microcystis* sp. (EPA and MDFRC 2008; McCarthy et al. 2009) (see Figure 23 for example of bloom at Lake Mournpall). Identification of algae focused on blue green species and so the relative importance/abundance of other species such as green algae and diatoms is not well documented (McCarthy et al. 2009).

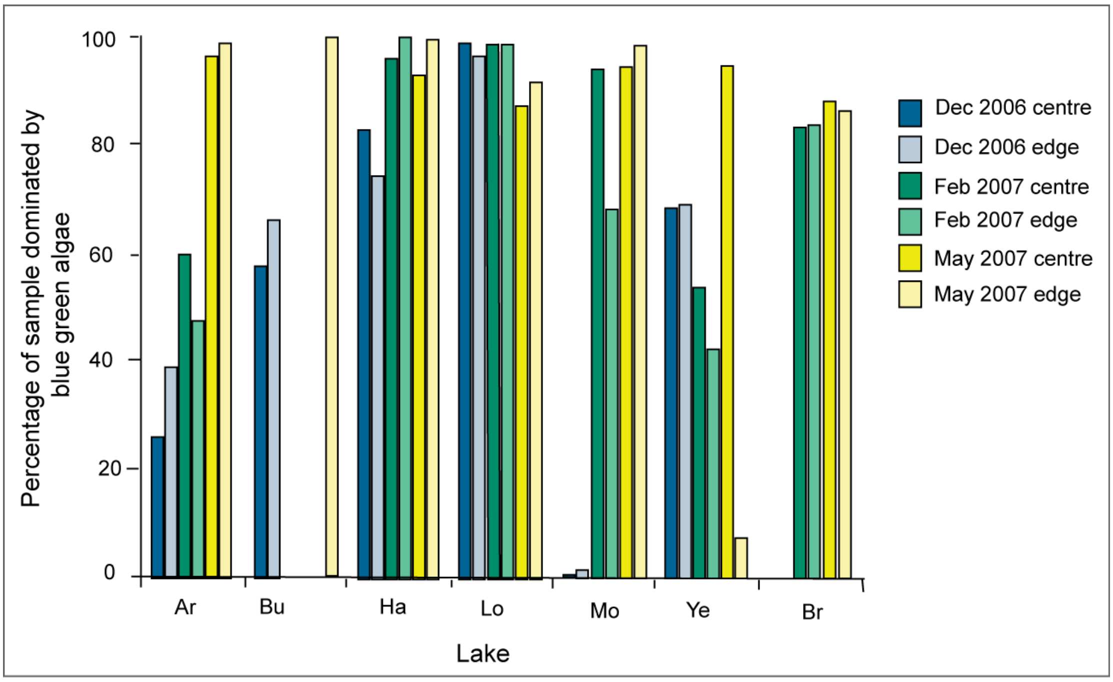


Figure 22: Percentage of blue green algae in edge and centre samples of selected lakes during intervention monitoring December 2006 to May 2007. Ar = Arawak, Bu = Bulla, Ha = Hattah, Lo = Lockie, Mo = Mournpall, Ye = Yerang, Br = Brockie (modified from EPA and MDFRC 2008).

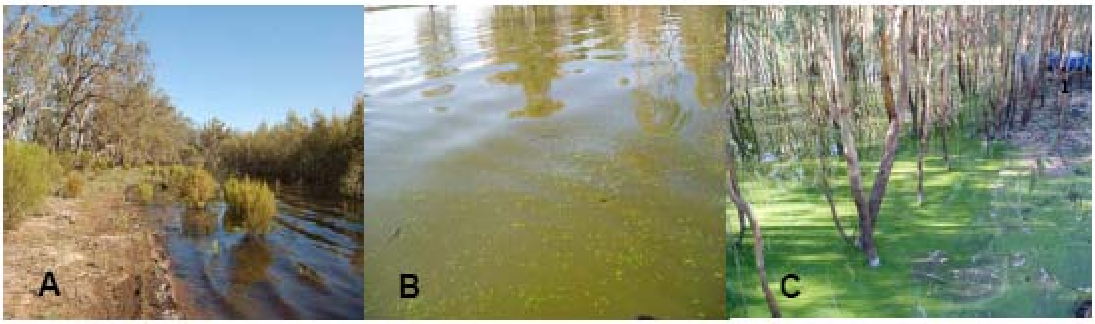


Figure 23: Algal blooms at Lake Mournpall; A = December 2006, B = February 2007, C = May 2007 (from EPA and MDFRC 2008).

3.2.5 Fringing woody vegetation

In Victoria, vegetation mapping is based on Ecological Vegetation Classes (EVCs), a native vegetation classification based on a combination of its floristics, life form and ecological characteristics, and through an inferred fidelity to particular environment attributes (DSE 2010). Similar EVCs have been assigned to 20 Simplified Native Vegetation Groups by DSE.

In the Hattah-Kulkyne Lakes Ramsar site, there are three Simplified Native Vegetation Groups present (Figure 24), and within these groups there are three wetland dependent and three non wetland dependent EVCs (Table 8). Lake Bed Herbland is by far the dominant EVC accounting for just over 90 percent of the Ramsar site and is considered a critical component (see Section 3.3.2 for more detail). The Intermittent Swampy Woodland and Red Gum community in the Riverine Grassy Woodland form the fringing woody vegetation of the site and only occur on the edges of the lakes and along connecting channels. There are two small patches of Mallee vegetation within the boundary of the site but as these are not wetland dependent they are not discussed further.

The EVC mapping completed in 2003 represents the only comprehensive vegetation mapping at the time (DSE 2010). The condition and extent of EVCs are vulnerable to water regime changes and grazing pressure. It is not known if the extent of EVCs has changed significantly since the time of listing (DSE 2010).

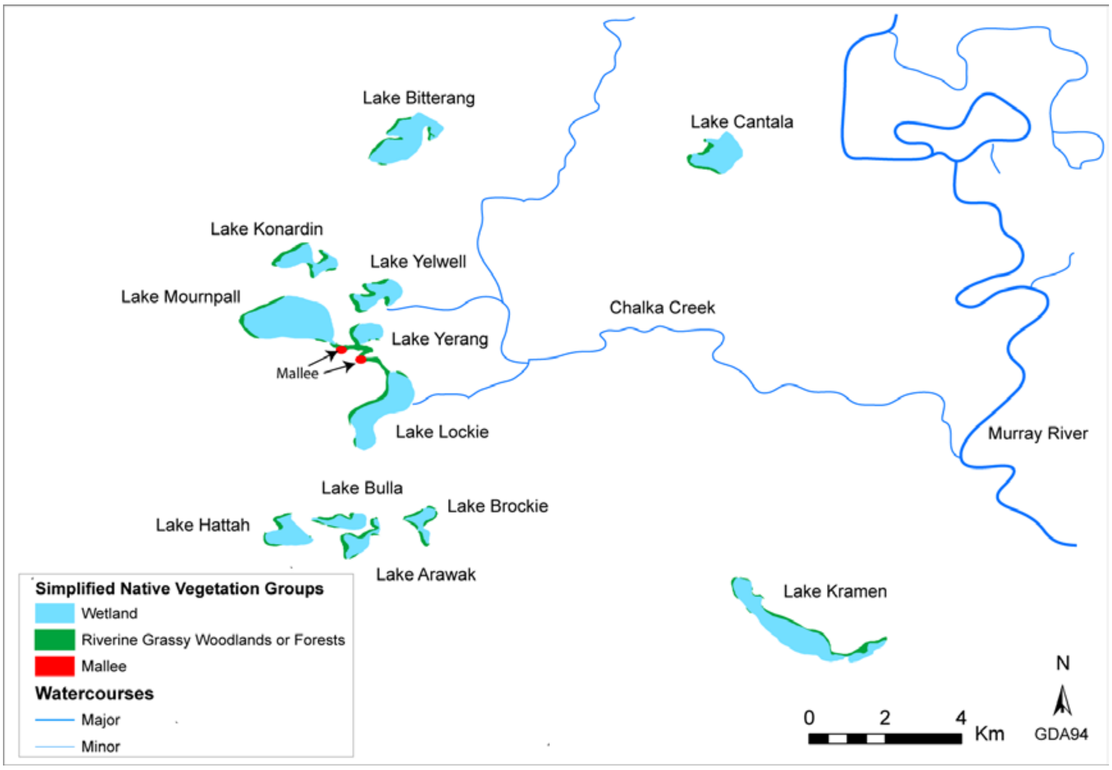


Figure 24: Vegetation Groups within Hattah-Kulkyne Lakes Ramsar site (data supplied DSE). Note area of Mallee vegetation groups is smaller than represented.

Contribution of organic carbon and structural habitat

Floodplain forests, most notably river red gum forests, are important in the cycling of organic carbon in lowland river systems in Australia (Robertson et al. 1999). Organic carbon is a major nutrient in freshwater systems and an important primary source of food in aquatic food webs. In forested catchments, the major terrestrial inputs of carbon to rivers are (Bunn et al. 2007):

- Coarse woody debris – logs and branches from riparian and floodplain vegetation;
- Particulate organic matter – litter inputs directly from riparian trees or washed from other areas of the floodplain; and
- Dissolved organic carbon – released from wetlands and floodplains and carried to the river on return flows.

Although there are no measures from within the Ramsar site itself on the relative importance of the input from the fringing woodlands surrounding the lakes, investigations on larger river red gum forested floodplains in south-eastern Australia provide some understanding of the relative contributions of organic carbon in functioning aquatic ecosystems.

Table 8: Vegetation groups, EVC descriptions and extent for the Hattah-Kulkyne Lakes Ramsar site (data supplied DSE).

Simplified Native Vegetation Group	EVC	Description	Area (hectares)
Wetland.	Lake Bed Herbland EVC 107.	Herbland dominated by species adapted to drying mud within lake beds. Some species evade periods of prolonged inundation as seed, others as dormant tuberous rootstocks.	862.75
Riverine Grassy Woodlands or Forest – Broader Plain.	Riverine Grassy Woodland EVC 295.	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. A forest dominated by River red gum with a groundlayer dominated by graminoids. Occasional tall shrubs present.	5.32
	Riverine Chenopod Woodland EVC 103 (not wetland dependent).	Eucalypt woodland with a diverse shrubby and grassy understorey occurring on most elevated riverine terraces. Confined to heavy clay soils on higher level terraces within or on the margins of riverine floodplains (or former floodplains), naturally subject to only extremely infrequent incidental shallow flooding from major events if at all flooded.	1.33
Riverine Grassy Woodlands or Forest – Creek line and or swampy.	Intermittent Swampy Woodland EVC 813.	Eucalypt woodland with a variously shrubby and rhizomatous sedgy – turf grass understorey, at best development dominated by flood stimulated species in association with flora tolerant of inundation. Flooding is unreliable but extensive when it happens. Occupies low elevation areas of river terraces (mostly at the rear of point-bar deposits or adjacent to major floodways) and lacustrine verges (where sometimes localised to narrow transitional bands). Soils often have a shallow sand layer over heavy and frequently slightly brackish soils.	88.6
Mallee – Calcareous dunefields.	Woorinen Sands Mallee EVC 86 (not wetland dependent).	Mallee shrubland, typically supporting a hummock grass (*Triodia* spp.) dominated understorey. This EVC could be considered intermediate between the heavier soil mallee woodlands and the lighter sandy soil mallee vegetation predominant on Lowan (siliceous) sand.	0.14
Mallee – Siliceous sands.	Loamy Sands Mallee EVC 87 (not wetland dependent).	Low woodland to mallee shrubland commonly dominated by the mallee form Desert Stringybark *Eucalyptus arenacea* with a heathy understorey. Found on deep to moderately deep siliceous sands of aeolian origin.	0.02

Whilst production of coarse woody debris would be lower within the Hattah system compared to the Barmah or Gunbower Forests, the contribution of coarse woody debris (Figure 25) to the lake ecosystems is considered to be important in supporting the biodiversity values of the site. Wood decomposes slowly with a half-life of approximately 140 years and as such the role of coarse woody debris may be more important as structural habitat for biofilms in terms of carbon production than as a direct release of organic carbon to receiving waters (Robertson et al. 1999). Biofilms in turn provide a rich food source for many invertebrates and as such are important elements of the food chain.

Production of litter in floodplain forests and woodlands is variable, both seasonally and in response to frequency of inundation. Litter is more mobile than coarse woody debris and has a half-life of approximately one year in dry conditions or 50 days if inundated (Robertson et al. 1999). Inundation of the floodplain leads to mineralisation of organic carbon in litter and sediments. At the Ramsar site litter would also be an important part of the carbon cycle.

Figure 25: Coarse woody debris at Lake Lockie, 2006–2007 (image courtesy Victorian EPA).

3.2.6 Invertebrates

Semi-arid wetlands often display a ‘boom and bust’ ecology which is driven by the hydrological connectivity and flooding frequencies (Jenkins and Boulton 2003). Inundation triggers different ecological responses according to differing species requirements. The flush of zooplankton growth on the arrival of floodwaters provides the basis of the food chain on which the more iconic wetland fauna, fish and waterbirds, depend. Macroinvertebrates and zooplankton have many adaptations to deal with wetting and drying including having desiccation resistant stages, often as eggs in the sediment. Wetland invertebrate community structure often shows a dynamic and variable composition for the first six months of inundation, with species richness often rising in the first few months before stabilising. Community structure is heavily influenced by wetting and drying as well as historic patterns of inundation. Overall, the range of invertebrate responses to inundation, water quality, habitat complexity and duration of inundation ensure that wetland invertebrate fauna are highly variable, even in wetlands physically close to each other.

Despite macroinvertebrates being a common tool in biological assessments of riverine habitats, sampling of floodplain wetlands for macroinvertebrates has not been a widespread practice. There are no data for the aquatic invertebrates of the Hattah-Kulkyne Lakes for the time of listing; the earliest surveys occurred in the 1990s. Puckridge et al. (1997) recorded 143 taxa from several lakes from the Hattah system, which is comparable to other studies in the region such as Boulton and Lloyd (1991) who collected 5384 individuals from 95 different taxa from wetlands and anabranches of Chowilla (part of the 'Riverland' Ramsar site). The 2006–2007 intervention monitoring recorded 149 taxa from 46 families using Rapid Biological Assessment (RBA) from ten lakes (seven Ramsar lakes) and Chalka Creek. The number of species recorded from each sample ranged between nine and 40 taxa with mean species richness similar across most lakes (Figure 26). Comparison to data from other Victorian lake systems with RBA data suggests the Hattah lakes are reasonably diverse (EPA and MDFRC 2008). The intervention monitoring showed differences between the invertebrates in response to season and wetland type, which is common in wetland invertebrate communities. Patterns of species richness recorded during the intervention monitoring indicated that diversity in response to water pumping were similar to those recorded during natural flooding (Figure 27).

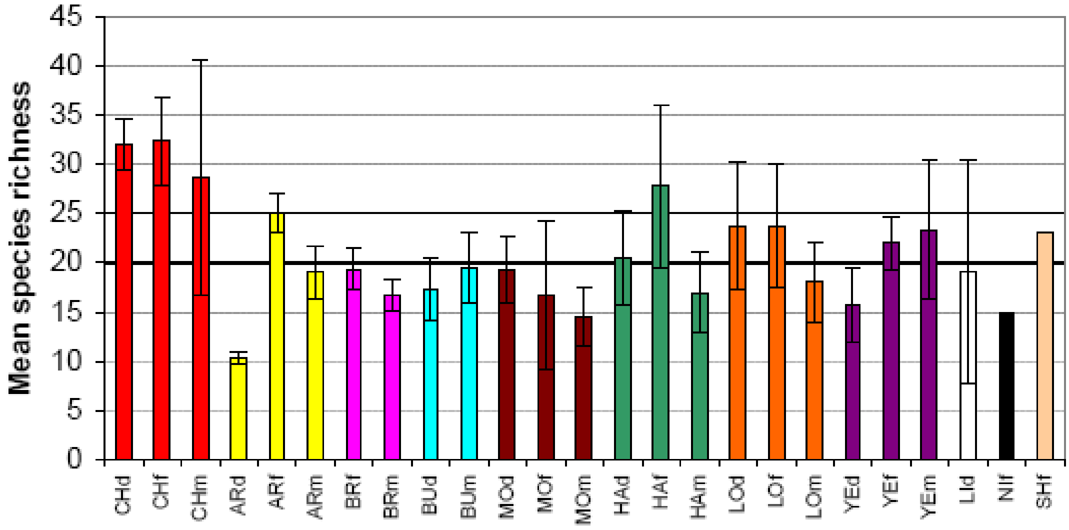


Figure 26: Mean number of species for each waterbody within each season from the RBA samples. CH = Chalka Creek, AR = Lake Arawak, BR = Lake Brockie, BU = Lake Bulla, MO = Lake Mournpall, HA = Lake Hattah, LO = Lake Lockie, YE = Lake Yerang, LI = Little Lake Hattah, NI = Lake Nip Nip, SH = unnamed ephemeral wetland, d = December 2006, f = February 2007, m = May 2007 (from EPA and MDFRC 2008).

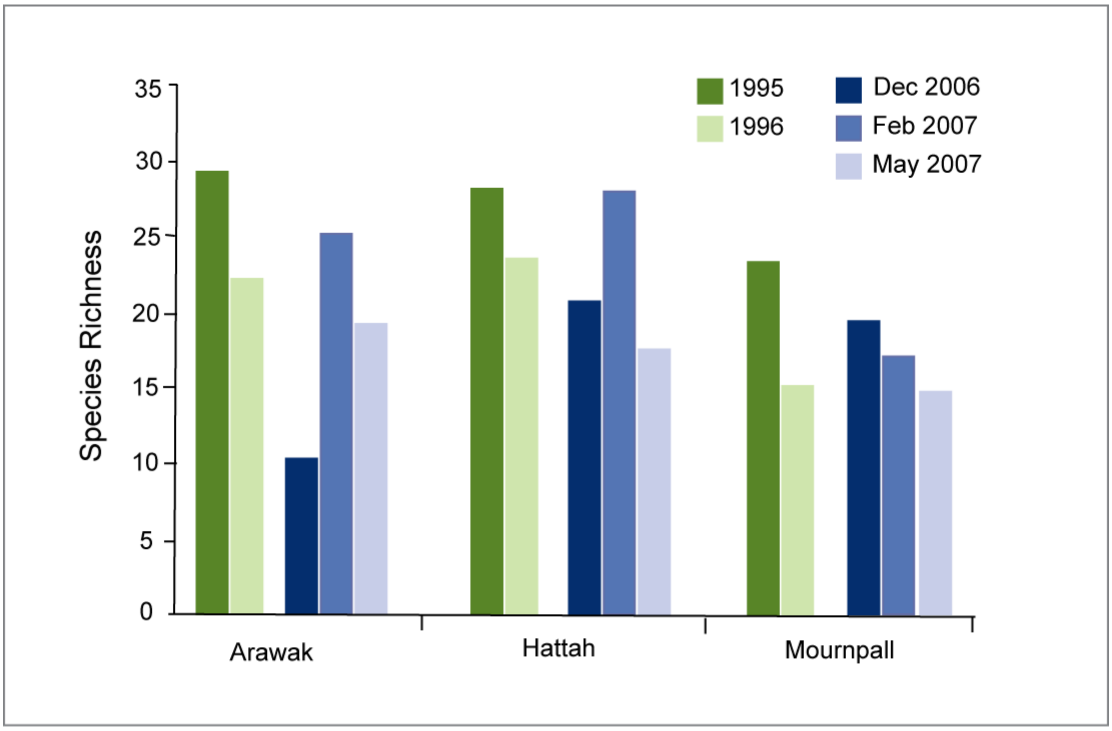


Figure 27: Macroinvertebrate species richness at three lakes during a natural flood in 1995/1996 and artificial flooding in 2005/2006 (modified from EPA and MDFRC 2008).

Zooplankton collected during the intervention monitoring of 2006–2007 showed a similar rotifer fauna across the lakes sampled for species richness, abundance and community structure (EPA and MDFRC 2008; McCarthy et al. 2009). Dominant species included *Filinia australis* and several *Keratella* species. Microcrustacea, however, displayed seasonal patterns as well as a clear response to time since filling. Abundances were higher in lakes that had been recently filled compared to those which had had water for over a year. Species richness is similar across the lakes but showed spatial partitioning within lakes, with the edges supporting more species (EPA and MDFRC 2008; McCarthy et al. 2009).

3.2.7 Amphibians, reptiles and mammals

The site supports a number of mammals including seven bat species and the water rat (*Hydromys chrysogaster*) (Table 9). Larger mammals such as the macropods are not recorded in the site often but do occur in the surrounding floodplain in significant numbers. The restriction of the Ramsar site boundary to the high water mark of the lakes means that vertebrate diversity is dominated by wetland dependent species such as waterbirds and fish (see Sections 3.3.3 and 3.3.4). The only truly wetland dependent mammal which occurs at the site is the water rat, however there are no data regarding the population of this species. The presence of eight bat species in and around the wetlands indicates they may be areas in which the bats feed (for example on emerging aquatic insects) or provide open areas for flight paths. Whilst the mammals species diversity is relatively low it does contribute to the diversity of the site overall.

The Ramsar site also has a good representation of the amphibians found in the region with five of the nine species found in the Mallee region being recorded from the site. They are the barking marsh frog (*Limnodynastes fletcheri*), eastern banjo frog (*Limnodynastes dumerilii*), spotted grass frog (*Limnodynastes tasmaniensis*), common froglet (*Crinia parinsignifera*) and Peron's tree frog (*Litoria peronii*) (DSE unpublished, Atlas of Victorian Wildlife). Amphibians, both as tadpoles and as adults, contribute to the diet of waterbirds and fish and are important for their role in the food chain.

The broad-shell river turtle (*Chelodina expansa*) is the largest of the three freshwater turtles found in the Murray-Darling Basin and the only species recorded at the site. This turtle is a specialised predator and prefers turbid waters where it ambushes its prey, which includes invertebrates and small fish. The surrounding floodplain plays host to a number of other reptiles not recorded within the site. This is a reflection of the boundary of the Ramsar site rather than a lack of reptiles in the Hattah-Kulkyne system.

Table 9: Mammals recorded from within the Hattah-Kulkyne Lakes Ramsar site (DSE unpublished, Atlas of Victorian Wildlife). * indicates an introduced species.

Common name	Species name
Chocolate wattled bat	*Chalinolobus morio*
Gould's wattled bat	*Chalinolobus gouldii*
Inland freetail bat	*Mormopterus sp. 3*
Lesser long-eared bat	*Nyctophilus geoffroyi*
Little forest bat	*Vespadelus vulturnus*
Southern forest bat	*Vespadelus regulus*
Southern freetail bat	*Mormopterus* sp. 4
White-striped freetail bat	*Tadarida australis*
Water rat	*Hydromys chrysogaster*
Black wallaby	*Wallabia bicolor*
Western grey kangaroo	*Macropus fuliginosus*
Mitchell's hopping-mouse	*Notomys mitchelli*
Red fox*	*Vulpes vulpes*

3.3 Critical components and processes

The attributes and characteristics of each of the critical components and processes of Hattah-Kulkyne Lakes Ramsar site are described below (Sections 3.3.1 to 3.3.4). Wherever possible, quantitative information is included in the description of each component or process. However, there are some significant knowledge gaps relating to the key characteristics of this site (see Section 8). A summary of the critical components and processes within Hattah-Kulkyne Lakes Ramsar site is provided in Table 10.

Table 10: Summary of critical components and processes of Hattah-Kulkyne Lakes Ramsar site.

