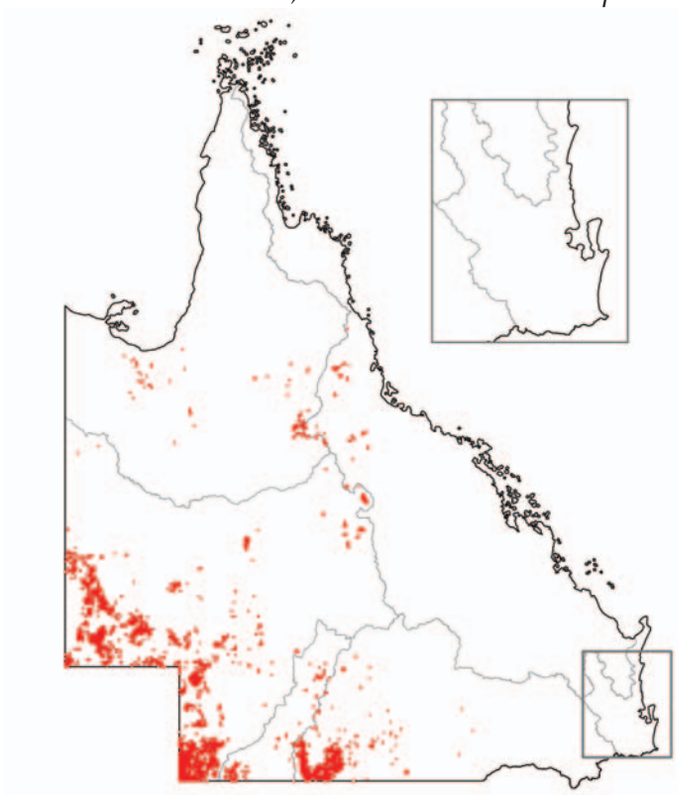
Australian Government

Queensland Government

WETLAND MANAGEMENT PROFILE

ARID AND SEMI-ARID LAKES

Arid and semi-arid lakes are key inland ecosystems, forming part of an important network of feeding and breeding habitats for migratory and non-migratory waterbirds. The lakes support a range of other species, some of which are specifically adapted to survive in variable fresh to saline water regimes and through times when the lakes dry out. Arid and semi-arid lakes typically have highly variable annual surface water inflows and vary in size, depth, salinity and turbidity as they cycle through periods of wet and dry. The main management issues affecting arid and semi-arid lakes are: water regulation or extraction affecting local and/or regional hydrology, grazing pressure from domestic and feral animals, weeds and tourism impacts.



Map showing the distribution of arid and semi-arid lakes in Queensland; grey lines show drainage divisions.
Map: From Queensland Wetlands Mapping v2.0 (September 2009)

This profile covers the habitat types of wetlands termed arid and semi-arid floodplain lakes, arid and semi-arid non-floodplain lakes, arid and semi-arid permanent lakes, and arid and semi-arid saline lakes.

*This typology, developed by the Queensland Wetlands Program, also forms the basis for a set of conceptual models that are linked to dynamic wetlands mapping, both of which can be accessed through the Wetland*Info *website <www.derm/qld.gov.au/wetlandinfo>.*

Description

This wetland management profile focuses on the arid and semi-arid zone lakes found within Queensland's inland-draining **catchment**s in the Channel Country, Desert Uplands, Einasleigh Uplands and Mulga Lands **bioregion**s.

There are two broad types of river catchments in Australia: exhoreic, where most rainwater eventually drains to the sea; and endorheic, with internal drainage, where surface **run-off** never reaches the sea but replenishes inland wetland systems.

In Queensland, arid and semi-arid lakes are a significant component of the endorheic catchments, and are found on the floodplains of inland rivers, in closed local drainage systems, and across sand plains. They occur where rainfall is low and