Component / process	Description
Hydrology	Lakes are filled via Chalka Creek with commence to flow occurring at 36 700 megalitres per day in the Murray River downstream of Euston. Impacts from river regulation and modifications to flow paths on the floodplain have altered the hydrology of the site, reducing frequency and duration of inundation, as well as timing of peak flows. The majority of the lakes dry within 12 months after inflows cease, Lakes Mournpall and Hattah can retain water for several years post flooding.
Lake bed herbland vegetation	Dominant vegetation across all lakes is EVC 107 lake bed herbland. It shifts from being dominated with aquatic and amphibious species with some terrestrial species on the edges in the wet phase, to being dominated by terrestrial species in the dry phase. The relative length of each inundation event and subsequent dry phase also influences the community structure. Aquatic macrophyte growth is variable across lakes, and data is limited. Seed bank species richness is high and suggests establishment of beds of aquatic macrophytes is possible with the right antecedent conditions.
Fish	Ecological connectivity between lakes is evident with the fauna of a particular lake being most similar to that of the lake immediately upstream. Intervention monitoring associated with the delivery of environmental water has shown the fish fauna to be dominated with small bodied native species. Relatively few exotic species have been recorded which may in part relate to the pumping mechanisms (e.g. water pumped from deep pools that are not favoured by Eastern gambusia (*Gambusia holbrooki*), which prevents them from entering via the pumped water).
Waterbirds	Supports 70 species of waterbirds, 12 of which are covered by international migratory bird treaties. Thirty four species breed at the site. Functional guilds are dominated by ducks, which is unusual in the major wetland systems of the Murray River.

3.3.1 Hydrology

The Hattah Lakes are filled via Chalka Creek, an anabranch of the Murray River, which flows west from the main channel for approximately 18 kilometres to enter Lake Lockie. Water moves through the lake system in several directions (Figure 28), however the main flow is via Chalka Creek with flows ultimately re-entering the Murray River 27 kilometres to the north near Colignan (SKM 2003b). Lake Cantala receives inflows via Cantala Creek, and Lake Kramen receives water via sheet flooding from Chalka Creek and also from the southern chain of wetlands. It is possible that flows also reach Lake Kramen along a secondary pathway, but this is not considered a common event.

Lake Hume was completed in 1936 and is taken to represent the beginning of river regulation in the Murray River. River regulation reduced inflows into the Hattah Lakes, and notably reduced the flooding of Lake Hattah. In 1972/73 Chalka Creek was channelised to improve flows into Lake Hattah. The channelisation led to Lakes Hattah and Mournpall being flooded more frequently, returning Hattah to pre-regulation conditions (Souter 2005). However the channelisation did not affect the remaining lakes in the Ramsar site, and was not successful in fully restoring the hydrological variability of pre-regulation conditions (Souter 2005).

In addition to modifications to the channel of Chalka Creek, a regulator was installed at Messengers Crossing to prevent flood waters from receding. Overall the impacts of river regulation and modifications on the floodplain have led to a reduction in both the frequency and duration of lake inundation. The timing of flooding has also been altered, with the most common month of flood initiation changing from August (pre-regulation) to October (post-regulation) (SKM 2003b).

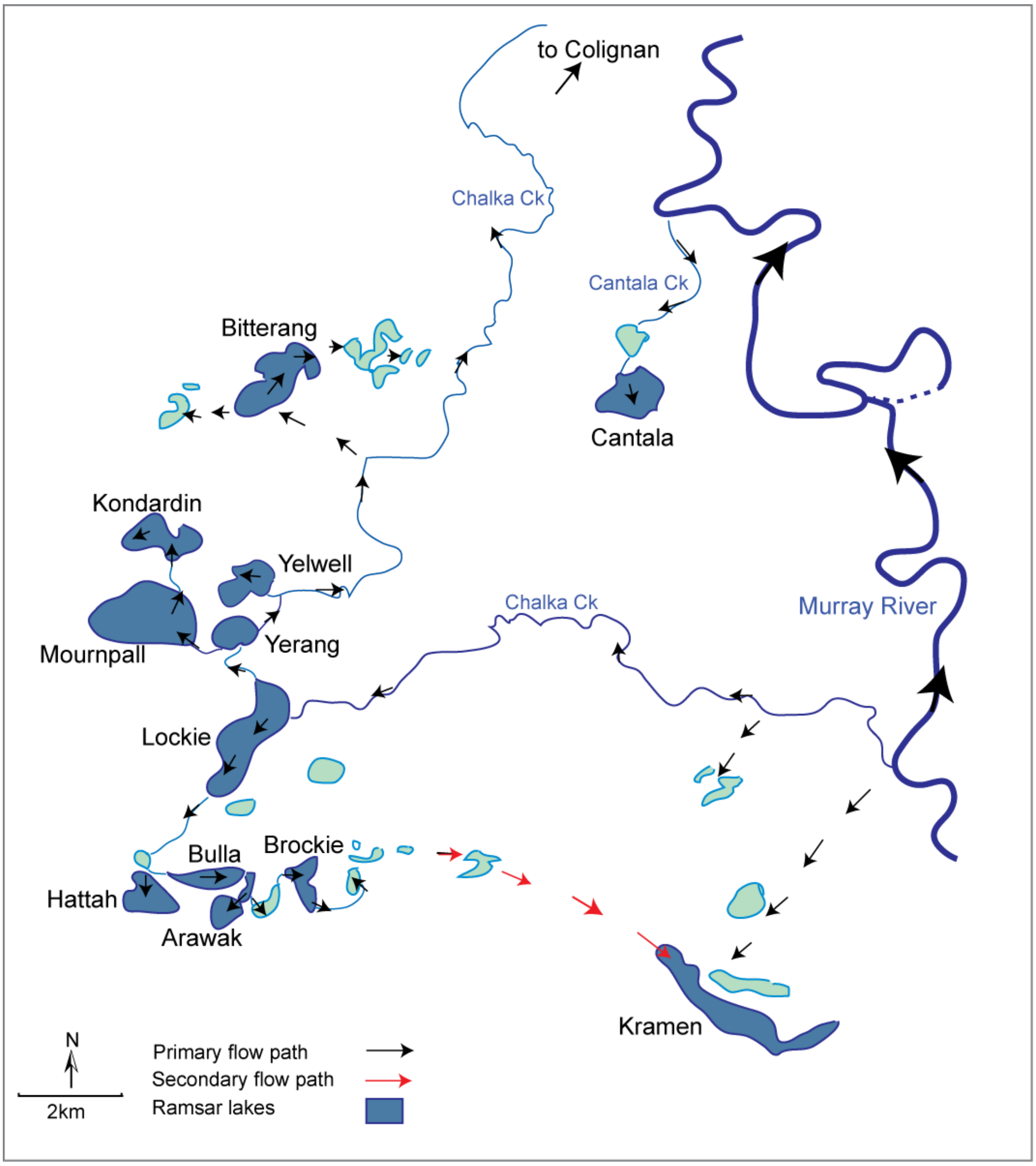


Figure 28: Primary and secondary flow paths between Ramsar lakes (modified from SKM 2003a).

The Ramsar site was listed in 1982 and as such the hydrological regime at listing was determined by a regulated flow regime in the Murray River, plus the modifications to Chalka Creek. Under these conditions the lakes only fill during high flow events (see Table 11 and Figure 29). Lake Mournpall is the largest and one of the deepest lakes. Hattah Lake is also relatively deep (Table 12). Lakes Mournpall and Hattah, being deeper, can retain water for up to four and three years respectively (SKM 2003b; Souter 2005). The surface area and capacity of each lake is presented in Table 11; Murray River flows required to fill the lakes are also presented. Lake Kramen only fills in very large floods.

Table 11: Surface area, capacity and critical flow thresholds for the Hattah-Kulkyne Lakes Ramsar site (from SKM 2003b; MDBA 2010).

Wetland	Surface area (hectares)	Capacity (megalitres)	Flow in Murray River at Euston for lake to fill (megalitres per day)
Arawak	40	617	50 500
Bitterang	73	885	70 000
Brockie	28	345	53 000
Bulla	40	740	45 000
Cantala	101	1233	45 000
Hattah	61	1476	36 700
Konardin	121	1476	60 000
Kramen	124	221	152 000
Lockie	141	1291	36 700
Mournpall	195	2220	40 000
Yelwell	81	738	55 000
Yerang	65	787	40 000

The hydrograph for modelled natural and actual discharge at Euston clearly shows the loss of small to medium sized floods, a key feature of the impacts of river regulation (Figure 29). Reduced inflows are particularly noticeable post 1996 with only one flooding event in 2010 exceeding the commence-to-flow threshold in the 2000–2010 period (Figure 30). This period represents one of the driest on record and led to the instigation of emergency allocation of environmental water in 2005 through to 2010 (see Section 7). Based on modelled weekly lake level data over a 92 year period (1908 to 1999) it is clear that under conditions at the time of listing all lakes within the Ramsar site are dryer than under pre-regulation conditions (Figure 31) (Ecological Associates 2007).

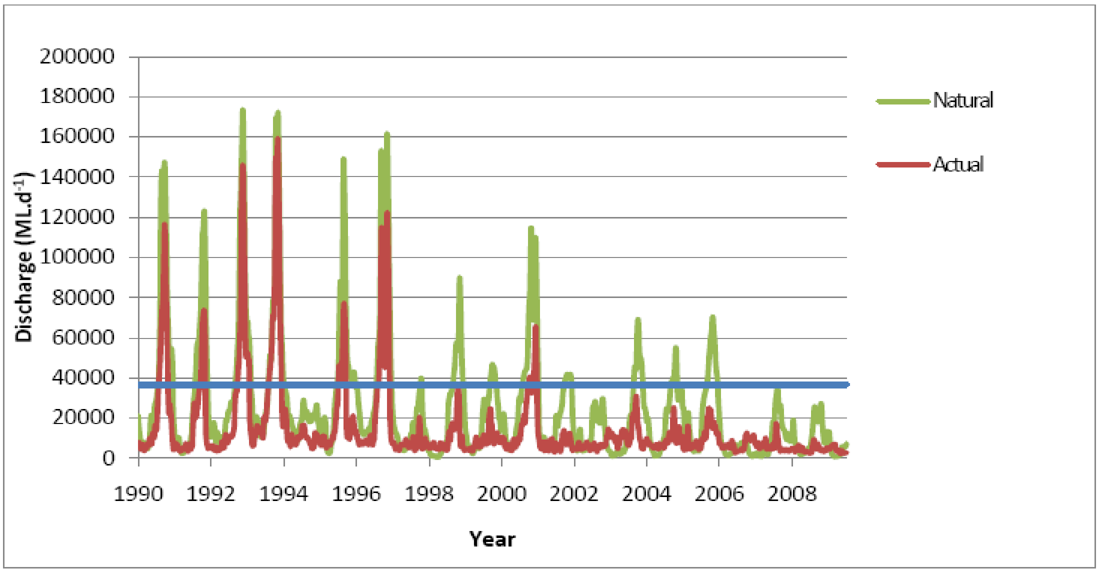


Figure 29: Modelled natural (green) and actual (red) discharge at Euston on the Murray River. The commence to flow (CTF) of 36 700 megalitres per day is presented (blue). Data courtesy of Andy Close, MDBA from MSM BIGMOD (run 9 November 2010) (from Walters et al. 2010).

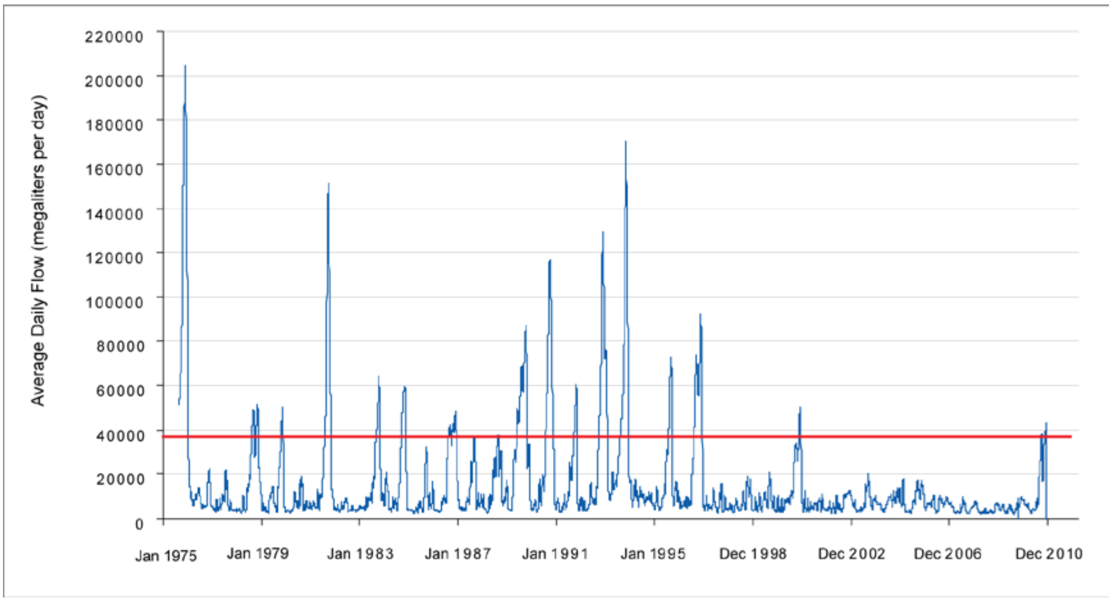


Figure 30: Average daily flow (megalitres per day) in the Murray River at Euston from 1975 to 2010 (data from the Victorian Water Resources Data Waterhouse). Red line show commence to flow level (36 700 megalitres per day).

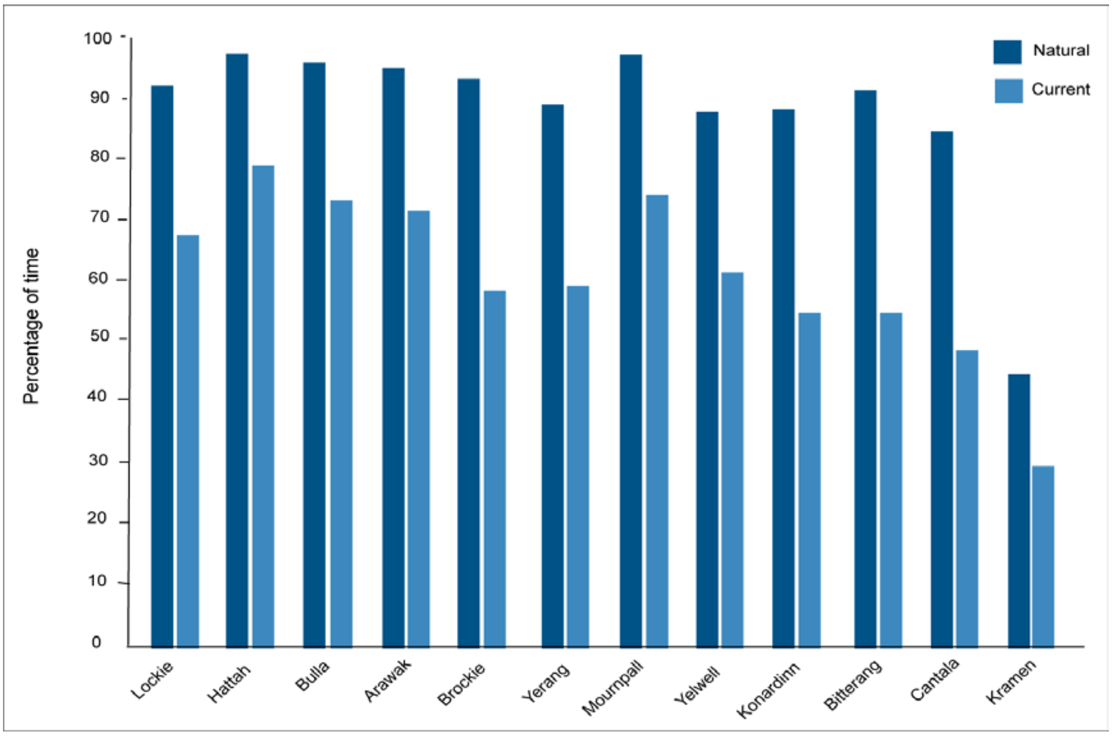


Figure 31: Percentage time Ramsar site lakes are wet (1908 to 1999) (modified from Ecological Associates 2007).

Ecological Associates (2007) provide a detailed description of the hydrology of the Hattah Lakes. Results from Spell analysis for current conditions are the best available data representative of the time of listing for the Ramsar site. Whilst there has been some additional development since listing up until consumtive allocations were capped in 1995, data which account for this are not available. Current conditions as used by Ecological Associates (2007) represent the Murray River flow under all known system modifications including existing operating rules, and the hydraulic model includes current floodplain and channel morphology within the Hattah Lakes system.

The results indicate that under current (as opposed to natural) conditions, the semi-permanent wetlands of Hattah, Bulla, Arawak, Mournpall and Brockie are greater than 50 percent full from 29 percent of the time at Lake Brockie to 56 percent of the time at Lake Hattah. Dry events occur between 14 to 20 percent of years and can last for over a year to nearly four years at Lake Brockie. Lake Bulla reaches full level 11 percent of years and Hattah reaches full levels 38 percent of years and is generally exceeded for around 15 weeks (Table 12). The persistent temporary wetlands are shallower and as such are 50 percent full between 24 percent (Lake Cantala) to 46 percent of the time at Lake Lockie. In terms of dry events, the median duration is highly variable in this group of lakes; Lockie dries for about eight months whereas Bitterang and Cantala can have much longer dry periods. Lake Konardin has low median dry event duration of 14 weeks but very high average event duration of 231 weeks (Ecological Associates 2007), which suggests considerable extremes in the hydrology of this lake. The persistent temporary wetlands dry out on average one in four years (Ecological Associates 2007).

Groundwater surface water interactions

SKM (2003a) provide a review of the groundwater-surface water interactions in the vicinity of the Ramsar site which indicates that there is little hydraulic connection. There is a strong locally steep groundwater gradient from east to west across the site which suggests that groundwater is recharged from the Murray River, probably all year long. The Parilla Sands aquifer connects with the base of Lake Kramen and during extended dry periods may flow into the basal sediments of the lake. However as the lake is frequently dry, evaporation is higher than groundwater inflows (SKM 2003a). Thorne et al. (1990 cited in SKM 2003a) argued that there is poor hydraulic connection between surface and groundwater in all lakes except Lake Kramen, as they have clay bases and low seepage rates. The rate of drying of the lakes would support this (SKM 2003a). Groundwater salinity is not considered a major threat, which is supported by low salinity in a shallow bore near Lake Hattah (SKM 2003a).

Table 12: Hydrology of wetland classes under current conditions (Ecological Associates 2007).

Wetland	Depth	% time > 50% full	Events < 25% full (dry events)		Events > 100% full (full events)	
			% years with events	Median event duration (weeks)	% years with events	Median event duration (weeks)
Semi-permanent wetlands						
Mournpall	3.2	42	21	52	25	15
Hattah	3.1	56	14	65	38	14
Bulla	2.5	48	19	71	11	15
Arawak	2.4	46	20	73	34	15
Brockie	2.3	29	14	139	21	19
Persistent temporary wetlands						
Bitterang	2.4	28	14	143	21	18
Cantala	2.2	24	17	120	22	4
Konardin	1.7	29	14	14	17	31
Yerang	1.5	33	43	71	40	11
Yelwell	1.3	39	25	84	36	21
Lockie	1.0	46	32	36	47	23
Episodic wetlands						
Kramen	2.9	6	3	1898	2	52

3.3.2 Lake bed herbland vegetation

Data on aquatic vegetation at the time of listing are not available. Early investigations into the aquatic ecology of the site focused on water quality, invertebrates and fish (EPA and MDFRC 2008). As with all floodplain ecosystems the pattern of wetting and drying drives the ecological response, and this is most obvious in the diversity, distribution and condition of wetland dependent vegetation. What limited information is available from the1990s suggests that aquatic macrophytes were not dominant due to high turbidities. Only two records of aquatic macrophytes exist; Ward et al. (2000 cited in EPA and MDFRC 2008) reported that Lake Kramen was dominated by *Myriophyllum* and Smith (1996 cited in EPA and MDFRC 2008) reported that Lake Hattah supported *Cyperus rigidellus*. Despite this, the species diversity of the Hattah-Kulkyne Lakes Ramsar site is quite high, with records for over 200 native species and over 50 exotic (DSE unpublished; EPA and MDFRC 2008). EPA and MDFRC (2008) reported 114 species on the lake beds from five lakes, of which 26 were exotic species. As the lakes progress from wet to dry to wet the plant community composition changes from being dominated with aquatic and amphibious species with some terrestrial species on the edges in the wet phase, to being dominated by terrestrial species in the dry phase. The relative length of each inundation event and subsequent dry phase also influences the community structure.

Contemporary vegetation monitoring data are available from the TLM Icon Site condition monitoring and also for the intervention monitoring associated with environmental watering. Data exist for seven lakes, from 2006 to 2007 (Intervention monitoring) (EPA and MDFRC 2007, 2008; McCarthy et al. 2009) and for five lakes from 2008 to 2010 (TLM Icon Site condition monitoring). Both data sets show changes in plant functional groups in response to patterns of inundation.

Findings from the TLM condition monitoring indicated that Lake Yerang underwent a significant change in plant functional groups, particularly in the areas which were inundated in 2009 with the establishment of the obligate aquatic ribbonweed (*Valisineria americana* var *americana*). This species was recorded at Lake Yerang for the first time in 2010 (McCarthy et al. 2009). Sampling at Lake Mournpall and Lake Hattah were limited to the littoral zone due to the presence of algal blooms, however the aquatic macrophyte communities were believed to have established at Mournpall. Amphibious and terrestrial damp species such as red water-milfoil *Myrophyllum verrucosum*), water primrose (*Ludwigia peploides* ssp. *Montevidensis*), waterwort (*Elatine gratioloides*) pale knotweed (*Persicaria lapathifolia*) and small mud-mat (*Glossostigma elatinoides*) were recorded at Mournpall and a number also at Lake Hattah (McCarthy et al. 2009).

Seed bank trials were undertaken for seven of the Ramsar lakes as part of the intervention monitoring. Findings indicate that the lakes support a diverse and abundant soil seed bank with over 30 species. The composition is dominated by forbs, grasses and sedges (see Figure 32 and Appendix C) with common, widespread, species including the grass *Lchnagrostis filiformis* and the forbs *Polygonum plebeium, Chenopodicum pumilo, Limosella australis* and *Elatine gratioloides* (EPA and MDFRC 2008). Over 92 percent of all propagules were native species (EPA and MDFRC 2008), which provides an excellent reservoir of species from which recolonisation of lakes can occur when suitable conditions prevail. Spatially, the edges of lakes were more diverse and supported greater numbers of seeds than did lake centres. Of the seven lakes assessed, Lake Lockie and Hattah had the lowest species richness and lower abundances than the other lakes and would be expected to support a depauperate macrophyte community (EPA and MDFRC 2008). Overall the seed bank is not considered a limiting factor in re-establishing aquatic macrophyte communities (EPA and MDFRC 2008).

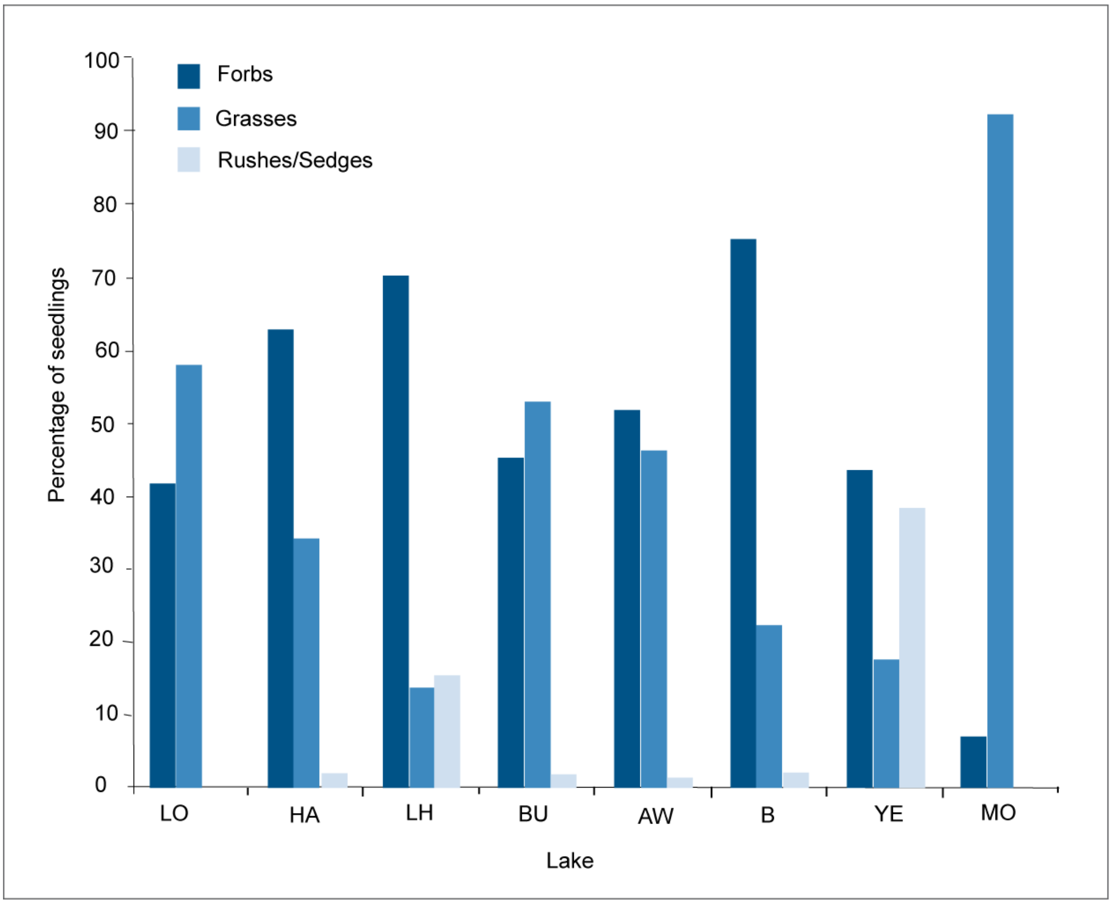


Figure 32: Percentage of total number of seedlings emerging from sub-samples of each lake in major plant groups. Lake codes; LO – Lockie, HA – Hattah, LH – Little Hattah, BU – Bulla, AW – Arawak, B – Brockie, YE – Yerang, MO – Mournpall. Note the lakes are arranged in order of filling by inflows as determined by MDBC 2005 (modified from EPA and MDFRC 2008).

3.3.3 Fish

Hattah-Kulkyne Lakes represent an important, highly connected, floodplain habitat for fish. Flooding from the Murray River, with inflows via Chalka Creek, feeds the system of lakes and allows movement of fish onto and off the floodplain. Sustained quantity and quality of water is important for maintaining a fish population on the floodplain; however, isolation and drying of the lakes in drought periods and subsequent recolonisation during seasonal overbank flooding results in a fluctuating fish population (EPA and MDFRC 2008).

Twelve native species and five exotic species have been recorded from the Ramsar site (Table 13). The freshwater catfish and flat-headed galaxias have only single records post 1960, with the freshwater catfish considered likely to have been present at the time of listing as it was recorded at the site in 1981 and is likely to be encountered in the future. The flat-headed galaxias underwent a decline in the region post 1980 and as such is not considered likely to have been at the site at listing or in the future. Several of the native species are threatened at the state level under the *Flora and Fauna Guarantee Act*, nationally under the EPBC Act or internationally on the IUCN Red List (Table 13) (EPA and MDFRC 2008).

Table 13: Fish species recorded within the Ramsar site or in waterways immediately connected to the Ramsar site. Data for 1960-1982 from DSE (unpublished), 1994-1997 from Puckridge et al. (1997), 2005-2010 from Walters et al. (2010) and 2010-2011 from MDFRC (in prep).

Common name	Species name	1960-1982	1994-1997	2005-2010	2010-2011	Conservation status
Australian smelt	*Retropinna semoni*		✓	✓	✓	
Bony herring	*Nematalosa erebi*		✓	✓	✓	
Carp gudgeon	*Hypseleotris* spp.			✓	✓	
Murray-Darling rainbowfish	*Melanotaenia fluviatilus*		✓	✓#	✓	FFG
Flat-headed galaxias	*Galaxias rostratus*	✓				IUCN; DSE-Vu
Flat-headed gudgeon	*Philpnodon grandiceps*		✓	✓	✓	
Fly-specked hardyhead	*Craterocephalus stercusmuscarum*			✓	✓	FFG
Freshwater catfish	*Tandanus tandanus*	✓				FFG; DSE-En
Golden perch	*Macquaria ambigua*			✓	✓	DSE-Vu
Murray cod	*Maccullochella peelii*			✓*		EPBC-Vu
Silver perch	*Bidyanus bidyanus*			✓*	✓	FFG; DSE-CE; IUCN
Western carp gudgeon	*Hypseleotris klunzingeri*		✓			
Common carp	*Cyprinus carpio*			✓	✓	
Goldfish	*Carassius auratus*		✓	✓	✓	
Eastern gambusia	*Gambusia holbrooki*		✓		✓	
Redfin perch	*Perca fluviatilis*		✓			
Weatherloach	*Misgurnus anguillicaudatus*				✓	

FFG = listed under Flora and Fauna Guarantee Act; DSE = DSE (2007) Advisory list status. Ce = critically endangered, En = endangered, Vu = Vulnerable; IUCN listed under IUCN (2010) Red list; EPBC = Environment Protection and Biodiversity Conservation Act. ✓*recorded from Little Hattah. ✓# recorded from Murray River and Chalka Creek only.

Fish present in the Ramsar site include species that spawn in response to floods, species that are main channel specialists and generalists and species that are wetland specialists and low-flow specialists (SKM, 2003a; MDBC 2005) (see Appendix D for details). CRCFE (2003) assigned the identified the following habitat groups (note some species classified as belonging to more than one group) (from CRCFE 2003 and MFAT Zone D):

- **Wetland specialists:** Includes Australian smelt, carp gudgeon, Western carp gudgeon, bony herring, and hardyheads which occur in gently flowing waters of billabongs, wetlands and backwaters. These species spawn and recruit in floodplain wetlands and lakes, anabranches and billabongs during in-channel flows. Often they are found among aquatic plants and debris along the margins of water bodies. Many of these fish are distributed throughout the Murray-Darling system, and in coastal lakes and streams. The species often form schools, particularly in open waters, and range in size from around four centimeters (carp gudgeon), to 15-20 centimeters (bony herring).

- **Low flow specialists:** Includes Murray-Darling rainbowfish and carp gudgeons which only spawn and recruit during low flows in either a main channel or floodplain habitat. These species can be found in a range of habitat types, such as rivers, creeks, drains, billabongs and backwaters, and are distributed inland throughout the Murray-Darling system, and also in coastal streams.

- **Main channel generalists:** Can include Australian smelt, bony herring and flathead gudgeons. Spawn and recruit in high or low flow in the main channel. Generally these fish are found in quiet, slow flowing water, often in billabongs and lakes, and spawn during the spring and summer. These fish are found throughout the Murray-Darling Basin, and coastal drainages of eastern Australia.

- **Main channel specialists**: Murray cod. Spawn and recruit under high or low flow in the main channel of rivers. Snags and boulders are an important habitat feature for these fish, as these are used as a hard substrate for spawning. They are found in a range of flow conditions, from fast flowing shallow waters in upland areas, to slow flowing, deep and turbid waters at lower elevations, and are distributed throughout the Murray-Darling system. These fish are often quite large, with Murray cod for example, growing up to 180 centimetres and 113 kilograms.

- **Freshwater catfish**: Spawn in coarse sediment beds (usually sand or gravel) during any flow conditions. Live in slow moving streams and lakes with fringing vegetation and gravel bottoms. They are distributed throughout the Murray-Darling system and east coast drainages. They grow up to 90 centimetres, but are more commonly only 45 centimetres.

- **Flood spawners**: Includes golden perch and silver perch. These species migrate upstream to spawn in flooded backwaters during spring and summer. Silver perch live in rivers, lakes and reservoirs with rapid flows, and grow up to 40 centimetres and weigh up to eight kilograms. Golden perch prefer warm, slow-moving turbid sections of rivers, and grow up to about 76 centimetres and weigh up to 23 kilograms.

Data for the time of listing are not available; however, two sets of data are available for 1994–1997 and 2005–2011. These are the most complete data sets for fish, but represent data for lakes with two distinct flooding types. Data from 2005–2010 represents lakes filled with pumped environmental water rather than in response to natural overbank floods and as such should be treated with caution in terms of being representative of the fish populations at the site. The 1990s data set and the most recent sampling under The Living Murray initiative (2010 to 2011) are for natural large flood events and as such should be more representative of the typical fish fauna in the lakes. As might be expected, there are some notable differences between the fish fauna reported by Puckridge et al. (1997) and by Walters et al. (2010) (see Table 13).

Puckridge et al. (1997) described the fish fauna of the Hattah Lakes in 1994 to 1997 as being depauperate of native fish, having a prominence of exotic fish and lacking evidence of recruitment of the large native species. In the 1990s the fish fauna was dominated by exotic species, notably gambusia. During the period 2005–2010 there were relatively few exotic species, and gambusia, whilst present in the Murray River, was not found in large numbers in the lakes. This was most likely an artefact of the pumping, as water was extracted from the Murray River in areas not favoured by gambusia (that is, the pump was away from the shallow warmer surface waters) (I. Ellis, MDFRC, pers. comm.). This pattern has changed somewhat with the most recent data indicating exotic species are in larger numbers throughout the site (MDFRC in prep). An additional exotic species, weatherloach, was recorded at all sites sampled in 2010–2011 (MDFRC in prep). Weatherloach was first recorded in freshwater systems in Australia in 1984 (Keller and Lake 2007).

Puckridge et al. (1997) identified Murray hardyhead (*Craterocephalus fluviatilis*) as occurring at the site; however, considering the characteristics of the lakes (predominantly freshwater) it is likely that this species is actually the fly-specked hardyhead. Only the one species is known from the area, but at the time of the Puckridge survey the taxonomy of the species was poorly known and species were likely to be misidentified (I. Ellis, MDFRC, pers. comm.).

SKM (2003a) stated an ecological objective to 'reinstate' populations of freshwater catfish and flat-headed galaxias to Hattah Lakes, supporting the idea that the species were once found at the site. Freshwater catfish underwent a serious decline in the 1970s and 1980s (P. Clunie, DSE, pers. comm.). However, it is likely that catfish were present at the time of listing as current catfish populations are known in the Robinvale area and downstream to Mildura and there is a single record for 1981 from within the site. Lintermans (2007) states that there was a similar decline in flat-headed galaxias and that the species has not been recorded in the area since before 1980. It is considered unlikely that this species still occurs at the site.

A rare occurrence of a single spangled perch (*Leiopotherapon unicolor*) from Little Lake Hattah may represent the first record of this species in Hattah Lakes and possibly in Victorian waters. This is a northern species and is a rare vagrant in the Murray River after flooding in the Darling, but usually downstream of the Murray-Darling confluence. The perch would have come from the upper Darling in the recent floodwater and then moved upstream into Hattah Lakes (MDFRC in prep.). This species is not included in the table below as it is a vagrant species.

As would be expected, the most abundant and diverse fish fauna in the lakes are found in those that flood more frequently and retain water for longer periods (Souter et al. 2000; SKM 2003a). Fish species richness and the ratio of exotic to native species abundance are correlated with the depth, wetting and drying patterns, including historic inundation patterns (Puckridge et al. 1997; SKM 2003a).

The data from 2005–2007 are for seven lakes from the Ramsar site, showing that three small native species, Australian smelt, carp gudgeon and flat-headed gudgeon account for most of the catch (Figure 33). Species compositions vary between sampling events both within and between lakes, as does the number of fish caught (Figure 34). Abundance data for 2010–2011 are not yet available, but in general there were large numbers of carp gudgeon and moderate numbers of fly-specked hardyhead, flat-headed gudgeon and Australian smelt at all sites except Little Lake Hattah for the smelt (only one recorded) (MDFRC in prep).

The lower abundances observed in the lakes leading up to their drying in 2009 probably reflects declining conditions and loss of the fish population at the time. Pumping recommenced in September 2009 inundating Lake Hattah, Little Hattah, Mournpall and Lockie. The May 2010 survey data is indicative of a short duration of inundation (Walters et al. 2010). EPA and MDFRC (2008) noted that fish communities reflect patterns of how the lakes fill, with two different flow paths showing different communities. The northern trajectory where inflows progress from Lake Lockie to Lake Yerang and then Lake Mournpall are distinct from communities' characteristic of the southern flow pattern from Lake Lockie to Lake Hattah to Lake Arawak to Lake Brockie. Fish communities in each lake are similar to that of the preceding lake in the chain EPA and MDFRC 2008).

A single record of Murray cod was recorded at Little Hattah in 2010 which is the first record for the species in the floodplain lakes. Although not part of the Ramsar site, the cod would have had to traverse through Lake Lockie to be caught in Little Hattah. In addition, there are records for three Murray cod within Chalka Creek (Walters et al. 2010), which suggests this species may be found within the Ramsar site on occasion. Similarly, seven silver perch were found in Little Hattah in May 2010, the first record in the intervention monitoring and TLM Icon condition monitoring (Walters et al. 2010). Only a single silver perch was recorded in Lake Yerang in 2010-2011 (MDFRC in prep). Golden perch were recorded from all lakes except Lake Arawak in 2010-2011, with adults, young of the year/1+ size classes recorded (MDFRC in prep).

Large bodied fish such as golden perch and Murray cod may have suffered declines in the Ramsar site in the past decade due to poor habitat and drying of the wetlands in 2009 (Walters et al. 2010). In addition, a large blackwater event in the Murray River through late 2010 to early 2011 probably resulted in suppression of cod, golden and silver perch breeding events and abundance (MDFRC in prep). Overall the pattern for the large bodied fish is that they occur in low numbers, particularly silver perch and Murray cod with golden perch being more variable. Young of the year were recorded from wetland habitats for golden perch, fly-specked hardyhead, carp gudgeons, flat-headed gudgeon, Australian smelt, goldfish and carp. However, with the drying of the lakes in 2009 none of the fish communities which developed from 2006 through to 2008/09 had an opportunity to recolonise the main channel. As such the main ecological role of fish in the Ramsar site was limited to trophic interactions; that is, contributing to food webs. Recruitment into the riverine adult population is reliant on connectivity with the main river channel (Walters et al. 2010).

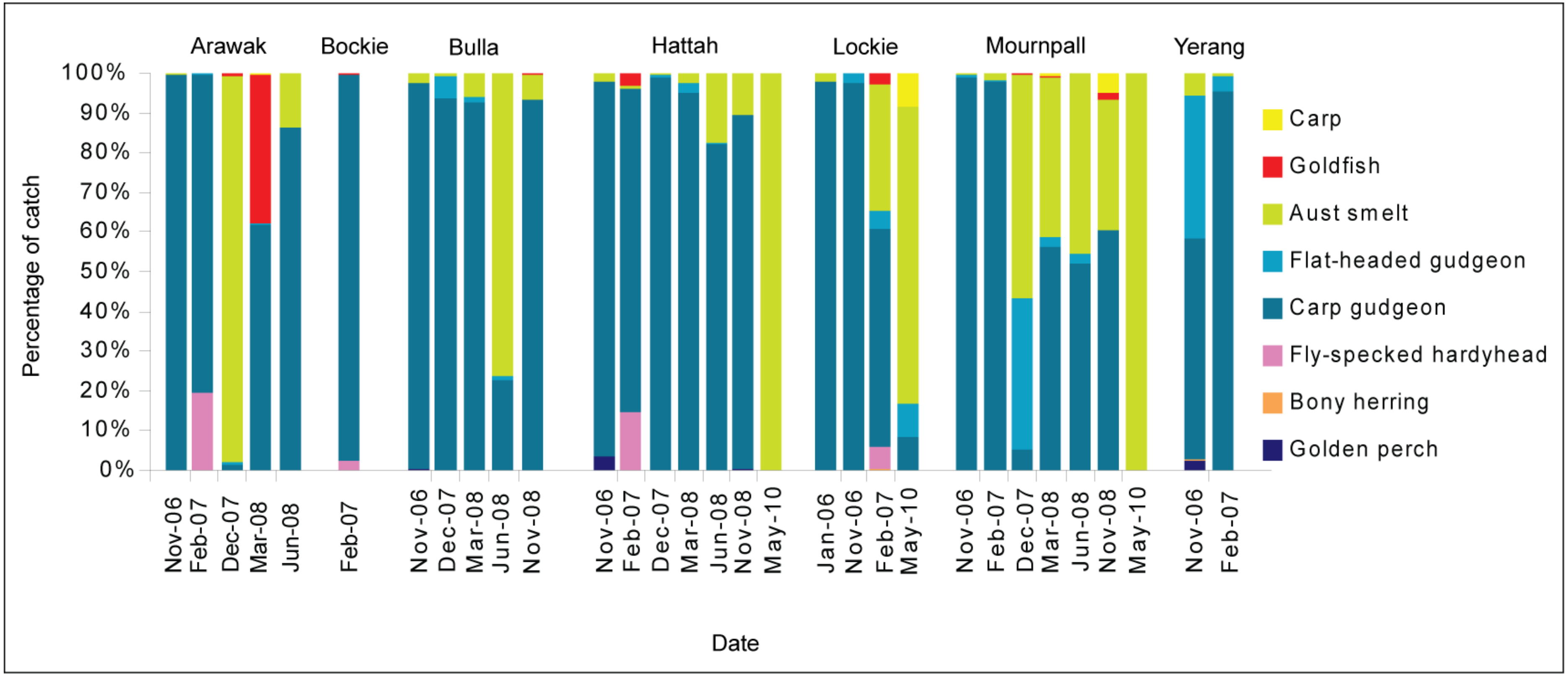


Figure 33: Percentage of catch for fish species from seven of the Ramsar lakes from 2006-2010 (data from Walters et al. 2010).

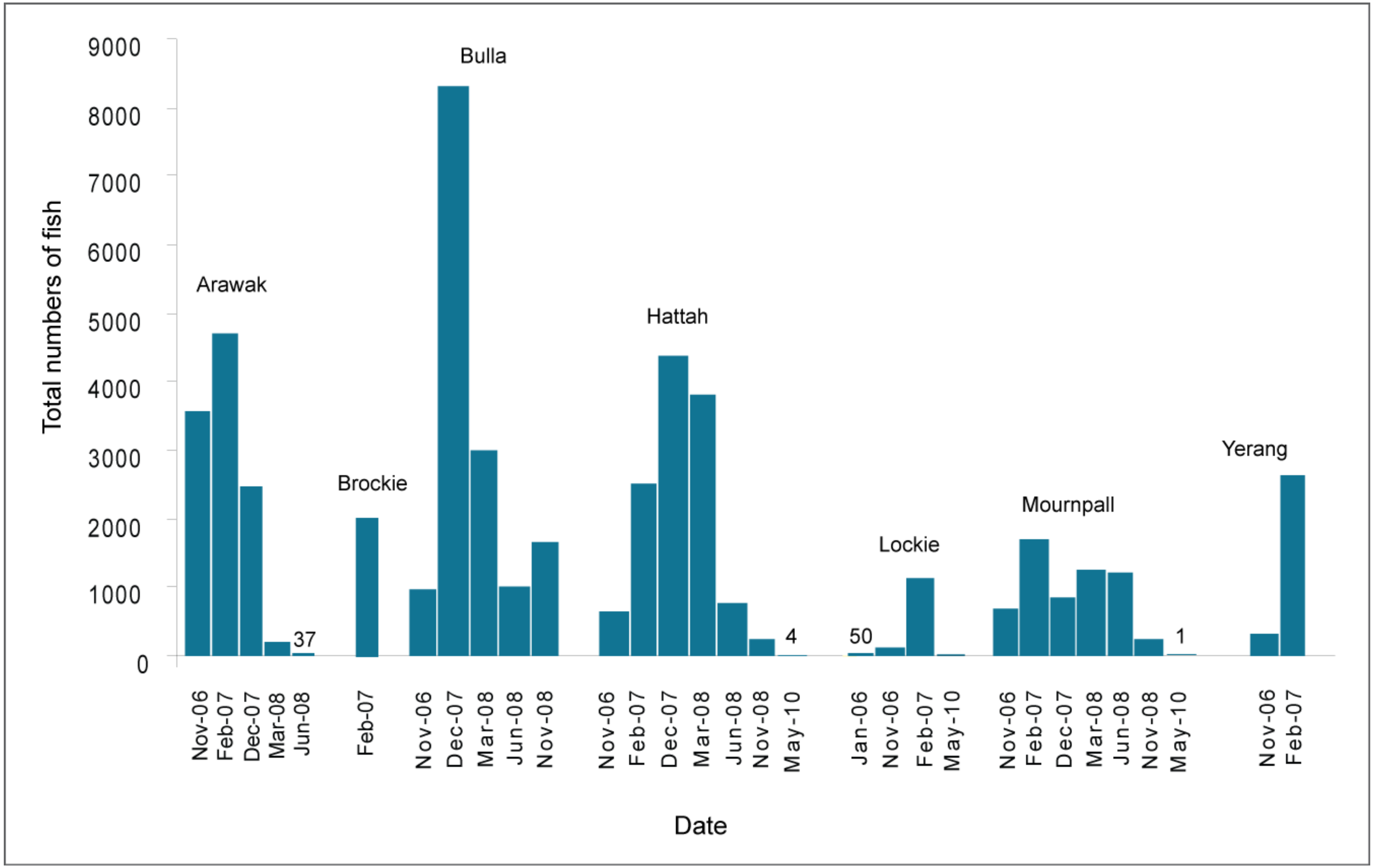


Figure 34: Total number of fish caught from seven of the Ramsar lakes 2006 to 2010 (data from Walters et al. 2010).

3.3.4 Waterbirds

A total of 70 species of waterbird have been recorded within the Ramsar site, which contributes to the site's listing as a Wetland of International Importance (see Table 14 and Appendix B). This includes 12 species that are listed under one or more international migratory agreements Bonn (8), CAMBA (12), JAMBA (9) and ROKAMBA (7). These species are also listed as migratory under the EPBC Act. The waterbird diversity is comparable to several other Ramsar sites within the Murray-Darling Drainage Division, with the number of species in each bird group being similar. Interestingly, Hattah Lakes has a greater number of species of shorebirds recorded from the site, but these are not dominant in terms of abundance (see Section 4.3.2 and Table 15).

Table 14: Number of wetland birds recorded within the Hattah-Kulkyne Lakes Ramsar site.

Bird Group	Typical feeding habitat	Number of species
Ducks and allies.	Shallow or deeper open water foragers. Vegetarian (for example black swan) or omnivorous with diet including leaves, seeds and invertebrates.	15
Grebes.	Deeper open waters feeding mainly on fish.	3
Pelicans, cormorants, and darters.	Deeper open waters feeding mainly on fish.	6
Heron, ibis, and spoonbills.	Shallow water or mudflats. Feeding mainly on animals (fish and invertebrates).	11
Hawks and eagles.	Shallow or deeper open water on fish and occasionally waterbirds and carrion.	2
Cranes, crakes, rails, water hens, and coots.	Coots in open water; others in shallow water within cover of dense emergent vegetation such as sedge. Some species vegetarian, others mainly take invertebrates, some are omnivores.	7
Shorebirds.	Shallow water, bare mud and salt marsh. Feeding mainly on animals (invertebrates and some fish).	18
Gulls and Terns.	Terns, over open water feeding on fish and invertebrates; gulls, opportunistic feeders over a wide range of habitats.	5
Other.	Non water birds that are reliant on wetlands for breeding or feeding (sacred kingfisher).	3
Total		**70**

Table 15: Number of species in each bird group for four Ramsar sites in the Murray-Darling Drainage Division (from Butcher et al. 2011; Hale and Butcher 2011; Harrington and Hale 2011).

Bird Group	Hattah-Kulkyne Lakes	Narran Lake Nature Reserve	Barmah Forest	Central Murray Forest
Ducks and allies.	15	13	13	13
Grebes.	3	3	3	3
Pelicans, Cormorants, and Darters.	6	6	6	6
Heron, Ibis, and Spoonbills.	11	15	14	14
Hawks and Eagles.	2	2	2	2
Cranes, Crakes, Rails, Water Hens, and Coots.	7	6	8	9
Shorebirds.	18	16	7	12
Gulls and Terns.	5	5	2	3
Other.	3	2	5	5
Total	**70**	**68**	**60**	**62**

Records prior to the time of listing are not systematic and generally only record presence. Annual counts of waterbirds on Victorian wetlands, including Hattah-Kulkyne Lakes, have been conducted during mid to late summer since 1983 and as part of a Victorian Waterfowl Summer Count Program since 1987 (DSE 2010). Additional sightings have been made at other times of year when the wetlands are flooded (DSE 2010). Counts made in mid to late summer may not represent the highest abundance and diversity of waterbirds at the site, which might be expected to occur in spring (DSE 2010).

This is evident by comparing data from 2007 from the Icon site condition monitoring (Kingsford and Porter 2008) with the Summer Waterfowl Count data. Kingsford and Porter (2008) reported high waterbird numbers in November 2007, with a total of 16 097 birds, comprising mainly grey teal, hardhead, Eurasian coot, Pacific black duck and Australasian shoveler. Lake Lockie and Lake Yerang supported the most waterbirds (12 200 and 2800 mean total respectively). This contrasts with the count data collected in the Summer Waterfowl Count of only 4091 in March 2007 (Figure 35), with Lake Yerang (931 birds) and Lake Mournpall (898 birds) having the highest counts. In March 2007 the dominant species were grey teal, Pacific black duck, Australian shoveler and pink-eared duck.

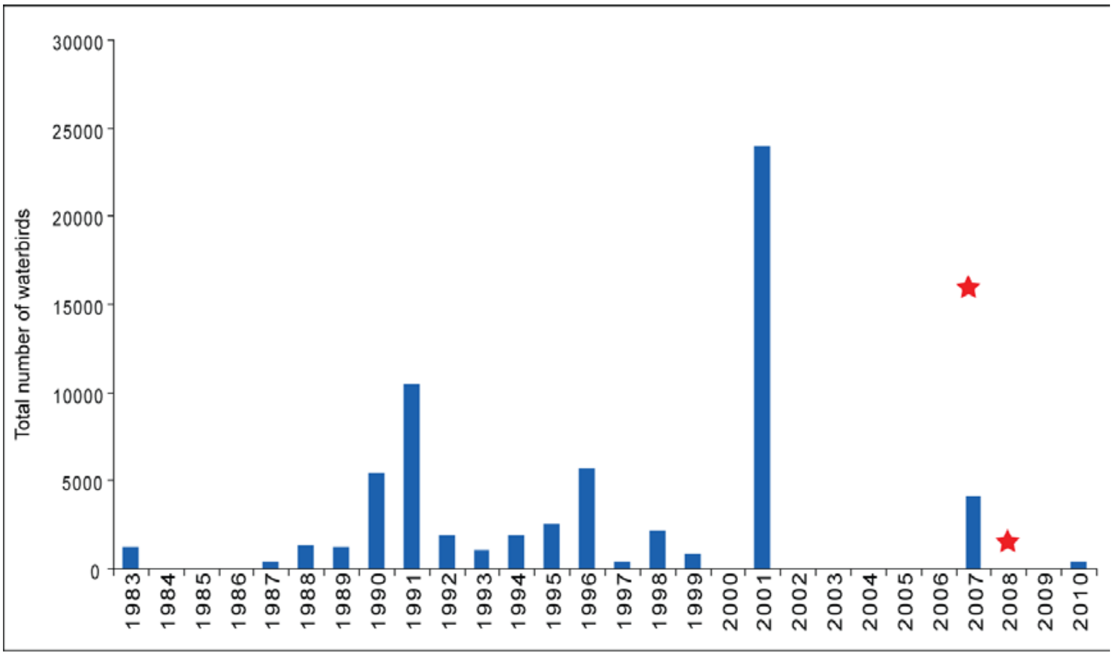


Figure 35: Total number of waterbirds from Summer Waterfowl Counts 1983 to 2010 (no data for 2002 to 2006) and annual waterbird count for Hattah Lakes Icon site (red star: count data from Kingsford and Porter 2008, 2009).

Of the TLM Icon sites, Hattah Lakes was ranked second in terms of abundance and diversity for waterbirds in 2007 (Kingsford and Porter 2008). The site also supported a very distinct suite of species with a very distinctive pattern of functional feeding groups – proportionally more ducks than the other icon sites (Kingsford and Porter 2008; 2009).

DSE (2010) reported that the highest abundances of waterbirds are mostly associated with the sequence of flooding events that occurred between 1989 and 1993 and during 2000. The species observed in the highest abundance was grey teal. Three other waterfowl species were among the ten most abundant species.

Thirty four species breed within the Ramsar site (DSE 2010; Ecological Associates 2007 – see Appendix E). Kingsford and Porter (2008) found no evidence of a significant waterbird breeding event at the Hattah Lakes in 2007/08 (see Section 4.3.2 for more detail).

4. Ecosystem services

4.1 Overview of benefits and services

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

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

The ecosystem benefits and services of Hattah-Kulkyne Lakes Ramsar site are summarised in Table 16 and described below.

Table 16: Ecosystem services and benefits provided by Hattah-Kulkyne Lakes Ramsar site at the time of listing.

Category	Description
Regulating services	
Natural hazard reduction.	The Ramsar site and floodplain make a contribution to flood mitigation on the Murray River. However, flood mitigation at Hattah is not considered a key ecosystem service in the context of other Murray floodplain systems in Victoria and New South Wales such as Barmah-Millewa (66 000 hectares) and Gunbower-Pericoota (50 000 hectares), Lindsay-Walpolla and Chowilla (17 700 hectares) which are significantly larger. In addition, Barmah-Millewa and Gunbower-Pericoota flood at lower river levels and, hence, more frequently (DSE 2010).
Provisioning services	
Water supply	Provides an emergency stock and domestic water supply for Hattah township (DSE 2010).
Cultural services	
Cultural heritage and identity.	Considered an important area for Aboriginal cultural heritage (DSE 2010). The lakes have been a focus for traditional Aboriginal society for thousands of years as evidenced by over 1000 registered Aboriginal archaeological sites within the Hattah-Kulkyne National Park. The local Indigenous community maintains a strong connection to the area.
Recreation	Supports recreational activities (bushwalking, camping, driving, fishing, canoeing, swimming and nature study) (DSE 2010).
Tourism	Supports tourism (DSE 2010).
Science and education.	Has educational values regarding floodplain wetlands. Is a site for ecological research on grazing, floodplain ecology and hydrology (DSE 2010).

Aesthetic and amenity.	Contributes to the scenic values of the landscape (DSE 2010).
Supporting services	
Sediment trapping, stabilisation and soil formation	Retains sediments and nutrients (DSE 2010).
Supports near-natural wetland ecosystem.	Represents the largest series of floodplain lakes along the Murray River and is in relatively good condition. Supports wetlands representative of two of Victoria's six natural wetland types including a depleted wetland type (in Victoria) (DSE 2010).
Provides physical habitat (for breeding waterbirds).	Provides habitat that supports waterbird breeding and feeding. Seventy species of waterbird frequent the site with 34 having used the Ramsar site for breeding.
Threatened wetland species, habitats and ecosystems.	Supports seven nationally or internationally listed species.
Priority wetland species.	Supports 12 migratory waterbirds listed under international agreements and the EPBC Act. The site is not considered significant for shorebirds (DSE 2010).
Special ecological, physical or geomorphic features.	The persistence of water in Hattah-Kulkyne Lakes for several years between inflow events provides an important drought refuge for waterbirds and other aquatic fauna. Records of water levels in Lake Hattah between 1908 and 1982 show that the lake only dried out on nine occasions with a maximum dry period of 36 months. Although the lakes had a regulator gate to retain flood water longer than the other lakes, this record indicates that that flooding was a persistent state for the system, and that it would have provided a reliable aquatic habitat.
Biodiversity.	The site supports regionally significant range and number of species comparable to other sites within the Murray-Darling Basin. This includes supporting a large number and variety of waterbirds, including breeding habitat for many waterbird species, a rich and diverse flora and seed bank.
Ecological connectivity.	Hattah-Kulkyne Lakes are hydrologically and ecologically connected and provide semipermanent surface water in a semi arid environment thus ensuring ecological persistence of aquatic habitats. The relative importance of this service is a knowledge gap, but is believed to be important in shaping the character of the site.

4.2 Identifying critical ecosystem services and benefits

The critical ecological ecosystem services and benefits of the Ramsar site have been identified using criteria specified in the National Framework (DEWHA 2008):

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

Using these criteria it was considered that the five of the eight supporting services (i.e. those that are ecologically based) could be considered 'critical'.

In summary, the following critical services (all supporting services) occur at the site:

- near natural wetland ecosystem;
- provides physical habitat for waterbird breeding and feeding;
- threatened species;
- biodiversity; and
- ecological connectivity.

With respect to threatened species, only those for which the site comprises important habitat were considered to meet all four of the DEWHA (2008) criteria for determining critical components processes and services. Species that have been recorded on single occasions, or for which the site does not contain core habitat were not considered to be "important determinants of the sites unique character". As such the threatened species that are identified as critical to the ecological character of the Hattah-Kulkyne Lakes Ramsar site are:

- Australian painted snipe;
- regent parrot (eastern); and
- winged peppercress.

4.3 Critical services

4.3.1 Natural or near natural wetland ecosystems

The Hattah Lakes are the most extensive series of floodplain lakes on the Murray River (Joyce et al. 2003). They lie within a National Park and are relatively intact providing excellent examples of near natural permanent and intermittent floodplain lakes. River regulation impacts (see Section 5.1) have reduced the frequency of inundation; however these impacts were in place at the time of listing. They are considered to reflect the ecological character of the site at the time of listing. As the boundary of the Ramsar site is delineated by the high water mark of the 12 lakes, the diversity of wetlands type is low (see Section 2.3 for description of wetland types).

4.3.2 Provides physical habitat for waterbird breeding and feeding

Waterbird breeding

Hattah-Kulkyne Lakes provides breeding habitat for 34 waterbirds when conditions are suitable (see Appendix E). An additional six waterbird species have bred in the surrounding floodplain (DSE 2010). Breeding habitat for most waterbirds is dependent on vegetation, either dead or live trees or shrubs, tree hollows, sedges and reeds, floating vegetation, or nests made from vegetation on the ground. Waterbirds breed in response to flooding, in relation to nesting habitat availability, and available food resources. There is evidence to suggest that waterbird breeding occurs when food resources are at a maximum (Kingsford and Norman 2002), which, depending on the season and diet of the species can lag behind the commencement of inundation for periods of four weeks to seven months. Once breeding has commenced, many Australian waterbirds require surface water to remain in and around nesting sites until offspring are independent feeders (Jaensch 2002). Drying prior to this can lead to abandonment of nests and young by parents or insufficient food resources for successful fledging. It is suggested that inundation for a minimum of four months would be required to allow for courting/mating, nest site selection and building, incubation and raising of young to independence (Jaensch 2002).

The breeding stimulus for each species is presented in Table 17. The most frequently breeding waterbird in the Ramsar site is the great cormorant. The most frequently breeding waterbird on the combined Hattah floodplain and Ramsar site is the great crested grebe (DSE 2010). However, data on waterbird breeding are unlikely to be comprehensive as counts have mainly been conducted once a year in mid to late summer (DSE 2010). Also, most of the species recorded breeding at the Ramsar site respond to flooding as a breeding stimulus, and these species tend to be highly mobile and may not breed at the site each year (Scott 2001).

Table 17: Main breeding stimuli for some of the waterbirds which breed within Hattah-Kulkyne Lakes Ramsar site (from Scott 2001).

Breeding stimuli	Common name
Flooding	Australian darter, black swan, black-tailed native hen, Eurasian coot, freckled duck, great crested grebe, grey teal, little egret and pink-eared duck.
Flooding, season	Australasian grebe, Australian shelduck, chestnut teal, dusky moorhen, little pied cormorant, Pacific black duck, white-faced heron and white-necked heron.
Season, flooding	Great cormorant, little black cormorant, pied cormorant and yellow spoonbill.
Season	Blue-billed duck and musk duck.
Rainfall, season	Australian wood duck.

Foraging and feeding

The Hattah-Kulkyne Lakes Ramsar site is quite different to the other major wetland and TLM Icon sites along the Murray River in terms of the proportion of functional feeding groups (Figure 36), with the Ramsar site being dominated by ducks. This is a reflection of the major habitat type present within the site. For example, although there are records for 18 species of shorebird for the site, there is limited shorebird habitat and therefore they do not occur in large numbers. The relative differences in functional groups at the site in 2007 and 2008 reflect an increase in the area of available shorebird habitat and a decrease in duck habitat as the lakes dried out in 2008. The main functional feeding groups are briefly described below.

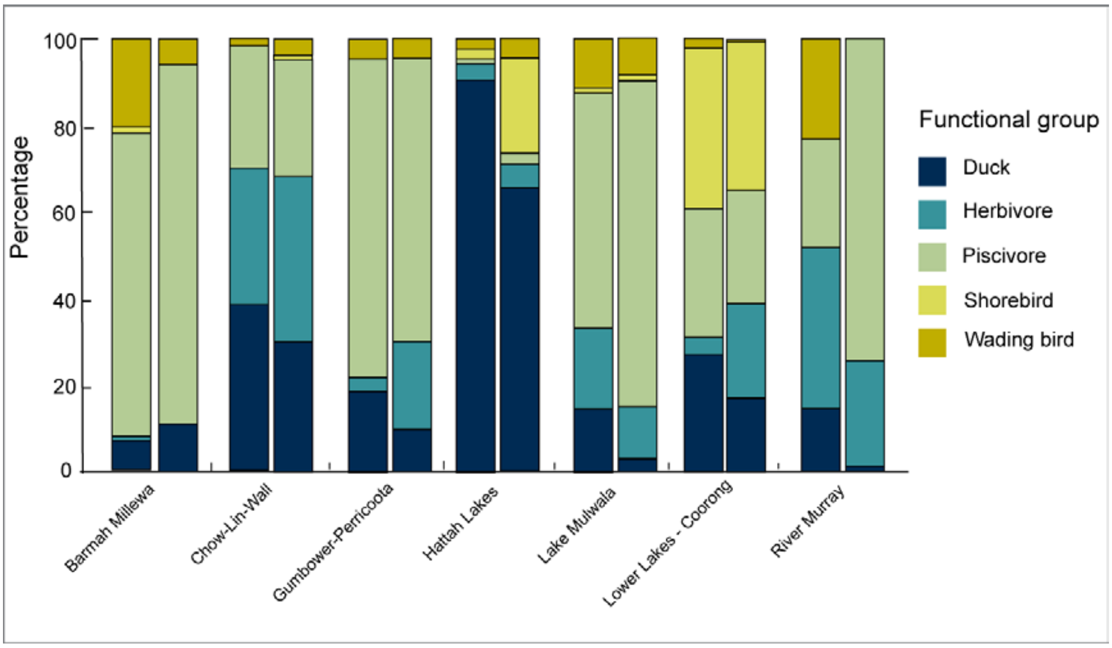


Figure 36: Functional feeding groups for Icon sites and Lake Mulwala in 2007 (left bars) and 2008 (right bars) (from Kingsford and Porter 2008; 2009).

<u>Ducks and herbivores</u>

This group includes the waterfowl and associated waterbirds which are the ducks, swans and geese, grebes, coots and waterhens. There are a range of feeding strategies and foraging and roosting habitats for this group of waterbirds. The foraging and feeding behaviours of the species which breed at the site are presented in Appendix E. Under the functional feeding groups provided by Kingsford and Porter (2009), the herbivores are the black swans, Eurasian coots and “ducks”, which include the diving and dabbling ducks and grebes.

Piscivores

Permanent and semi-permanent floodplain lakes, such as those found at the Ramsar site, are generally favoured by fish-eating waterbird species including cormorants, the Australian pelican and darter (Scott 2007). The site does support a number of waterbirds within the Ramsar site whose diet is wholly or mostly comprised of fish. This includes the terns, cormorants and darters as well as the white-bellied sea eagle. A number of these species require relatively deep water (greater than one metre) in which to feed and plunge. Pursuit divers such as terns require open water expanses. The general habitat requirements for a number of piscivorous waterbirds that have been recorded breeding within the Ramsar site are provided in Appendix E. The proportion of piscivores present in November 2007 was low (Figure 36) but higher in 2008 when the lakes were rapidly drying. The drying of the lakes may have provided a concentration effect, by forcing the fish population into smaller areas and potentially making them easier to catch.

Waders and shorebirds

Kingsford and Porter (2009) classify members of two families, Ardeidae and Threskiornithidae (herons, egrets, spoonbills and ibis) as “large waders”. There are 11 large waders recorded from Hattah-Kulkyne Lakes which typically feed in shallow water (usually less than 15 centimetres). There are 18 species of shorebirds, and as stated above, based on recent data, these are not abundant within the site. The foraging and feeding strategies of some of the wader and shorebird species found within the Ramsar site are provided in Table 18.

Table 18: General feeding habitat requirements of selected species of waders and shorebirds within the Ramsar site (information from Marchant and Higgins 1990; 1993).

Species	Habitat characteristics
Waders	
Straw-necked ibis, *Threskiornis spinicollis*	Favours inland, freshwater or brackish wetlands. Feeds mainly on terrestrial invertebrates, but also frogs, small reptiles and mammals. It forages by probing in the mud or taking prey from the surface of shallow water.
Yellow-billed spoonbill, *Platalea flavipes*	Prefers inland, freshwater wetlands with shallow margins and feeds predominantly invertebrates. Forage in shallow mud using the vibration detectors in its bill to detect movement of prey in the mud.
White-faced heron, *Egretta novaehollandiae*	Very diverse array of habitats from arid inland to temperate coasts. Feeds on a diversity of prey including aquatic insects, molluscs, crustaceans, frogs and fish. Forage using a variety of techniques, wading and disturbing prey, ambush hunting and probing crevices and mud.
Shorebirds	
Black-fronted dotterel, *Elseyornis melanops*	Forage in soft sediments, usually at edge of water, but also occasionally in shallow water. Sometimes found on open mudflats with sparse low vegetation, near gravely shorelines of lakes. Eats small molluscs as well as aquatic and terrestrial invertebrates. During foraging behaviour it keeps its body horizontal while bobbing its head to look for food, often in a walk-run pattern then suddenly pecking at food items.
Black-winged stilt, *Himantopus himantopus*	Prefer inland freshwater and saline marshes. The diet consists mainly of aquatic insects, but also crustaceans and molluscs. Wade in shallow water to forage and seize prey at or near the surface, occasionally taking sub-surface prey.
Red-necked avocet, *Recurvirostra novaehollandiae*	Diurnal. Forage in shallow water, rapidly sweeping through water and soft mud with long upturned bill slightly opened, close to bottom. Rely on touch to locate prey. Will place head and neck underwater, and even upend, still using scything motion. Swim readily; glean insects from surface of water. Beak, leg and foot morphology are adapted to foraging in deeper water than some other wading species of bird. Will take insects, crustaceans, occasionally seeds and vegetation, but there is limited understanding of the diet.

4.3.3 Supports threatened species

Several of the species that occur at the site have either single or very few records. This is partly a reflection of limited survey work, antecedent conditions prior to sampling but also the fact that the species concerned are rare. For example, silver perch and Murray cod are Murray River channel specialists, yet both were recorded at Little Hattah Lake (one cod and seven silver perch) in May 2010, and as such would had to traverse Lake Lockie in the Ramsar site. The most recent TLM Icon Site condition monitoring in 2011 recorded one silver perch in Lake Yerang (MDFRC in prep). No Murray cod were recorded but this is likely due to a large blackwater event in the Murray River suppressing cod, silver perch and golden perch breeding events/abundance (I. Ellis, MDFRC pers. comm.). This suggests that at particular times the listed large bodied species, such as Murray cod and silver perch, do utilise the floodplain lakes. These species however are not considered critical to the site's ecological character. Only species considered critical components of this service are discussed below.

Australian painted snipe (*Rostratula australis*)

Australian painted snipe are rarely recorded due to their cryptic nature. It is possible the site supports this threatened species and that low records are a reflection of the survey methods employed for most bird surveys (e.g. aerial surveys), which are not the most appropriate methods for sighting this species. Australian painted snipe prefer shallow freshwater (occasionally brackish) wetlands including temporary and permanent lakes, swamps and claypans. Preferred sites often have rank emergent tussocks of grass, sedges, rushes, reeds or samphires, sometimes with lignum, cane grass or tea-tree. The painted snipe will occasionally use sites lined with trees or with fallen timber (Marchant and Higgins 1993).

Records from the Ramsar site include sightings of two birds loafing at Lake Yerang in 2007. GHD (2009 cited in Goulburn-Murray Water 2010) also reported the species at Hattah Lakes, but it is unclear if this was within the Ramsar site or on Chalka Creek.

Regent parrot (eastern) (*Polytelis anthopeplus monarchoides*)

The population at Hattah Lakes is one of three in Victoria and is considered one of the key breeding sites in Victoria. During the non breeding season birds typically move away from the riverine breeding habitat, however at Hattah the birds can be found all year round (Baker-Gabb and Hurley 2010). Sightings of small flocks feeding along Chalka Creek between Lake Lockie and Mournpall indicate that the species also feeds within the site (B. McCarthy, MDFRC Mildura, pers. comm.).

The habitat requirements of the regent parrot include both river red gum and mallee woodland. They require mallee woodland within 20 kilometres of the riverine habitat, preferably less than five kilometres for foraging during breeding. In addition they require treed flight paths between the two main habitat types as they avoid flying in open areas. They use hollow bearing trees of river red gum close to water (within 120 metres) for breeding (Baker-Gabb and Hurley 2010). Nesting trees are usually large (approximately 30 metres), healthy mature river red gums with lots of hollows. Nesting occurs predominantly in hollows in branches high within the tree (Baker-Gabb and Hurley 2010).

Winged peppercress (*Lepidium monoplocoides*)

Winged peppercress is a small annual herb found in a range of habitats including floodplain wetlands on seasonally damp or waterlogged soils in semi-arid areas with an average rainfall of 200 to 450 millimetres per year. Whilst not a true aquatic species, its essential habitat is waterlogged soils associated with a range of wetland plant communities including wetlands and floodplain woodlands dominated by *Eucalyptus coolabah* and *Eucalyptus largiflorens*, and chenopod shrublands dominated by *Atriplex, Maireana* and/or *Nitraria* species (Mavromihalis 2010).

Within the Ramsar site it is located in a small area between Lake Hattah and Bulla Lake over an area of approximately 0.1 hectares (Mavromihalis 2010). Population size is reported to fluctuate considerably in response to wetting and drying cycles, making accurate estimates of populations difficult. In dry years the species can virtually disappear from a location, being most obvious after significant rainfall. The plant is inconspicuous except during seeding. The seed storage in the seed bank is believed to be large but has not been quantified (Mavromihalis 2010).

In 1991 the population estimate for Hattah-Kulkyne Lakes National Park was in the order of 1000 plants. In 2003 numbers were estimated at 100 to 150 plants. Threats to the species at the site include grazing pressure from kangaroos and rabbits (*Oryctolagus cuniculus*) and changed inundation patterns (Mavromihalis 2010).

4.3.4 Biodiversity

In addition to the nationally and internationally listed species discussed in the previous Section, the Ramsar site supports a significant number of state listed threatened species.

Despite the boundary of the Ramsar site limiting the range of habitats found within the site, the site still has very high species richness across a number of different groups. The wetting and drying promotes diversity through disturbance, with the lakes representing an interface between aquatic and terrestrial systems which supports a richer biodiversity than either environment would alone. The soil seed bank of the lakes has a high proportion of native species and is species rich compared to other major floodplain systems in the Murray-Darling Drainage Division such as Narran Lakes in northern NSW (EPA and MDFRC 2008). In addition the number of waterbirds supported is greater than several other Ramsar sites on the Murray River, including Barmah Forest, Central Murray Forest and Banrock Station. Floral diversity is high, especially on the adjacent floodplain.

Ecological Associates (2007) report over 251 species of fauna (excluding invertebrates, except for one threatened mollusc) from within the Hattah Lakes Icon site of which 22 percent are considered as being significant. SKM (2003b) report over 281 species, with more than 230 being bird species and of these nearly 30 percent are wetland dependent. Of the listed threatened bird species, the regent parrot (eastern) and Australian painted snipe are wetland dependent species listed as threatened at the national level. In addition, 11 waterbirds are listed at the state level under the *Flora and Fauna Guarantee Act.*

4.3.5 Ecological connectivity

Being a serially connected system of floodplain lakes, hydrological connectivity is obviously important. The importance of ecological connectivity is assumed but not proven definitively. There are some indications that ecological connectivity and gradients are occurring at the site; for example, the similarity of fish communities between each lake and its ‘parent’ lake suggest that ecological connectivity is important for the site. It is assumed that if hydrological connectivity is maintained, in the right temporal sequence (that is flows reflect natural, or near natural patterns/seasons of inflows) that biological cues and environmental cues relating to connectivity will also be maintained for aquatic species. Hydrological connectivity also affects the transport of nutrients as well as biota. Lake Kramen and Lake Cantala are not as connected to the other ten lakes as they receive water via different flow paths.

Ecological connectivity is most relevant to native fish spawning and recruitment (see Section 3.3.3 and Appendix D). A critical aspect of the connectivity of the lakes for fish populations is re-connection to the Murray River at key times to allow fish recruitment to be completed. Recent intervention pumping has not achieved reconnection with the Murray River and fish populations which established in the lakes during 2006 to 2008/09 perished when the lakes dried in 2009. Overall, the relative importance of ecological connectivity is a knowledge gap for the site.

As detailed in Section 4.3.3 above, the regent parrot (eastern) requires connected patches of critical habitat of river red gum and mallee woodland, and represents another aspect of the importance of ecological connectivity within this site.

4.4 Interactions and conceptual models

Documenting the ecological character of a site requires an understanding of how components, processes and services interact: how the unique combination present at a site determines the ecological character of the site. Wetlands are dynamic and complex ecosystems and documenting how they work at the fine scale is a daunting task, often beyond the limits of the data in hand. In order to aid describing the ecological character of the site a number of character conceptual models, specific to the site, have been developed. These models show the components, processes and services which contribute to the ecological character of the site. The models are simple models and do not attempt to show every interaction.

The drivers of the site's ecology are climate, geomorphology and hydrology, which produce the physical habitat template. These in turn support (and in some cases are influenced by) species, communities and ecological processes which in turn culminate in the ecosystem services provided at the site. Two models are presented: the first is is an overarching model which provides a simple outline of the linkages between components, processes, services and the Ramsar criteria for which the site was listed (Figure 11).

The second model is representative of three of the 12 lakes, Hattah, Bulla and Arawak associated with a filling event (Figure 37). Lake Hattah and Lake Bulla are represented in the model at different stages of inundation.

The following processes are associated with the arrival of floodwaters (modified from Boon 2006):

- dry and aerated sediments quickly become waterlogged and devoid of oxygen;
- there is a mineralisation and release of nutrients and carbon from the sediments and litter deposited by fringing vegetation; and
- depending on the water quality of source water, velocity of flooding and sediment type, the floodwaters may be highly turbid and sediments may be deposited on the low relief surfaces.

Biological processes that occur upon wetting include (modified from Boulton and Brock 1999):

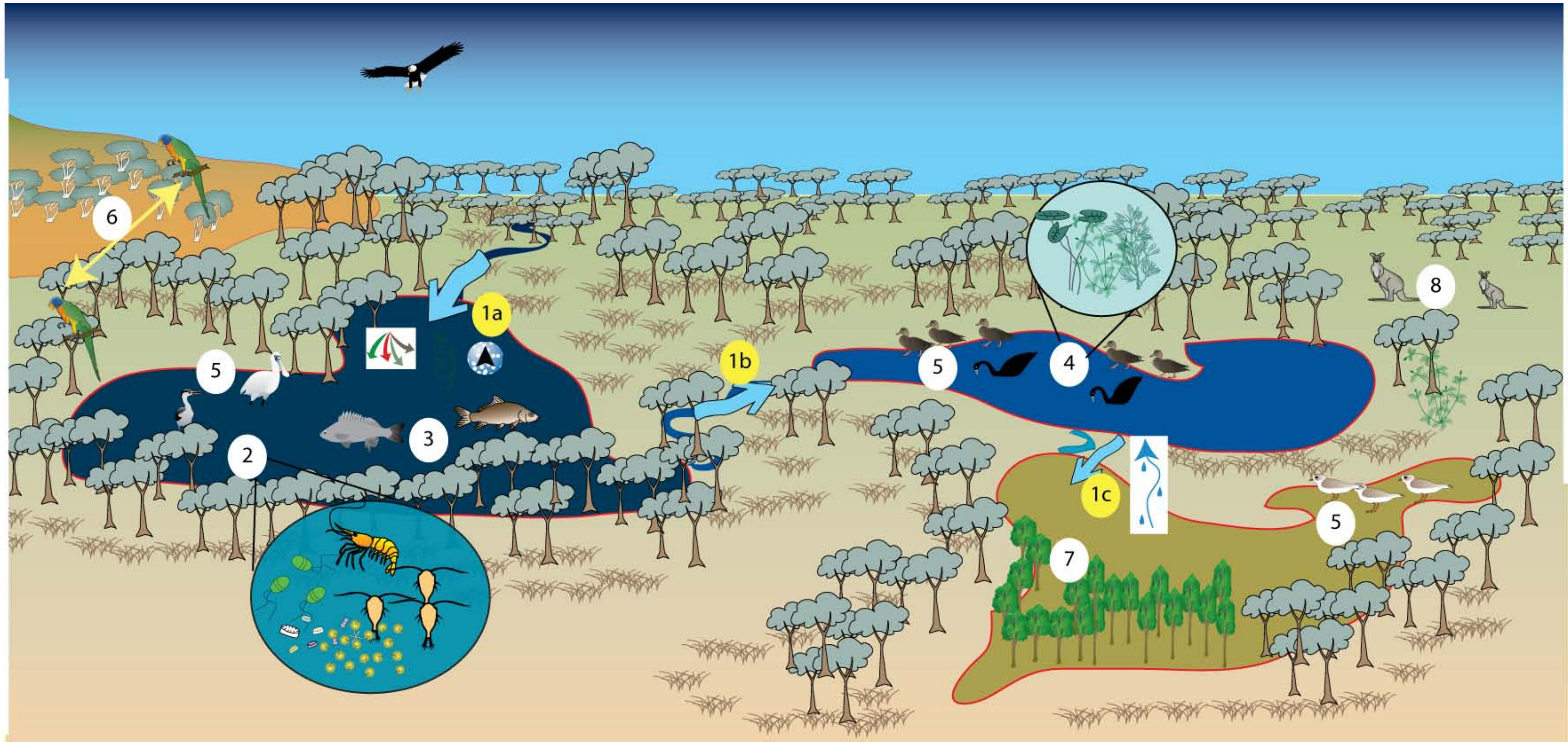
- microorganisms (bacteria and algae) process mineralised nutrients and a "boom" of productivity commences which includes the germination and hatching of seed and eggs from reservoirs in the sediments; the boom in productivity acts as the basis of food webs and cues the arrival of waterbirds, fish, frogs and turtles;
- fish arrive with the floodwaters whilst some invertebrates also arrive with the floodwaters or aerially; and
- aquatic plant growth is stimulated.

When inundated the following ecological processes can be expected (modified from Boulton and Brock 1999):

- a productivity boom may be maintained for some time (depending on conditions of light, temperature and nutrients released into the water column; at Hattah Lakes algal blooms are common as nutrients are not limiting;
- submerged aquatic plants grow and flower, while amphibious aquatic plants exist in their aquatic form;
- aquatic invertebrates occur in both larval (aquatic stages as well as some emerging into mature aerial forms); temporary wetland specialists undergo rapid growth and reproduction laying eggs into the sediments for the next period of inundation;
- the productivity boom provides important food resources for waterbirds, fish, frogs, turtles as well as insectivorous and nectivorous terrestrial species;
- flooding triggers breeding in several groups of biota including waterbirds and fish; and
- frogs breed in shallow water and inundated vegetation, tadpoles mature and grow.

In Figure 37, Lake Arawak is represented in a dry phase with receding floodwaters and subsequent drying of the soil which results in the following ecological processes (modified from Boulton and Brock 1999):

- as waters recede nutrients and salts become concentrated in the lake bed as it dries by evaporation;
- nutrients and organic carbon become stored in the sediment;
- aquatic plants set seed to be stored dormant in the sediment for subsequent floods;
- floodplain plants such as river red gum can germinate and seedlings emerge on the damp soil; if the lake remains dry for several years these seedlings grow to become established sapling as has been seen in many of the lakes, encroaching into the drier lake beds during the drought years;
- most waterbirds fledge and disperse, however some shorebirds may take advantage of exposed lake bed as temporary habitat;
- turtles migrate to nearby wet refuges, some aestivate; and
- fish return with receding waters to the Murray River or remain in the deeper lakes until flows reconnect the lakes to the river.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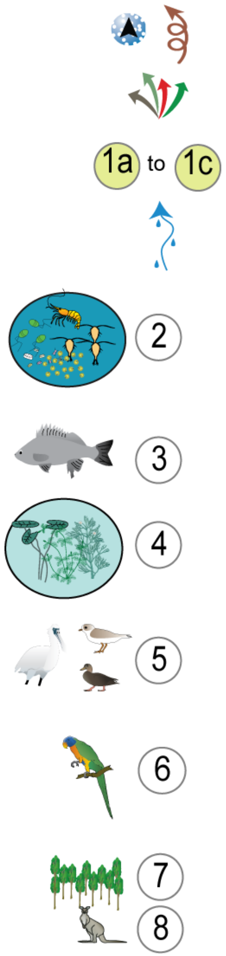
Components, processes, and services.



Water is fresh, however electrical conductivity is temporally and spatially variable. Turbidity levels can be moderate to high

Sediments, dissolved nutrients and allochthonous material are transported into floodplain lakes via channels between the lakes. Some overland transmission may occur in heavy rainfall periods, but mainly delivered via inflows. Biota disperse into and out of lakes with floodwaters.

Hydrology. This model represents Lakes Hattah, Bulla and Arawak during an inflow which would fill Hattah and partially inundate Bulla and Arawak. During this situation there is significant hydrological connectivity. Water moves between lakes via distinct channels. The magnitude of inflows via Chalka Creek dictate the rate of fill and which lakes fill. Of the three illustrated Lake Hattah is deeper and can retain water for longer than the other two. Once full Hattah can retain water for several years. Water moves along the main flow paths and fills the lakes (1b) sequentially. There are lag times involved with the movement of water through the system due to the capacities of the lakes and transmission loss (1c). The further down the chain of lakes the water travels the shorter the inundation periods. Contributes to meeting criterion 1.

Productivity is high as the site exhibits a classic boom and bust ecology. On arrival of floodwaters primary productivity booms with a corresponding flush of zooplankton, which both arrive on floodwaters and emerge from the egg and seed bank. Larger invertebrates such as aerial insects arrive and provide an abundant food resource for secondary consumers such as fish. High productivity supports high biodiversity values and contributes to meeting criterion 3.

Native fish species are a mixture of wetland specialists, low flow specialists and occasionally main channel species such as golden and silver perch move onto the floodplain with floods. Several species have been recorded spawning in the lakes. Hydrological connectivity to the Murray River is required for recruitment. Contributes to meeting criteria 4 and 8.

Lake bed herbland vegetation. The lakes are dominated by the one vegetation association and is maintained by a significant seed bank. Establishment of macrophytes is variable and dependent on antecedent conditions and water quality. Once established macrophyte beds are important for many biota including waterbirds and fish.

Waterbirds. Seventy species have been recorded from the site, 34 of which breed at the site. The site is unusual in that despite supporting similar numbers of species from different functional guilds as other Ramsar sites in the Murray Darling Basin, it is dominated by ducks and herbivores. This is a reflection of the predominance of open water habitat. Shorebirds whilst present are limited by the relatively small amount of their preferred habitat being present. Contributes to meeting criterion 3 and 4.

Supports threatened species. Seven nationally listed species are found within the site. Three are considered critical components, regent parrot, Australian painted snipe and winged peppercress. Contributes to meeting criterion 2. Regent parrot require vegetated flight pathways between river red gum woodland and mallee woodland.

Threatening processes. Water resource use, climate change, and invasive species are among the threats to the ecological character of the site. Water resource use combined with climate change has significantly altered the inundation pattern in the decade 2000 to 2010. River red gum encroachment has occurred in many of the lakes within the site and constitutes a significant change in habitat within the boundary of the site. Grazing pressure from rabbits and kangaroos is an ongoing issue within the broader National Park as well as within the site. Disruption of lake bed sediments by pigs is also a threat.

Figure 37: Character conceptual model for a filling event which fills Lake Hattah, partially inundates Lakes Bulla and Arawak with subsequent drying of Lake Arawak.

5. Threats to Ecological Character

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

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

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

In evaluating threats it is useful (in terms of management) to separate the threatening activity from the stressor. In this manner, the causes of impacts to natural assets are made clear, which provides clarity for the management of natural resources by focussing management actions on tangible threatening activities.

There are a number of potential and actual threats that may impact on the ecological character of Hattah-Kulkyne Lakes Ramsar site. The stressor model (Figure 38) only illustrates the major threatening activities (boxes), stressors (ellipses) and resulting ecological effects (diamonds) on the components processes and services (hexagons) in Hattah-Kulkyne Lakes Ramsar site. A description of these major threats is provided below. Note not all threats are described in detail, only those considered likely to have a potential impact on the ecological character of the site.

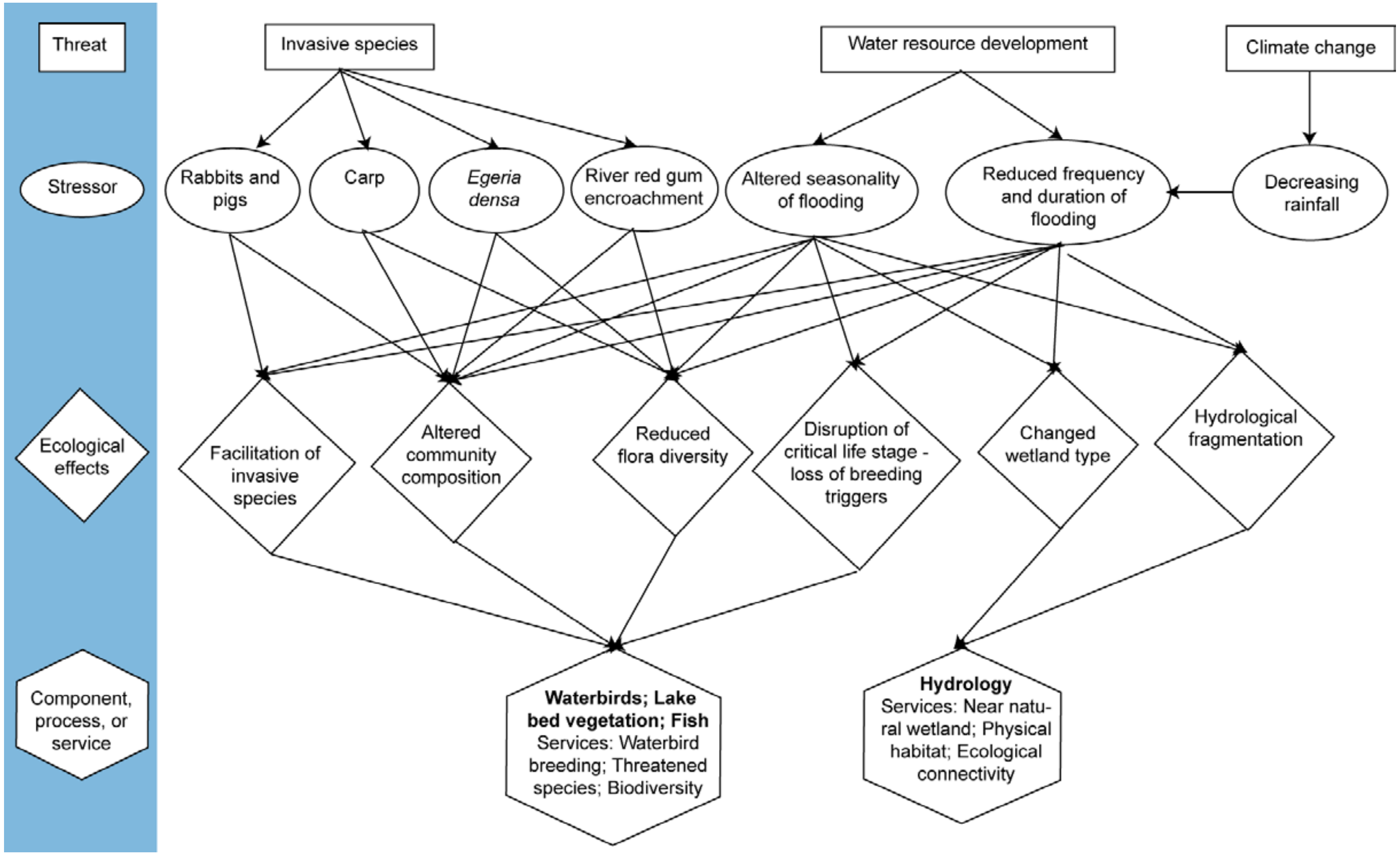


Figure 37: Stressor model of major threats to ecological character of Hattah-Kulkyne Lakes Ramsar site (after Gross 2003 and Davis and Brock 2008).

5.1 Water resource development

Water regime is considered the key driver of wetland ecosystems and determines the ecological signature of a wetland. Altered water regimes are considered the single most damaging impact on wetland and floodplain ecosystems (Bunn and Arthington 2002). Disruption of the hydrological integrity of a system such as the River Murray can affect several attributes including (Bunn and Arthington 2002):

- physical and geomorphic processes;
- the timing, duration and extent of floodplain inundation;
- habitat availability at both local and landscape scales;
- biological and ecological processes for riverine and floodplain flora and fauna (e.g. breeding, migration, recruitment, metabolism, competition);
- water quality and the cycling of nutrients and energy; and
- resilience to invasive flora and fauna species.

Wetlands along the Murray River have had their natural hydrological regimes significantly altered by river regulation (CSIRO 2008). Frequency, timing and duration of floods have all been altered (SKM 2003b; Souter 2005; MDBC 2006; Ecological Associates 2007; CSIRO 2008). Despite the fact that an altered hydrological regime was in place at the time of listing and that the site's ecology would have had several decades to adjust to this state, changes to ecological character arising from river regulation are still possible. As surface water diversion for consumptive purposes was not capped until 1995 (a decade after listing), altered hydrology should still be considered a threat to the ecological character of the site as the negative impacts of regulation are still developing. This is particularly the case when regulation is combined with the impacts of long term drought and possible climate change. As such, past water resource management could have current and future impacts on the Ramsar site through time-delayed or "lag" effects acting either directly on the lakes, or by reducing their resilience to other environmental factors such as drought, climate change, grazing or introduced species, or by changing the competitive interactions among different species.

SKM (2003b) list the following hydrological impacts to the Hattah Lakes:

- decreased frequency of inundation and increased time since last inundation;
- decreased duration of inundation;
- decreased extent of inundation;
- increased frequency of dry periods
- increased duration of dry periods; and
- altered timing of inundation.

Average annual flood volumes at Hattah Lakes have been reduced with flood volumes now only 17 percent of what they would be under without-development conditions under the historical climate (CSIRO 2008). In addition there has been a 57 percent reduction in the frequency and 65 percent reduction in the duration of some flooding events due to water resources development and the works on Chalka Creek (CSIRO 2008).

Human activities across catchments and in waterbodies can exacerbate the impacts of drought, with changes to land use leading to changes in run-off and groundwater dynamics (Bond et al. 2008). Drought inevitably leads to greater extraction from water supplies (i.e. greater proportion of available water going to consumptive use), which in turn reduces the availability of water for maintaining natural systems and compounding the impacts of drought (Bond et al. 2008).

Reduced inflows due to river regulation and the impacts of drought led to declining condition of ecological values of the Hattah Lakes Icon site. A lack of overbank flooding between 2000 and 2010 gave rise to concern regarding the condition of floodplain vegetation, most notably river red gum. Delivery of environmental water commenced in April 2005 with water being pumped into Chalka Creek and a number of the Ramsar wetlands as an emergency measure to maintain existing river red gum communities (EPA and MDFRC 2007). .

5.2 Climate change

Wetlands are highly susceptible to climate change impacts as they are at the interface between aquatic and terrestrial ecosystems, being subject to direct impacts as well as climate change being a compounding factor for other environmental stresses such as salinisation (Jin 2008). More critically for Hattah Lakes, the impacts of climate change on the availability of environmental water may be significant.

The following are the general impacts from climate change predicted for the mallee region of Victoria (from DSE 2008):

- During 1998 to 2007 average annual temperatures were 0.4 degrees Celsius warmer than the 30 year period 1961 to 1990. Average maximum temperatures increased by 0.7 degrees Celsius.
- During 1998 to 2007 the region's average rainfall declined by 13 percent compared to the period 1961 to 1990. Decreases were greatest in autumn and winter, while average summer rainfall actually increased by 18 percent.
- By 2030 average annual temperatures will be around 0.9 degrees Celsius warmer with the greatest increase expected in summer.
- By 2030 reductions in total average annual rainfall of around four percent, with the greatest reductions in spring (seven percent).
- Evaporation is likely to increase combined with reduced humidity will contribute to drier conditions.
- By 2070, further increases in temperature are expected even under a lower emissions growth scenario (1.4 degrees Celsius); under higher emissions this doubles (2.8 degrees Celsius).
- By 2070 reductions in total average annual rainfall of around 11 percent, with the greatest reductions in spring (20 percent).

Increases in the intensity of flood-producing rainfall events are likely to change flood behaviour, but catchment conditions at the time of each rainfall event (soil moisture conditions and levels in major water storages) will affect the degree of change. Water quality may decline due to lower flows and higher temperatures, with a likely increase in the incidence of algal blooms. Widespread changes in natural ecosystems are likely. The biological communities most vulnerable to species loss are those of rivers and wetlands. Composition of communities will change and climate change will exacerbate the impacts from invasive species (DSE 2008).

The Sustainable Yields Project (CSIRO 2008) provides a basis for examining the rainfall and hydrological implications of climate change on the Hattah-Kulkyne Lakes Ramsar site. The Sustainable Yields Project modelled a number of scenarios as well as a wet and dry extreme for 2030. The CSIRO (2008) assessment is based on the following hydrological indicator of 36.7 gigalitres per day at Euston for 60 days during August to January. Under current conditions, this flow event occurs less than half as often as under without-development conditions. The different scenarios tested are summarised in Table 19.

The main findings for Hattah-Kulkyne Lakes Ramsar site from CSIRO (2008) are presented in Table 20.

Table 19: Descriptions of climate scenarios used by CSIRO (2008).

Scenario	Description
P – without development	This scenario incorporates the model for Scenario A0* and covers the common historical climate period. Current levels of development such as public storages and demand nodes are removed from the model to represent without-development conditions. Natural water bodies, fixed diversion structures and existing catchment runoff characteristics are not adjusted. It includes the net effect of Snowy Mountains Hydro-electric Scheme transfers to the Murrumbidgee and Murray regions.
A – historical climate & current development	This scenario incorporates Scenario A0 and the effects of current groundwater extraction at dynamic equilibrium. This scenario is the baseline for comparison with scenarios B, C and D.
B – historical climate and current development	This scenario represents a future climate condition based on the climate of 1997 to 2006. The level of development is the same as Scenario A. A without-development model run is undertaken that uses Scenario B climate and Scenario P development conditions.
C – future climate and current development	Scenarios Cwet, Cmid and Cdry represent a range of future (2030) climate conditions that are derived by adjusting the historical climate and flow inputs used in Scenario A. The level of development is the same as Scenario A (2000/01 level of development). Without-development model runs are undertaken that use Scenario Cwet, Cmid and Cdry climates and Scenario P development conditions.
D – future climate and future development	Scenarios Dwet, Dmid and Ddry incorporate Scenario C with flow inputs adjusted for 2030 projected development in farm dams, commercial forestry plantations and groundwater.

* Scenario A0 incorporates the Scenario O model but covers the shorter common historical climate period (1/6/1895 to 30/6/2006). This scenario does not include the effects of current groundwater extraction at dynamic equilibrium. Scenario O represents the latest version of the Murray and Lower Darling river systems model supplied by the Murray-Darling Basin Commission (MDBMC, 2000). It models 2000/01 development and 2006/07 management rules and covers the original planning period 1 May 1891 to 30/4/2006. It is used by the Murray-Darling Basin Commission to (i) audit compliance with the Cap on surface water diversions; (ii) develop Water Sharing Plans in New South Wales (DIPNR, 2004a and b); and (iii) model Victorian entitlements to the Murray (DSE, 2006).

Table 20: Environmental indicator values under scenarios P, A, B, and percent change (from scenario A) in indicator values under scenarios C and D (from CSIRO 2008). P = without development; A = historical climate and current development; B = recent climate and current development; C = future climate and current development; and D = future climate and future development.

	P	A	B	Cdry	Cmid	Cwet	Ddry	Dmid	Dwet
	Years		**Percent change from Scenario A**						
Average period between floods	1.6	3.7	35%	38%	12%	-7%	38%	14%	-4%
Maximum period between floods	4.6	11.7	223%	231%	9%	-18%	231%	82%	-17%
	Gigalitres		**Percent change from Scenario A**						
Average flood volume per year	2379	403	-88%	-93%	-52%	23%	-93%	-55%	17%
Average flood volume per event	3373	1326	-84%	-91%	-46%	15%	-91%	-48%	12%

5.3 Invasive species

A number of invasive species are considered threats to the ecological character of the site. The more serious include rabbits, common carp and other non native fish, river red gum encroachment, pigs (*Sus scrofa*) and leafy elodea (*Egeria densa*), an aquatic weed. These are discussed in more detail below. River red gum encroachment is considered under invasive species as a problematic native species.

Foxes, goats (*Capra hircus*) and noogoora burr (*Xanthium occidentale*) are also threats at the site but not considered to be serious. Noogoora burr is considered a riparian weed, infesting riparian and floodplain habitats. As a seedling it is toxic to stock and has been the focus of past biological control programs in northern Australia.

<u>Rabbits</u>

Rabbits are considered one of the most significant threats to the conservation of native vegetation and habitats in the mallee environments, having potentially greater impacts than native grazers such as kangaroos and domestic stock. Impacts from rabbits can be very selective and can have a significant impact on the regeneration of woody perennials (Sandell and Kerr 2008). The Rabbit Haemorrhagic Disease virus (RHDV) had a significant impact on rabbit populations within the Hattah-Kulkyne National Park for a period of six to eight years, however numbers have been steadily increasing since 2004 (Figure 39) (Sandell and Kerr 2008). With the effectiveness of the virus now declining, there is concern that the grazing pressure from rabbits will increase.

Sandell (2002) reported on changes in condition of semi-arid woodlands in the Hattah area for the two years after RHDV had been introduced. Major findings were an increased persistence of vegetative regrowth of some tree species, continued absence of widespread seedling recruitment, and increased presence of native grasses and forbs in the pasture layer compared to weeds where there was no cattle grazing and relatively low numbers of kangaroos (Sandell 2002). In 2008 a program of control was implemented which has helped reduced the number of rabbits in key areas of the national park (Sandell and Kerr 2008).

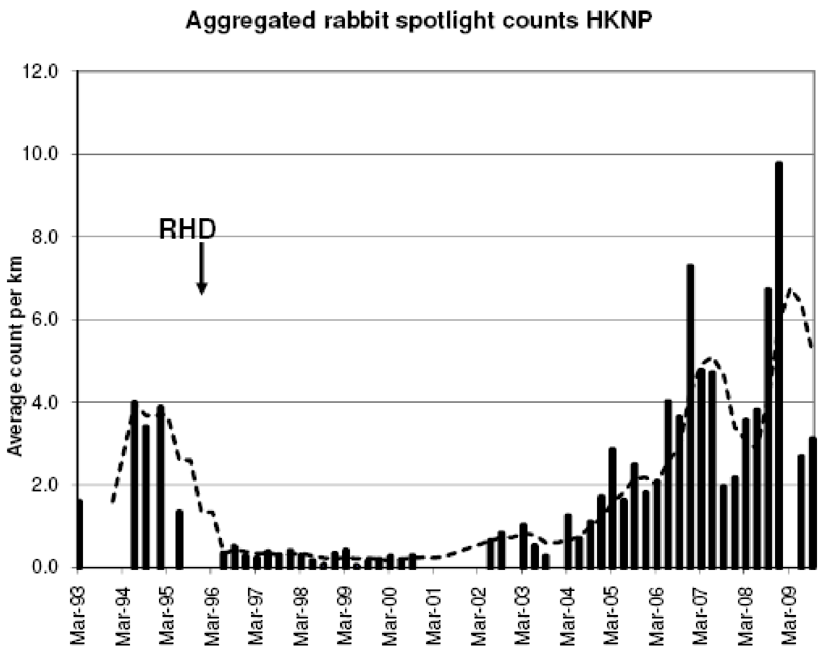


Figure 39: Average spotlights counts of rabbits from transects conducted quarterly over a combined distance of 86 kilometres within Hattah-Kulkyne National Park (from Sandell and Kerr 2008). RHD represents the onset of Rabbit Haemorrhagic Disease.

Infestations have been shown to be closely associated with the lake margins indicating a close reliance on the lakes for water (Sandell and Kerr 2008) and there are clear indications that the rabbits are utlising the sapling areas in and around the lakes. The Mournpall management block (Figure 40) captures the majority of the Ramsar lakes and this area has been the highest priority for management actions. See Section 5.4 for discussion on grazing impacts.

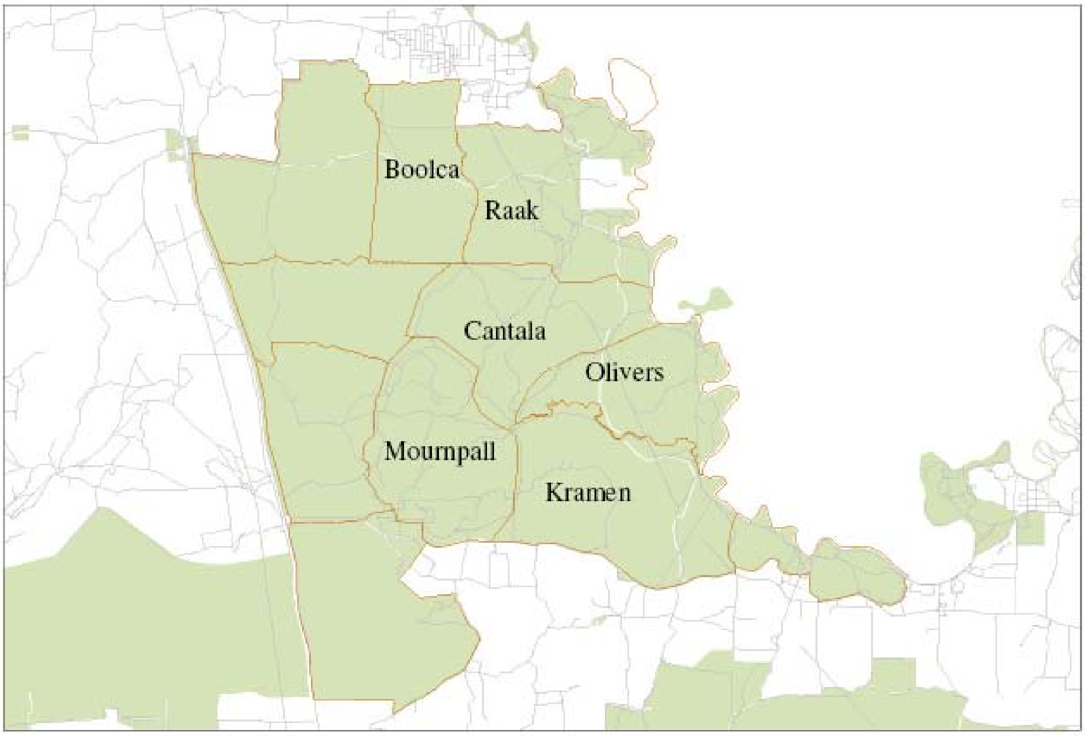


Figure 40: Defined management blocks for Hattah-Kulkyne National Park. The boundaries are fenced in some cases. The named blocks are priority areas for recovery of semi-arid woodlands (from Sandell and Kerr 2008).

Non native fish

Invasive fish species that occur in the Ramsar site (when wet) include the common carp, goldfish, redfin and Eastern gambusia. In 2010 weatherloach were also recorded for the first time from a number of lakes (MDFRC in prep). These species are able to adapt quickly to changed environmental conditions, allowing them to establish quickly and can cause changes in species composition and exclusion of native species (MDBC 2006). During the delivery of environmental water to the lakes from 2005 to 2010 the proportion of invasive species was considerably lower than during periods where the lakes are inundated with overbank flows. This is likely a reflection of the delivery mechanism which tended to prevent some of the invasive species from entering the lakes. For example, water pumped from deep pools that are not favoured by gambusia may have assisted in preventing them from entering via the pumped water.

Feral pigs

Feral pigs are believed to have increased in numbers in the Ramsar site since 1992 (P. Murdoch, DSE, pers. comm.). Prior to this some fencing has kept the pigs out of the lakes. Pigs disrupt the soil between the water line and drier high ground, where they preferentially feed. This disrupts the soil, promotes invasive weeds and can cause loss of aquatic plants. The extent or seriousness of this impact has not been documented and remains a knowledge gap for the site. Feral pigs can have significant impacts on waterbird breeding; however the impacts of pigs on waterbirds are likely to be minimal at this site. Disruption of the sediments on the edges of lakes is considered the greater threat.

Leafy elodea

Leafy elodea is a submergent aquatic plant which prefers slow moving waters and nutrient rich conditions. It can become problematic by obstructing water flow and out-competing native vegetation. This species has not yet been recorded from the site, but is believed to be a threat to the site should it establish within the lakes. It has been recorded from the Murray River there is a very high potential for it to enter the site and become established.

A clear understanding of the relative impacts of several of the invasive species within the Ramsar site on the critical components, processes and services is lacking and remains a knowledge gap.

River red gum encroachment

During recent dry years river red gum has encroached onto the lake beds of most of the lakes with an obvious band of regenerating trees in the shallow areas of the lakes. This is considered a potential threat to the character of the site as the band of regenerating trees occupies a zone which would support aquatic macrophytes and thus may shade out these species. The actual impacts, other than a change in extent of habitat types, are not well understood.

5.4 Grazing

The native vegetation around the Hattah-Kulkyne Lakes Ramsar site has been degraded by excessive grazing pressure by rabbits, goats, Western grey kangaroo (*Macropus fuliginosus*) and red kangaroo (*M. rufus*). Grazing pressure has also degraded the quality of habitat available to other fauna. Grazing has suppressed woody species, such as river red gum and river coobah (*Acacia stenophylla*), and reduced the abundance of perennial taxa in the shrub and ground layers (DSE 2003; DSE 2010).

A kangaroo management plan was initiated in the Mournpall Block (see Figure 40 above) of the Hattah-Kulkyne National Park in 1990. The kangaroo density was reduced from an estimated 46 per square kilometre in 1990 to five per square kilometre in 2003. Kangaroo control around the remaining lakes began in 1996. Vegetation responses to stratified kangaroo grazing pressure at Hattah Hattah-Kulkyne National Park have been documented by Sluiter et al. (1997 cited in DSE 2010).

Rabbit numbers in and around the Ramsar lakes have also been significantly reduced since control programs began in the mid 1980s and the introduction of the rabbit calicivirus in the 1990s (see previous section) (MDBC 2006; DSE 2010).

The impact of grazing pressure from goats is largely unknown but their preferential grazing habits may remove those plants critical to the survival of some native animal species. The social nature of goats can also lead to localised impacts on vegetation, particularly near night camps. Goat numbers are currently controlled through trapping and opportunistic shooting. The kangaroo fence surrounding the Mournpall Block enabled the exclusion of goats from most lakes between 1982 and 2001. Since 2001, a small population of approximately 40 goats has been recorded inside the Mournpall Block (DSE 2003; DSE 2010).

As a result of reduced grazing pressure by kangaroos and rabbits, some regeneration of woody species and perennial shrubs has been recorded. Red kangaroo and western grey kangaroo grazing monitoring data collected since 1983 provides a benchmark for grazing pressure by these species. Data supplied by Parks Victoria indicate increased red kangaroo numbers inside and outside the Mournpall Block exclosure from 1983 to 1990, with a steep decline following this date. Numbers in the exclosure have generally remained lower than outside after 1990. Red kangaroo numbers have been relatively low throughout the benchmark period and are similar inside and outside the exclosure (DSE 2010).

Investigations and management activities have not focused on the Ramsar site per se, and as such it is not clear what direct affects grazing is having on the actual Ramsar site. It is likely that current and past management actions have reduced this threat significantly.

5.5 Summary of threats

Although a risk assessment is beyond the scope of an ECD, the DEWHA (2008) framework states that an indication of the impacts of threats to ecological character, likelihood and timing of threats should be included. The major threats considered in the previous Sections have been summarised for each location within the Ramsar site in accordance with the DEWHA (2008) framework Table 21.

Table 21: Summary of the main threats to the Hattah-Kulkyne Lakes Ramsar site.

Actual or likely threat	Potential impact(s) to wetland components, processes and/or service	Likelihood[1]	Timing
Increased water resource development	Reduced frequency and duration of inundation leading to loss of habitat and diversity of hydrological regimes. Impacts on waterbirds, fish and aquatic macrophytes are likely.	Low	Current
Climate change	Declining rainfall and increased summer rainfall intensity will alter flood behaviour, but catchment conditions at the time of each rainfall event (soil moisture conditions and levels in major water storages) will affect the degree of change. Water quality may decline due to lower flows and higher temperatures, with a likely increase in the incidence of algal blooms.	Certain	Long term
Grazing	Uncontrolled grazing from native and introduced herbivores has the potential to change vegetation community structure and affect recruitment of woody vegetation such as river red gum.	Certain	Current
Invasive species	Increased numbers of invasive fish species leading to loss of value of site as having a high proportion of native fish. Increased predation on waterbirds. Disruption of sediment by pigs leading to loss of species and increased weed invasion. River red gum encroachment leading to change in habitat.	Certain	Current

[1] Where Certain is defined as known to occur at the site or has occurred in the past; Medium is defined as not known from the site but occurs at similar sites; and Low is defined as theoretically possible, but not recorded at this or similar sites.

6. Limits of Acceptable Change

6.1 Process for setting Limits of Acceptable Change (LACs)

Limits of Acceptable Change are defined by Phillips (2006) as:

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

LACs and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that LACs should be beyond the levels of natural variation. Setting limits in consideration with natural variability is an important, but complex concept. Wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability such that trends away from "natural" can be reliably detected is far from straightforward.

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set LACs beyond those limits. What is required is a method of detecting change in pattern and setting limits that indicate a distinct shift from natural variability (be that positive or negative). This may mean accounting for changes in the frequency and magnitude of extreme events, changes in the temporal or seasonal patterns and changes in spatial variability as well as changes in the mean or median conditions.

The LACs described here represent what may constitute a change in ecological character at the site in absolute terms with no regard for detecting change prior to irrevocable changes in wetland ecology. Detecting change with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is the role of wetland management and the management plan for a site should develop and implement a set of management triggers with this aim.

Additional Explanatory Notes for LACs

Limits of Acceptable Change are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LACs does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LACs may require investigation to determine whether there has been a change in ecological character.

In reading the ECD and the LACs, it should be recognised that the hydrology of many catchments in the Murray-Darling Basin is highly regulated, despite many of the wetlands forming under natural hydrological regimes that were more variable and less predictable. Many of the Ramsar wetlands of the Murray-Darling Basin were listed at a time when the rivers were highly regulated and water over allocated, with the character of these sites reflecting the prevailing conditions. When listed under the Ramsar Convention, many sites were already on a long-term trend of ecological decline.

While the best available information has been used to prepare this ECD and define LACs for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The LACs may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this ECD and carefully evaluate the suitability of the information for their own purposes.

Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

6.2 LAC for Hattah-Kulkyne Lakes

Limits of Acceptable Change have been set for the Hattah-Kulkyne Lakes Ramsar site based on conditions at the time of listing (Table 22). It is preferable to use site specific information to statistically determine LACs. However, in the absence of sufficient site specific data, LACs are based on recognised standards or information in the scientific literature that are relevant to the site. In these cases, the source of the information upon which the LAC has been determined is provided. For Hattah-Kulkyne Lakes there are very limited site specific data for most of the critical components, processes and services, therefore qualitative LACs based on the precautionary principle are recommended and will require careful review with increased information gained from future monitoring. In addition, some LACs will require long timeframes in which to characterise variation of the components, process or service.

The Hattah-Kulkyne Lakes Ramsar site was listed under conditions of altered hydrology and as such, the hydrological regime may be insufficient to maintain the character of the site in the longer term. While LACs should be set for conditions at the time of listing, it is not the intent to ensure that poor condition/health is maintained. Obligations for member nations under the Ramsar Convention are to “protect and *enhance*” wetlands. However, LACs are not synonymous with management targets and should not be used to set ideal future benchmarks or targets. As such, LACs for hydrology have been set as conditions at the time of listing on the understanding that any further decrease in the frequency of filling events is likely to result in a change in character.

All identified critical components, processes and services require a LAC to be set (DEWHA 2008). However, due to the interrelated nature of components, processes and services a single LAC can account for multiple components, process and services. For example, the LACs which address hydrology often account for several other critical processes and services, such as supporting a diversity of wetland types and physical habitat for waterbirds, productivity and ecological connectivity. This is because hydrology is a key determinant of many aspects of the ecological character of a site and a change in hydrology would lead to a loss of related services. In order to limit repetition in the LACs for Hattah-Kulkyne, a hierarchical approach has been adopted where LAC have been set for components or processes, which in this case has also covered critical services.

The columns in Table 22 contain the following information:

Component / Process/ Service	The component or processes for which the LAC is a direct measure.
Baseline / supporting evidence	Relevant baseline information (relevant to the time of listing) and any additional supporting evidence from the scientific literature and/or local knowledge.
Limit of Acceptable Change	The LAC stated as it is to be assessed against.
Confidence level	The degree to which the authors are confident that the LAC represents the point at which a change in character has occurred. Assigned as follows:

High – Quantitative site specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measurable.

Medium – Some site specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measurable.

Low – no site specific data or reliable evidence from the scientific literature or expert opinion, LAC may not be objectively measurable and / or the importance of the indicator to the ecological character of the site is unknown.

Table 22: Limits of Acceptable Change (LACs) for Hattah-Kulkyne Lakes Ramsar site.

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
Hydrology	The hydrology of the site, at the time of listing in 1982, can be characterised in terms of annual return intervals of Murray River flows at Euston, which are considered important for the critical components of the site and which produce filling events for the lakes (Ecological Associates 2007; MDBA 2010): • ARI of 1 in 3 of 40 000 megalitres per day for 60 days at Euston fills Lake Lockie, Hattah, Yerang, and Mournpall. • ARI of 1 in 5 of 50 000 megalitres per day for 60 days at Euston fills Lake Cantala, and Bulla. • ARI of 1 in 8 of 70 000 megalitres per day for 42 days at Euston fills Lakes Arawak, Brockie, Bitterang, Konardin and Yelwell. • ARI of 1 in 16 of 152 000 megalitres per day for 30 days at Euston fills Lake Kramen. Filling events can also be achieved by delivery of environmental water via pumping. LACs are set based on groupings of lakes with similar annual return intervals under current conditions as this represents the best available data. However as water delivery options are available at this site, the LACs are expressed in terms of number of filling events not a river flow. The LACs are assessed over a 10 and 20 year time spans to account for the variability in hydrology at the site (i.e. to allow for several occurrences of the specified flow events within the assessment period) and can be measured based on overbank flows (as above) or by delivery of environmental water via pumping.	No less than three filling events for Lakes Lockie, Hattah, Yerang and Mournpall in any 10 year period. No less than two filling events for Lakes Cantala and Bulla in any 10 year period. No less than one filling event for Lakes Arawak, Brockie, Bitterang, Konardin and Yelwell in any 10 year period. No less than one filling event at Lake Kramen in any 20 year period.	Medium.
Lake bed herbland vegetation	The extent of lake bed herbland vegetation at the time of listing was 862 hectares indicated by EVC mapping (data supplied by DSE). Although there is information on extent for part of the Ramsar site, there is no indication of variability. In addition, information on variability in these ecosystems from comparable sites could not be sourced. As such, an objective, statistically based LACs cannot be determined and a figure of 10 percent change has been selected informed by local knowledge and expert opinion of the steering committee.	Extent of lake bed herbland vegetation to be no less than 776 hectares.	Low.

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
Fish	Data for native fish are limited to a small number of surveys, most in recent years in relation to pumping. Native fish species dominate the system with 12 species recorded from several surveys (Walters et al. 2010; MDFRC in prep). Survey results indicate that the fish species present are relatively predictable, with a reasonable probability that all common species recorded to date would be encountered over several sampling events. This LAC is set on expert opinion and assumes annual monitoring under TLM Icon Site condition monitoring and that rare fish may not be recorded (freshwater catfish, flat-headed galaxias). It excludes consideration of flood spawners (golden and silver perch) and main channel specialists (Murray cod) and focuses on wetland specialist species.	Presence of the following wetland specialist species of native fish recorded over any three sampling events over a five year period in which at least three of the lakes are inundated. • Australian smelt *Retropinna semoni* • Bony herring *Nematalosa erebi* • Carp gudgeon *Hypseleotris* spp. • Western carp gudgeon *Hypseleotris klunzingeri* • Fly-specked hardyhead *Craterocephalus stercusmuscarum*	Medium.
Waterbirds – number of species	The site supports a diversity of waterbirds with a total of 70 species recorded from the site. Data from Lake Hattah for the period 1990 to 2001 has species richness ranging from 13 to 36 with an average of 22 (data supplied by DSE). Using data from 2007 to 2009 species richness ranges from 14 to 24 with an average of 20 (data from Annual summer waterfowl counts and TLM Icon Site condition monitoring). However, trends in species richness since listing are not discernable due to differences in wetting and drying, as well as sampling effort across lakes and years. As such the LAC is set on a 20 percent decline in the presence of a subset of common species identified by DSE (2010). These species were encountered in at least 10 years within a 20 year period. LAC is based on expert opinion.	Presences of at least 8 of the following species in at least 10 years of any 20 year period in which at least three of the lakes are inundated: • Australian pelican *Pelecanus conspicillatus* • Australian wood duck *Chenonetta jubata* • Black-winged stilt *Himantopus himantopus* • Australian darter *Anhinga novaehollandiae* • Great cormorant *Phalacrocorax carbo* • Great crested grebe *Podiceps cristatus* • Little black cormorant *Phalacrocorax sulcirostris* • Masked lapwing *Vanellus miles*	Medium.

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
		• Pacific black duck *Anas superciliosa* • White-faced heron *Egretta novaehollandiae* • Yellow-billed spoonbill *Platalea flavipes*	
Waterbirds – number of species breeding	The Ramsar site supports breeding for a total of 34 waterbird species; however the number of species recorded breeding in any single year is highly variable and not well documented. Many records are for single breeding events only. Multiple year records are only available for seven species. A long term monitoring program with annual records for breeding is required before setting a LAC.	Data insufficient to set a LAC.	Not applicable.
Near natural wetland type	This critical service is linked principally to changes in the hydrology as well as changes in extent and condition of wetland vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in lake bed herbland vegetation and the frequency of flow events.	*See LAC for hydrology and lake bed herbland vegetation.*	Not applicable.
Physical habitat which supports waterbird breeding.	This critical service is linked to changes in the frequency of wetland wetting periods and drying as well as changes in extent and condition of wetland and floodplain vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the hydrological regime and lake bed herbland vegetation.	*See LACs for hydrology and lake bed herbland vegetation.*	Not applicable.
Physical habitat which supports waterbird feeding.	This critical service is linked to changes in the frequency of wetland wetting and drying periods as well as changes in extent and condition of wetland and floodplain vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the hydrological regime and lake bed herbland vegetation.	*See LACs for hydrology and lake bed herbland vegetation.*	Not applicable.
Threatened species – Australian painted snipe	Australian painted snipe has been reliably recorded from Lake Yerang in 2007. The species is known to be cryptic and not easily detected. Currently there are inadequate data to set a LAC.	Data insufficient to set a LAC.	Not applicable.

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
Threatened species – regent parrot (eastern)	Limited data are available for regent parrot (eastern) within the bounds of the Ramsar site. Continued presence is considered an appropriate LAC for this species as it will be utilising the floodplain as well as the surrounding mallee habitat. Large river red gum trees with hollows in the branches are preferred roosting and nesting habitat. This LAC is set on expert opinion.	Presence within Ramsar site on an annual basis.	Low.
Threatened species – winged peppercress	Winged peppercress is listed as occurring in the site. The species is located between Lake Hattah and Lake Bulla in an area covering approximately 0.1 hectares (Mavromihalis 2010). Mavromihalis (2010) reports the population to be in decline at the site, however due to the fact that this species exhibits a highly variable population size in response to wetting and drying, the LAC is based on presence/absence data only. This LAC is set on expert opinion.	Presence between Lake Hattah and Lake Bulla in years when conditions are suitable.	Low.
Biodiversity	The site is hydrologically connected with the river and on the floodplain there are interconnections between some of the lakes in which wetland dependent species establish. The wetting and drying of the lakes promotes diversity and this service is maintained by hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology. Changes in the LACs for fish and waterbirds (number of species) could also be used as surrogate measures for this service.	*See LACs for hydrology.*	Not applicable.
Ecological connectivity	This service is maintained by hydrology and can be indicated by the species richness of native fish. The key elements of connectivity are uninterrupted flow from the Murray River into and between the wetlands and reconnection to the Murray River to allow recruitment of species into the regional population. The delivery of environmental water by pumping may affect connectivity.The relative importance of connectivity and timing of connecting flows remains a knowledge gap for the site. No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and native fish populations.	*See LAC for hydrology and native fish, noting that filling events achieved through environmental watering do not necessarily contribute to connectivity.*	Not applicable.

7. Current Ecological Character and Changes since Designation

7.1 Site and management changes since listing

There have been no boundary or land tenure changes since the time of listing.

Under The Living Murray initiative a series of planned works will be implemented which will help restore natural flooding regimes to the Hattah Lakes. Specifically the works will inundate 5583 hectares of floodplain which will include 11 of the 12 Ramsar lakes as well as substantial areas of water dependent vegetation (river red gum and black box) on the surrounding floodplain.

The specific works will include (Goulburn-Murray Water 2010; MDBA in prep):

- lowering high points (sills) within Chalka Creek to increase the frequency of natural inflows;
- the construction of a permanent pump station to top up natural floods and fill the lakes during long dry periods;
- the construction of a single regulator that facilitates water delivery to Lake Kramen; and
- the construction of a system of regulators and stop banks that will allow water to be retained in the system to increase the duration of natural flood events and enable water to be pumped into the system to water red gum and black box at higher elevations.

The works will be operated in conjunction with natural high flows to provide three small floods every 10 years, filling lakes and watering fringing river red gums, and one large flood every eight to 10 years. Lake Kramen will be watered once every eight to 10 years.

7.2 Changes in critical components, processes and services

Assessment of changes since designation in 1982 for the Hattah-Kulkyne Lakes Ramsar site is hampered by a lack of baseline data from around the time of listing. This is particularly so for biotic critical components, processes and services. An assessment of current conditions with respect to LACs is provided below and illustrates the problems in assessing change at this site.

Declines in floodplain vegetation which have been noted through The Living Murray program and intervention monitoring are not relevant to this assessment of ecological character as the boundary of the lakes does not include any substantial area of floodplain. Variation in flora and fauna reflect drought impacts and responses to environmental watering. For example, river red gum encroachment into the lake beds of several lakes is a reflection of recent drought conditions.

The need for environmental water allocation and the management intervention detailed above is highlighted by drought impacts which occurred at the site over the past decade. In response to a lack of overbank flows from 2000 to 2005 and an associated severe decline in the condition of biodiversity values (most notably river red gum) at the Hattah Lakes Icon site, environmental water was pumped into the site under emergency measures. A summary of pumping data is presented in Table 23.

The hydrology of the site may have changed since listing, with several of the hydrology LACs being exceeded (Table 24). However, whether this is a result of sustained change or the effects of the recent (2000 to 2010) drought is unknown. It is likely due to a combination of a number of factors that include water resource development, climate change and shorter term climatic cycles. Three (Cantala, Mournpall and Bitterang) of the 12 lakes failed to meet the required number of filling events, which resulted in two of the four LACs being exceeded.

Table 23: Pumping history at Hattah Lakes (note not all Lakes included, just Ramsar site lakes) (from Walters et al. 2010). Pumping commenced again in May 2009.

Wetland	Pumping period and commencement dates of inflows			
	15/04/2005 – 30/06/2005	15/09/2005 – 5/12/2005	20/03/2006 – 30/06/2006	12/09/2006- 9/12/2007
Chalka Creek	15 April 2005	15 Sept. 2005	20 March 2006	12 Sept 2006
Lake Lockie		26 Sept. 2005	29 March 2006	Sept 2006
Lake Yerang			21 April 2006	Sept 2006
Lake Mournpall*				20 Sept 2006
Lake Hattah*			12 May 2006	30 Nov 2006
Lake Bulla*			20 June 2006	30 Nov 2006
Lake Arawak			5 July 2006	30 Nov 2006
Lake Brockie				12 Dec 2006
Volume pumped	**1200 ML**	**4211 ML**	**6900 ML**	**13545 ML**

* contained surface water in 2008

Data suggest that the fish populations have not changed since listing. The drying of the lakes during the drought led to a crash in the fish populations of the lakes and subsequent pumping of water established a different composition due to the mode of water delivery. A return to overbank flooding as opposed to pumping will lead to the establishment of a fish fauna more similar to that of the time of listing in terms of the number of exotic species present. Data from the most recent TLM Icon Site condition monitoring seems to support this (MDFRC in prep). The critical service of ecological connectivity appears to have been artificially maintained, in part, through the delivery of environmental water, as does the provision of physical habitat for waterbird breeding and feeding.

Available data suggest that despite drought impacts at the site, waterbirds do not appear to have undergone significant change since listing. As mentioned above the encroachment of river red gum has occurred in many of the lakes however the degree of change has not been determined in this assessment as adequate baseline imagery is not available. Threatened species are likely to still be supported by the site, although only the regent parrot has been assessed and has its LAC met.

As noted above there have been some vegetation changes within the Ramsar site, with the encroachment of river red gum onto the lake beds. Whilst data was not available to assess the LAC, it is likely that the encroachment has caused a loss of lake bed herbland vegetation.

Despite these changes in some of the critical components and processes the sites ecological character has not changed significantly and it continues to meet Criteria 1, 2, 3, 4, and 8.

Table 24: Assessment of current conditions against LAC for the Hattah-Kulkyne Lakes Ramsar site.

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
Hydrology	No less than three filling events for Lakes Lockie, Hattah, Yerang and Mournpall in any 10 year period. No less than two filling events for Lakes Cantala and Bulla in any 10 year period. No less than one filling event for Lakes Arawak, Brockie, Bitterang, Konardin and Yelwell in any 10 year period. No less than one filling event at Lake Kramen in any 20 year period.	Based on flow data from the Murray River downstream of Euston and filling events from environmental watering (S Ramamurthy, DSE, pers. comm.): Lakes Lockie, Hattah, Yerang and Mournpall Six overbank filling events (based on events of 40 000 megalitres per day of 60 days duration) in the period 1982 to 2000, no overbank filling events in the period 2000 to 2010, but Lakes Lockie, Hattah and Yerang were filled via pumping three times between 2005 to 2010. Lake Mournpall was filled twice via pumping between 2005 to 2010. **LAC is considered not exceeded.** Lakes Bulla and Cantala No overbank filling events in the period 2000 to 2010, however four occurred between 1982 to 1990 (based on events of 50 000 megalitres per day of 60 days duration). Lake Bulla had three filling events via pumping between 2005 to 2010. **LAC is considered exceeded as Lake Cantala did not have any filling events in the past 10 years**. Lakes Arawak, Brockie, Bitterang, Konardin, and Yelwell One overbank filling event (based on 70 000 megalitres per day of 30 days duration) in the period 1990 to 2010. All lakes except Bitterang had one filling event in 2009 via pumping. **LAC is considered exceeded as there have been no filling events at Lake Bitterang in the past 10 years.** Lake Kramen No overbank filling events (152 000 megalitres per day for 30 days duration) since listing. Single filling event in October 2010 via pumping. **LAC is considered not exceeded**. **Overall the LAC has been exceeded; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency of filling events.**

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
Lake bed herbland vegetation	Extent of lake bed herbland vegetation to be no less than 776 hectares.	Not quantitatively assessed but on visual assessment of limited number of aerial photographs taken in 2009 this LAC is likely to be exceeded. Need baseline aerial photography at or near the time of listing against which to assess change. **LAC not assessed but presumed exceeded.**
Fish	Presence of the following wetland specialist species of native fish recorded over any three sampling events over a five year period in which at least three of the lakes are inundated. • Australian smelt *Retropinna semoni* • Bony herring *Nematalosa erebi* • Carp gudgeon *Hypseleotris* spp. • Western carp gudgeon *Hypseleotris klunzingeri* • Fly-specked hardyhead *Craterocephalus stercusmuscarum*	All target species have been recorded from intervention monitoring and icon site condition monitoring undertaken from 2006 to 2010 (Walters et al. 2010). **LAC has not been exceeded.**
Waterbirds – number of species	At least eight of the following species in at least 10 years of any 20 year period in which at least three of the lakes are inundated: • Australian pelican *Pelecanus conspicillatus* • Australian wood duck *Chenonetta jubata* • Black-winged stilt *Himantopus himantopus* • Australian darter *Anhinga novaehollandiae* • Great cormorant *Phalacrocorax carbo* • Great crested grebe *Podiceps cristatus* • Little black cormorant *Phalacrocorax sulcirostris* • Masked lapwing *Vanellus miles* • Pacific black duck *Anas superciliosa*	Ten of the 11 target species have been recorded in 10 or more years over the period 1990 to 2010 (Birds Australia, 2011b). • Australian pelican -–14 years • Australian wood duck – 15 years • Black-winged stilt – 10 years • Australian darter – 9 years • Great cormorant – 12 years • Great crested grebe – 10 years • Little black cormorant – 10 years • Masked lapwing – 15 years • Pacific black duck – 16 years • White-faced heron – 13 years

Critical Components, Processes and Services	Limit of Acceptable Change	Current conditions
	• White-faced heron *Egretta novaehollandiae* • Yellow-billed spoonbill *Platalea flavipes*	• Yellow-billed spoonbill – 12 years **LAC has not been exceeded.**
Threatened species – regent parrot (eastern)	Presence within Ramsar site on an annual basis.	Annual data is limited, however it is expected that this LAC is met. Regent parrots were recorded at the site in eight of the past ten years, including the past four straight (Birds Australia, 2011b). **LAC has not been exceeded.**
Threatened species – winged peppercress	Presence between Lake Hattah and Lake Bulla in years when conditions are suitable.	No available data, LAC unable to be assessed. **LAC unable to be assessed.**

8. Knowledge Gaps

While it is tempting to produce an infinite list of research and monitoring needs, it is important to focus on the purpose of an ecological character description and identify and prioritise knowledge gaps that are important for describing and maintaining the ecological character of the system.

There are a number of significant knowledge gaps that are required to be addressed in order to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met (Table 25). Recent investigations into the ecology of the Hattah Lakes under The Living Murray initiative (condition and intervention monitoring) have provided an increased knowledge base on which to describe, and manage, the ecological character of the site. However there is a need to extend this knowledge base by continuing to monitor the condition of the several components, processes and services (see Section 9). All of the recommended actions are considered high priorities.

Table 25: Knowledge gaps for Hattah-Kulkyne Lakes Ramsar site

Component, Process, Service	Knowledge Gap	Recommended Action
Waterbirds	• Presence of cryptic species such as Australasian bittern and Australian painted snipe. • Mapping of waterbird feeding habitats within the Ramsar site. • Species richness data. • Habitat utilisation by breeding waterbird species. • Long term breeding record.	• Targeted surveys. • Continued aerial survey under TLM. • Behavioural observations of feeding and documenting food availability during key breeding events. • Annual breeding surveys in response to flooding and season.
Threatened species	• Threatened species – winged peppercress. • Frequency and habitat use by Australian painted snipe. • Regent parrot – proportion of Ramsar site utilised.	• Establish presence within site, abundance and frequency habitat preferences.
Ecological connectivity	• Document movement patterns of biota within the site, relative timing and importance of reconnection to Murray River for recruitment of fish.	• Investigate pattern of wetland use by different biotic groups. Include consideration of seasonality.
Water quality and biotic data for all lakes	• Data is available for only a subset of lakes. Lakes which are infrequently filled, and which didn't receive environmental water are data poor.	• Opportunistic sampling of lakes during filling events – notably Lakes Cantala, Bitterang, Yelwell, Konardin and Kramen.
Native fish	• Species composition, use of off-stream habitats, variability across site.	• Current monitoring programs conducted under TLM include fish surveys for some of the lakes within the site. Data collected to date has been from a short period of time (post 2005) and includes mostly drought years and response to pumping. An understanding of fish population dynamics in the site will improve over time with current monitoring.
Invasive species	• Impact of invasive species on ecological character of the site.	• Establish severity of impacts and requirement for potential management interventions.

9. Monitoring needs

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

A comprehensive monitoring program is beyond the scope of an ECD. What is provided is an identification of monitoring needs required to both set baselines for key components and processes and to assess against LACs. It should be noted that the focus of the monitoring recommended in an ECD is an assessment against LACs and determination of changes in ecological character. This monitoring is not designed as an early warning system whereby trends in data are assessed to detect changes in components and processes prior to a change in ecological character of the site. This must be included in the management plan for the site.

The recommended monitoring for Hattah-Kulkyne Lakes Ramsar site is provided in Table 26.

Table 26: Monitoring needs for Hattah-Kulkyne Lakes Ramsar site.

Component/ Process	Purpose	Indicator	Locations	Frequency	Priority
Hydrology	Assessment against LAC.	Daily flow at Euston. Number of events of specified magnitude and duration. Number of filling events (from above-threshold flows and/or environmental watering) within the Lakes.	Euston gauge Murray River. Lakes within Ramsar site.	Continuous.	High
Waterbirds	Assessment against LAC.	Abundance and species identifications, breeding observations.	Entire Ramsar site.	Event based or as per TLM monitoring guidelines.	High
Lake bed herbland vegetation	Assessment against LAC	Extent	Entire Ramsar site.	Once every five years.	High
Fish	Assessment against LAC.	Abundance, species richness, young of year.	Entire Ramsar site.	As per TLM monitoring guidelines and opportunist surveys of irregularly filled wetlands.	High
Threatened species	Assessment against LAC.	Location, abundance.	Targeted within Ramsar site.	Targeted surveys for each species.	Low

10. Communication and Education Messages

Under the Ramsar Convention a Program of Communication, Education, Participation and Awareness (CEPA) was established to help raise awareness of wetland values and functions. At the Conference of Contracting Parties in Korea in 2008, a resolution was made to continue the CEPA program in its third iteration for the next two triennia (2009–2015).

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

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

The Ramsar Convention encourages that communication, education, participation and awareness are used effectively at all levels, from local to international, to promote the value of wetlands.

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

Key CEPA messages for the Hattah-Kulkyne Lakes Ramsar site arising from this ECD, which should be promoted through this program, include:

- Hattah-Kulkyne Lakes is listed as a Wetland of International Importance under the Ramsar convention. At the time of listing in 1982, it met, and continues to meet, five of the nine Ramsar criteria.
- The Ramsar site is a key feature of the Hattah-Kulkyne Lakes National Park.
- The Hattah-Kulkyne Lakes Ramsar site is a series of 12 hydrologically connected lakes which constitutes the bulk of the floodplain lakes making up The Living Murray Hattah Lakes Icon Site.
- River regulation has altered the hydrological regime of the lakes in the Ramsar Site prior to listing and has the potential to lead to a change in ecological character unless carefully managed.
- Hydrological and ecological connectivity play a critical role at the site and are vulnerable to the impacts of river regulation. The ecological character of the site has an intrinsic value and needs to be maintained and conserved. This would help promote understanding in the community of the justification for environmental water allocations that divert water resources away from irrigated agriculture and other human uses.
- The Ramsar site is significant in supporting waterbird diversity and breeding. The site supports an unusual composition of the waterbird communities compared to other Icon sites along the Murray River.
- The site supports threatened fish species (Murray cod, silver perch) which have conservation value as well as being of value to recreational fishermen.
- Invasive species whilst present within the site are currently successfully managed with little overall impact on the ecology of the site.
- Climate change has the potential to exacerbate the impacts of river regulation through increased temperature and evaporation, as evidenced by the impact of the 2000–2010 drought.

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Appendix A: Methods

A.1 Approach

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

Project Inception:

Rhonda Butcher met with DSEWPaC project manager and DSE representative to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted.

Task 1: Review and compilation of available data

The consultant team undertook a thorough desktop review of existing information on the ecology of Hattah-Kulkyne Lakes Ramsar site. In addition data was supplied by DSE and presented in DSE (2010).

Task 2: Stakeholder engagement and consultation

A Steering Committee was formed for the preparation of Hattah-Kulkyne Lakes Ramsar site ECD. This group was comprised of stakeholders with an interest in the ECD and management planning process, and included representatives of the following organisations:

- Department of Sustainability and Environment;
- Parks Victoria;
- Mallee Catchment Management Authority; and
- Murray-Darling Freshwater Research Centre Midura.

Task 3: Development of a draft ECD

Consistent with the national guidance and framework (2008) the following steps were undertaken to describe the ecological character of Hattah-Kulkyne Lakes Ramsar site.

Steps from the national draft (2008) framework	Activities
1. Document introductory details.	Update where necessary DSE (2010) to provide basic details: site details, purpose, and legislation.
2. Describe the site.	Based on the Ramsar RIS, DSE (2010) and the above literature review describe the site in terms of: location, land tenure, Ramsar criteria, and wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services.	Identify all possible components, services and benefits. Identify and describe the critical components, services and benefits responsible for determining ecological character.
4. Develop a conceptual model of the system.	Conceptual models were developed for the site: • A control model and a character models that describe important aspects of the ecology of the site, including feedback loops. Aiding in the understanding of the system and its ecological functions. • A stressor model that highlights the threats and their effects on ecological components and processes. Aiding in understanding management of the system.
5. Set Limits of Acceptable Change.	For each critical component process and service, establish the limits of acceptable change.
6. Identify threats to the site.	This process identified both actual and potential future threats to the ecological character of the wetland system.

Steps from the national draft (2008) framework	Activities
7. Describe changes to ecological character since the time of listing.	This Section describes in quantitative terms (where possible) changes to the wetlands since the initial listing in 1982.
8. Summarise knowledge gaps.	This identifies the knowledge gaps for not only the ecological character description, but also for its management.
9. Identify site monitoring needs.	Based on the identification of knowledge gaps above, recommendations for future monitoring are described.
10. Identify communication, education and public awareness messages.	Following the identification of threats, management actions and incorporating stakeholder comments, a general description of the broad communication / education messages are described.

Task 4 Finalising the ECD

The draft ECD and RIS were submitted to DSEWPaC, and the Steering Committee for review. Comments from agencies and stakeholders were incorporated to produce revised ECD documents.

A.2 Consultant Team

Rhonda Butcher

Rhonda is considered an expert in wetland ecology and assessment. She has a BSc (hons) and a PhD in Wetland Ecology together with over twenty years of experience in the field of aquatic science. She has extensive experience in biological monitoring, biodiversity assessment, invertebrate ecology as well as wetland and river ecology having worked for CSIRO/Murray-Darling Freshwater Research Centre, Monash University/CRC for Freshwater Ecology, Museum of Victoria, Victorian EPA and the State Water Laboratories of Victoria. Rhonda has worked on numerous Ramsar related projects over the past eight years, including the first pilot studies into describing ecological character. She has subsequently co-authored, provided technical input, and peer reviewed a number of Ecological Character Descriptions. She project managed the preparation of Ramsar nomination documents for Piccaninnie Ponds Karst Wetlands in South Australia, which included preparation of the ECD, RIS and Ramsar Management Plan, and the preparation of the ECD for Banrock Station Wetland Complex. Other ECD project's Rhonda has had technical input to include the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, Peel-Yalgorup, Eighty-mile Beach, Port Phillip Bay. Rhonda is currently project managing the Ramsar Rolling Review developing a framework for reporting the status of ecological character at all 65 Ramsar sites in Australia.

Jennifer Hale

Jennifer has over twenty years experience in the water industry having started her career with the State Water Laboratory in Victoria. Jennifer is an aquatic ecologist with expertise in freshwater, estuarine and near-shore marine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for Port Phillip Bay and Bellarine Peninsula (current), the Peel-Yalgorup, the Ord River Floodplain, Eighty-mile Beach, the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites.

Halina Kobryn

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

Peter Cottingham

Peter Cottingham is a versatile and experienced facilitator and project manager, having worked in a diversity of technical and scientific environments over the past 25 years. He is currently the Principal of Peter Cottingham & Associates, undertaking a diverse range of projects for clients related to the management and rehabilitation of river and wetland systems across southeastern Australia. Prior to this, Peter was a senior Knowledge Broker with the Cooperative Research Centre for Freshwater Ecology and Leader of the River and Catchment Restoration program for the eWater CRC. Peter has led and facilitated numerous scientific panel deliberations, projects and workshops focusing on the management of river, lake and wetland across southeastern Australia. Example include key facilitation roles include projects on nutrient management in the Gippsland Lakes, the review of the MDBC Native Fish Strategy, the development of a fish information system for the MDB, wetland management priority for southeastern South Australia, and numerous scientific panels focused on environmental flow and drought management. Peter also led the development of a consistent monitoring and assessment framework from which to measure the performance of environmental flow releases. He has a proven track record in strategy and management plan development and communication at all levels of NRM organisations and across a broad range of stakeholder groups, as well as in project management and establishing and managing high-performing teams. Peter has exceptional skills as a knowledge broker and facilitator. He is very experienced in the preparation of technical and scientific reports, and in delivering presentations at conferences, seminars and workshops.

Appendix B: Waterbirds

Ma = Marine under the EPBC Act; Mi = Migratory under the EPBC Act; V = Vulnerable nationally or internationally; E = Endangered nationally or internationally; J = JAMBA; C= CAMBA; R = ROKAMBA, B = Bonn.

Species list compiled from DSE (unpublished), SKM (2003a); DSE (2010) and Birds Australia (2011b). Breeding records for 1983-2002 from DSE (2010), Ecological Associates (2007) and McCarthy et al. (2009) and Birds Australia (2011b).

Common Name	Scientific Name	Breeding	EPBC Act Listing
Australasian bittern	*Botaurus poiciloptilus*		E (EPBC, IUCN)
Australasian darter	*Anhinga novaehollandiae*	Yes	
Australasian grebe	*Tachybaptus novaehollandiae*	Yes	
Australian little bittern	*Ixobrychus dubius*		
Australian shelduck	*Tadorna tadornoides*	Yes	
Australasian shoveler	*Anas rhynchotis*		
Australian painted snipe	*Rostratula australis*		E (EPBC, IUCN), C
Australian pelican	*Pelecanus conspicillatus*	Yes	Ma
Australian spotted crake	*Porzana fluminea*		
Australian white ibis	*Threskiornis molucca*		Ma
Australian wood duck	*Chenonetta jubata*	Yes	
Azure kingfisher	*Alcedo azurea*		
Banded lapwing	*Vanellus tricolor*		
Banded stilt	*Cladorhynchus leucocephalus*		
Black swan	*Cygnus atratus*	Yes	
Black-fronted dotterel	*Elseyornis melanops*	Yes	
Black-tailed native-hen	*Tribonyx ventralis*	Yes	
Black-winged stilt	*Himantopus himantopus*	Yes	Ma
Blue-billed duck	*Oxyura australis*	Yes	
Brolga	*Grus rubicunda*		
Buff-banded rail	*Gallirallus philippensis*		Ma
Caspian tern	*Sterna caspia*		Ma, Mi, C, J
Chestnut teal	*Anas castanea*	Yes	

Common Name	Scientific Name	Breeding	EPBC Act Listing
Common greenshank	*Tringa nebularia*		Ma, Mi, B, C, J, R
Common sandpiper	*Actitis hypoleucos*		Ma, Mi, B, C, J, R
Crested tern	*Thalasseus bergii*		Ma
Dusky moorhen	*Gallinula tenebrosa*	Yes	
Eastern great egret	*Ardea modesta*		Mi, C, J
Eurasian coot	*Fulica atra*	Yes	
Freckled duck	*Stictonetta naevosa*	Yes	
Glossy ibis	*Plegadis falcinellus*		Ma, Mi, B, C
Great cormorant	*Phalacrocorax carbo*	Yes	
Great crested grebe	*Podiceps cristatus*	Yes	
Grey teal	*Anas gracilis*	Yes	
Gull-billed tern	*Gelochelidon nilotica*		Ma
Hardhead	*Aythya australis*		
Hoary-headed grebe	*Poliocephalus poliocephalus*	Yes	
Intermediate egret	*Ardea intermedia*		Ma
Latham's snipe	*Gallinago hardwickii*		Ma, Mi, B, C, J, R
Little black cormorant	*Phalacrocorax sulcirostris*	Yes	
Little egret	*Egretta garzetta*	Yes	Ma
Little pied cormorant	*Microcarbo melanoleucos*	Yes	
Magpie goose	*Anseranas semipalmata*		Ma
Marsh sandpiper	*Tringa stagnatilis*		Ma, Mi, B, C, J, R
Masked lapwing	*Vanellus miles*	Yes	
Musk duck	*Biziura lobata*	Yes	Ma
Nankeen night-heron	*Nycticorax caledonicus*		Ma
Pacific black duck	*Anas superciliosa*	Yes	
Pied cormorant	*Phalacrocorax varius*	Yes	
Pink-eared duck	*Malacorhynchus membranaceus*	Yes	
Plumed whistling-duck	*Dendrocygna eytoni*		

Common Name	Scientific Name	Breeding	EPBC Act Listing
Purple swamphen	*Porphyrio porphyrio*		Ma
Red-capped plover	*Charadrius ruficapillus*	Yes	Ma
Red-kneed dotterel	*Erythrogonys cinctus*		
Red-necked avocet	*Recurvirostra novaehollandiae*	Yes	Ma
Red-necked stint	*Calidris ruficollis*		Ma, Mi, B, C, J, R
Regent parrot (eastern)	*Polytelis anthopeplus monarchoides*	Yes	V (EPBC)
Royal spoonbill	*Platalea regia*		
Ruddy turnstone	*Arenaria interpres*		Ma, Mi, B, C, J, R
Sacred kingfisher	*Todiramphus sanctus*	Yes	Ma
Sharp-tailed sandpiper	*Calidris acuminata*		Ma, Mi, B, C, J, R
Silver gull	*Chroicocephalus novaehollandiae*		Ma
Straw-necked ibis	*Threskiornis spinicollis*		Ma
Swamp harrier	*Circus approximans*		Ma
Wandering whistling duck	*Dendrocygna arcuata*		Ma
Whiskered tern	*Chlidonias hybrida*		Ma
White-bellied sea eagle	*Haliaeetus leucogaster*	Yes	Ma, Mi, C
White-faced heron	*Egretta novaehollandiae*	Yes	
White-necked heron	*Ardea pacifica*	Yes	
Yellow-billed spoonbill	*Platalea flavipes*	Yes	

Appendix C: Seed bank species

Presence/absence of species in soil seed bank of the edge (E) and centre (C) of each lake, or at four elevations A-E (lake edge to centre) in Lake Brockie (from EPA and MDFRC 2008).

	Mournpall		Arawak		Yerang		Bulla		Lockie		Hattah		Brockie				
	E	C	E	C	E	C	E	C	E	C	E	C	A	B	C	D	E
Chara sp.			✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				
Nitella sp.	✓	✓	✓				✓	✓		✓	✓		✓				
Bromus rubens													✓				
Centipeda sp.			✓	✓		✓				✓	✓	✓		✓	✓		
Chenopodium pumilio		✓	✓	✓	✓	✓		✓				✓		✓	✓	✓	
Crassula sieberiana																✓	
Crassula tetramera					✓		✓						✓			✓	
Elatine gratioloides			✓		✓		✓		✓		✓	✓	✓	✓	✓		
Eleocharis pusilla	✓		✓								✓	✓					
Epaltes australis			✓					✓			✓		✓	✓	✓	✓	
Eragrostis dielsii							✓					✓				✓	
Glinus oppositifolius											✓			✓	✓	✓	

	Mournpall		Arawak		Yerang		Bulla		Lockie		Hattah		Brockie				
	E	C	E	C	E	C	E	C	E	C	E	C	A	B	C	D	E
*Heliotropium europaeum**																✓	
*Heliotropium supinum**												✓				✓	
*Hordeum gaucum**										✓							
Hordeum sp.*																✓	
Isoplepis cermia			✓		✓		✓					✓	✓		✓		
Juncus bufonius											✓		✓	✓	✓	✓	
Lanchnagrostis filiformis		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Limosella australis			✓		✓		✓		✓		✓	✓	✓	✓	✓	✓	
Lipocarpha microcephala			✓		✓		✓					✓	✓	✓		✓	
*Medicago minima**																✓	
Myosurus australis									✓								
Myriophyllum sp.				✓				✓			✓		✓				
*Pentaschisitis airoides**													✓	✓		✓	
Polygonum plebeium			✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Pseudognaphalium luteo-album							✓							✓	✓	✓	✓

	Mournpall		Arawak		Yerang		Bulla		Lockie		Hattah		Brockie				
	E	C	E	C	E	C	E	C	E	C	E	C	A	B	C	D	E
Rannunculus sp.									✓								
*Schismus barbatus**																	✓
*Silene apetala**																✓	
*Sonchus oleraceus**															✓		
Triglochin nana														✓			
Typha sp.								✓								✓	
Vallisineria sp.			✓		✓							✓					✓
*Vulpia muralis**									✓								

Appendix D: Native fish species and ecology

Native fish species recorded from the Hattah-Kulkyne Lakes Ramsar site. Four invasive species have also been recorded: carp, goldfish, gambusia and redfin. Migration type: P – Potamodromous.

Ecology and biological information sourced from FishBase (Froese and Pauly 2010) and Treadwell and Hardwick (2003).

Common name	Family	Scientific name	Migration type	Ecology/ biology
Australian smelt	Retropinnidae	*Retropinna semoni*	P	Pelagic in fresh to brackish waters including streams, backwaters, lakes, swamps and estuaries. One of the most widespread species in south-eastern Australia. Most common in slow-flowing streams and still waters, shoaling near the surface or around the cover of aquatic plants and woody debris. Forms large aggregations in open water. Feeds on aquatic insects, microcrustaceans and algae. Spawns throughout the Murray-Darling river system. Breeds between July and March (mostly in spring). Spawning temperature is about 15 °C. Eggs are laid among aquatic vegetation and hatch in about 10 days. Sexual maturity is attained by the end of the first year. There are no major threats to this species.
Bony herring	Clupeidae	*Nematalosa erebi*	P	Pelagic in fresh to brackish waters. Occur often far up rivers, but also in estuaries. Most commonly inhabit streams coursing through relatively dry eucalyptus-scrub or desert areas, preferring sluggish or quiet waters. May have actually benefited from river regulation. Also found in saline lakes (slightly less salty than sea water). Tolerant of water temperatures between 9° and 38°C and pH 4.8-8.6. Although these fish have a wide tolerance of temperature and pH, they are susceptible to oxygen depletion and are usually the first to perish when ephemeral habitats begin to dry up. Frequently noted in large shoals that feed on benthic algae; also feed on insects and small crustaceans. Spawning may occur repeatedly in the north with a peak during the wet season; probably annual in the south
Murray-Darling rainbowfish		*Melanotaenia fluviatilus*	P	Benthopelagic. Found in streams and backwaters of large rivers, drainage ditches, ponds and reservoirs. They prefer still littoral zones and backwaters with cover provided by submerged macrophytes and woody debris. Spawning occurs during low flow periods, thus river regulation with increased summer flows may reduce recruitment potential. In Victoria this species co-occurs with gambusia and have similar dietary and habitat preferences throughout their life history. Tolerant of water temperatures between 10 and 28°C. Strong preference of vegetated areas.

Common name	Family	Scientific name	Migration type	Ecology/ biology
Flat-headed galaxias	Galaxiidae	*Galaxias rostratus*	P	Benthopelagic. Prefers stream margins over rock or sand bottoms and is occasionally found among aquatic vegetation. Still or gently flowing water on the margins of lakes, billabongs and streams. Usually swims in midwater over rock or sand bottoms, also in the vicinity of aquatic plants. Shoal forming. Feeds on a wide range of aquatic insects and crustaceans. Spawning has been recorded between August and September. Each spawning female releases 3,000-7,000 eggs which are slightly adhesive and settle to the bottom. Hatching in nine days at 9-14°C; newly hatched fry are 6-7 mm long.
Flat-headed gudgeon	Eleotridae	*Philypnodon grandiceps*	P	Demersal. Found in still and flowing waters; often abundant in dams and lakes, usually among weeds or over mud bottoms. Occurs in reservoirs and brackish estuaries, less common in gently flowing streams). Feeds on invertebrates and other fishes and tadpoles. In breeding season (mainly spring to summer), males darken and display more vibrant fin markings. Females lay a clutch of eggs on a hard surface such as a rock or piece of wood. The male cares for the nest, chasing away intruders and fanning the eggs with his pectoral fins. Hatching occurs after 4-6 days
Fly-specked hardyhead	Atherinidae	*Craterocephalus stercusmuscarum*	P	Found predominantly in rivers but also in wetlands and billabongs. Preferred habitat includes pools and areas of low flowing or still water with vegetation, which is used for cover. Spawn in spring to summer triggered by water temperature around 23˚ C.
Freshwater catfish	Plotosidae	*Tandanus tandanus*	P	Demersal. Adults inhabit slow moving streams, lakes and ponds with fringing vegetation, typically a lowland species. They swim close to sand or gravel bottoms. More abundant in lakes than in flowing water. Usually solitary but juveniles sometimes form loose aggregations. Mainly bottom-feeders. Feed on insect larvae, prawns, crayfish, molluscs, and small fishes. Breeding occurs between spring and mid-summer when water temperatures rise to between 20° and 24°C. Once common in the Murray-Darling Basin this species is now declining and are protected in South Australia. Main threats include cold water discharges from dams, barriers to movement, siltation/smothering of nesting substrate and spawned eggs, and competition from carp and possibly over fishing.
Golden perch	Percichthyidae	*Macquaria ambigua*	P	Demersal, freshwater. Golden perch is a lowland to mid-slopes species with a wide distribution throughout the Murray-Darling Basin. Distribution and abundance has declined particularly above dams in the upper reaches of most tributaries in the Basin. For example abundance has decreased by approximately 50 % since the 1940s in the Murray River at Euston. They favour deep pools with plenty of cover from fallen timber, rocky ledges or undercut banks. Prefer warm,

Common name	Family	Scientific name	Migration type	Ecology/ biology
				slow-moving, turbid Sections of streams. Also occur in flooded lakes, backwaters and impoundments but not common in wetlands per se, except if they are deep (> 1.5 m), or have deep connecting channels with some flow. Tolerant of temperatures between 4° and 35°C and high salinity levels (up to 35 ppt.). Solitary species. Their diet is dominated by yabbies (*Cherax destructor*), and a variety of fish species. Juveniles disperse throughout the floodplain to find food and cover. They feed on abundant zooplankton on recently inundated floodplains. Adults feed on fishes, molluscs and crayfish. Spawn from early spring to late autumn. Golden perch is Australia's most migratory freshwater fish species, moving throughout the year. Spawn in flooded backwaters near the surface at night after heavy spring and summer rains. Usually a long upstream spawning migration is undertaken (movements of 2000 kilometres by tagged fish have been documented). Eggs float near the surface and hatch in 24-36 hours. Males mature after 2-3 years, females after 4 years. Important water quality parameters are temperature, oxygen, pH, transparency and nutrients. Larvae can be influenced by water quality. Threats to the species include altered flow regimes, thermal stratification and barriers to migration.
Silver perch	Terapontidae	*Bidyanus bidyanus*	P	Only known from the Murray-Darling system with its northern most range in the Condamine Valley. The species is benthopelagic occurring in rivers, lakes and reservoirs, preferring fast-flowing waters of rapids and races and usually forming aggregations near the surface. Often found below rapids and weirs, this species feeds on invertebrates and plants. Spawning occurs in summer (Nov.-Jan., 23-30°C water temp.), effect upstream migration.
Western carp gudgeon	Eleotridae	*Hypseleotris klunzingeri*	P	Demersal small bodied native. Typically found around littoral vegetation in dams, lakes and canals as well as streams. Inhabits slow-flowing rivers or in still water including billabongs. It congregates in large schools below dams and weirs. Feeds on insects, larvae, microcrustaceans and some plant material. Spawning occurs from late spring to summer when water temperatures rise above 22°C. The male guards and fans the eggs until hatching about 2 days later. Young reach sexual maturity by the end of their first year

Appendix E: Habitat requirements of waterbird species which breed at Hattah-Kulkyne Lakes

Information based on Higgins and Marchant (1990) and Simpson and Day (1996). Not all species which have been recorded at the site are included as many are only single records.

Species	Nesting habitat	Foraging habitat and behaviour
Australian darter, *Anhinga novaehollandiae*	Builds a substantial platform of twigs and sticks, in a low tree either overhanging or in water. Lays three to five greenish eggs covered in whitish lime, when conditions are suitable. If water falls during breeding the birds may move to deeper water. Have been records of decreased breeding if a wetland dries and refills, with breeding only occurring once the wetland has filled. Can use deeper reservoirs so have been less impacted from wetland drainage although adequate breeding sites may have been reduced. Eggs take up to 28 days to hatch, fledging may occur before or around 60 days.	Frequents freshwater and saline lakes, swamps, rivers, pools and billabongs, prefers sheltered areas. Most common on permanent water with large open areas of water at least half a metre deep with lakes or rivers. Occurs singly or in pairs, in inland lakes or waterways throughout mainland Australia. Needs open expanses of water up to half a metre in depth in order to feed, and fringing or projecting tree trunks, branches or stumps for perching and to dry wings. Eats small fish, insects and other small aquatic animals.
Australian grebe, *Tachybaptus novaehollandiae*	Breed on edges or in patches of emergent vegetation for anchoring and concealing nests, usually on fertile, permanent and semi-permanent wetlands. Builds the nest as a floating island of vegetation, can include Triglochin and sedges. Prefers a mosaic of cover and open water. Breeding poorly known. Breeds in simple pairs, territorially, main breeding period September to December.	Foraging habitat includes open water but also among vegetation. Feeding methods vary more than in most other grebes. They feed by mainly by diving but also swimming with head and neck immersed and swinging from side to side, floating in one position, peering through carpets of surface vegetation, stealing in crouched pose upon insects perched on floating vegetation, snatching insects from substrate. The feed on fish, snails and wide variety of aquatic invertebrates. Its likely they have a preference for free swimming prey.
Australian wood duck, *Chenonetta jubata*	Variable across Australia, depending on rainfall and available grass for grazing. Nests in tree hollows, not always near water, with down covering eggs and will often reuse the same site. Recorded as breeding all year. Form monogamous breeding pairs. Eggs take up to 28 days to hatch and fledging occurs at three months. Parents feed the young for up to a month after fledging.	Generally found inland associated with lightly wooded country near water including streams, rivers, dams, wetlands both permanent and temporary with abundant grazing. They feed mainly grazing on land, are sociable with family parties joining flocks, usually of less than 100 birds but occasionally of 2,000 or more. More territorial while breeding Often perch in trees or on waterside branches, also roost on water. Graze usually on waterside areas graze mainly at night Basically vegetarian, mainly grazes on land. Eats green grasses, herbs, sedges plus some aquatic plants in winter. Very few seeds eaten.

Species	Nesting habitat	Foraging habitat and behaviour
Australian shelduck, *Tadorna tadornoides*	Breeding occurs on shallow fresh/brackish lakes, lagoons, and marshes with short grasslands and with scattered trees surrounding. In winter they move onto large water bodies, estuaries and sheltered coasts. Breeding occurs June to November, usually in tree-hollows, but occasionally in crevices on shorelines and on the ground with a down lining to the nest. Eggs take up to 33 days to hatch and fledging occurs at three and a half months.	Mainly found grazing on land, also dabbling, head-dipping and scything on water. Territorial while breeding and not generally gregarious but gather to moult. Loaf along shorelines. Crepuscular (evening and morning) feeding pattern. The diet is poorly known, but appears to include a range of vegetation (*Medicago*, *Trifolium*, *Vallisneria*, *Potamogeton*, Cyperaceae, Poaceae, Chlorophyta and *Chara*) and invertebrates (molluscs, mussels, crustaceans, cladocerans, and insects).
Black swan, *Cygnus atratus*	Nest in colonies, often seen in thousands on favoured waters. Varies depending on geographic location, usually timed to coincide with highest water levels. Builds a large mound of vegetation, floating or on the ground with some down lining. Breeding events have been recorded all year. Minimum water depth of 30 – 50 cm until cygnets are independent. Eggs take up to 40 days to hatch with fledging occurring at 170 days/seven months.	Found on large lakes and lagoons, preferring shallow, permanent, fresh or brackish water. Prefer large open expanses of water, fresh through to saline with abundant vegetation. Dabbles on surface, upends. Grazes pasture or flooded fields. Highly gregarious. Basically vegetarian, mainly eating submerged aquatic plants, algae and pondweeds Sedentary if suitable habitat, but move to make use of temporary waters and also from usual waters if they dry in droughts. Non-breeding birds move to suitable safe areas ready for moulting.
Great cormorant, *Phalacrocorax carbo*	Great Cormorants are sociable birds and around breeding time they form colonies of about 2 000 birds, with colonies of up to 20 000 birds being reported. Breeding can occur at any time depending on food supply. Both sexes build the nest, which is a large structure of sticks placed in a low tree or on the ground. Both parents also incubate the eggs and care for the young.	Prefers large permanent freshwater including lakes, reservoirs, swamps, rivers, pools and billabongs. Prefers large open areas of water and lakes and major rivers, less common on temporary systems or small systems. Not affected by turbidity or salinity. Requires trees, branches or stumps for perching. Feeds on fish, crustaceans, frogs and aquatic invertebrates Diet mainly of fish, but supplemented with crustaceans and frogs. Feeds by capturing prey in shallow underwater dives, which often last for more than a minute.
Great crested grebe, *Podiceps cristatus*	Nests are solitary, dispersed or in loose colonies built by both sexes. A floating mound of aquatic vegetation is placed on floating weed mat or anchored to emergent vegetation. Normally on water near vegetated margins of large open waters two to ten metres from the shore in depths of one to two metres. Often among reeds, *Triglochin*, or under cover of trees or shrubs. Eggs take between 25 to 31 days to hatch. Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity. Four weeks incubation; one week leave nest, independent some weeks later.	Occur on fresh or brackish water with sizeable areas of open water half a metre up to five metres deep for foraging, and fringed with vegetation. Have been recorded on lakes, lagoons, estuaries and bays. They feed on fish, also insects, crustaceans, molluscs, and frogs.

Species	Nesting habitat	Foraging habitat and behaviour
Grey teal, *Anas gracilis*	Nests in tree holes, rocky crevices, rabbit burrows and on the ground; slight depression with vegetable material and considerable lining of down. Breeding is irregular and has been recorded occurring throughout the year. Eggs take up to 26 days to hatch, fledging occurs at 3 months.	Will utilise any available water including floodwaters, lakes, and dams. Found on marshes, lakes; almost any area with shallow water – fresh brackish or saline, making good use of temporary waters. Prefers inland wooded systems. Often feeds in small to large flocks, eating plants, seeds as well as invertebrates. Exhibits a range of feeding methods including dabbling, upend and feed from the bottom, or grazing from the surface.
Little pied cormorant, *Microcarbo melanoleucos*	In forks and branches of trees (*Eucalyptus*) and tall shrubs in or over water; sometimes over dry land or on artificial structures. Breeding requires a minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months. Responds to flooding and season as a breeding stimuli.	Feed on a wide variety of aquatic animals, including invertebrates and fish, with freshwater crayfish/yabbies being a preferred food item. Feeding mode includes deep underwater dives with both feet kicking outward in unison. Other crustaceans are also taken, with shrimps being a large part of their diet in cooler months.
Masked lapwing, *Vanellus miles*	Masked Lapwings may breed when conditions are suitable with both sexes contributing to the nest building. Nests are typically a simple scrape in the ground away from ground cover. Both sexes incubate the eggs and care for the young birds which are born with a full covering of down and are able to leave the nest and feed themselves a few hours after hatching.	Found in marshes, mudflats, beaches and grasslands. Often seen in urban areas. Feed on terrestrial insects and their larvae, and earthworms. Most food is obtained from just below the surface of the ground, but some may also be taken above the surface. Birds are normally seen feeding alone, in pairs or in small groups.
Pacific black duck, *Anas superciliosa*	Usually prefers to breed on deep permanent heavily vegetated wetlands, but will also use open water, wet paddocks and ornamental lakes. On the ground, in tree holes or in the old nests of other birds. Lined with down. Eggs take up to 32 days to hatch, fledging occurs at 3.3 months. Mostly sedentary, but use inland temporary wetlands after rains then disperse, sometimes long distances, including Australian birds reaching New Guinea.	A common species which occurs across a wide range of habitats from deep, permanent, reed-dominated freshwater wetlands to rivers, creeks and brackish or saline wetlands. Predominantly vegetarian, eating seeds of aquatic and fringe vegetation, and other plants. Some animal material is taken including bivalve molluscs, aquatic insects, and freshwater crayfish. Feed mainly nocturnally. Will use various wetlands, fresh, brackish and saline, but preferring permanent waters with abundant vegetation, swampy areas.
Yellow-billed spoonbill, *Platalea flavipes*	Breeds July to May. Nest is a platform of sticks, rushes in bush or tree over water, may be on ground. Often breeds in colonies. Both sexes incubate the eggs. Produces up to four eggs and returns to the same breeding area each year.	Prefers inland, freshwater wetlands with shallow margins. Diet is predominantly invertebrates. Foraging occurs in shallow mud using the vibration detectors in its bill to detect movement of prey in the mud.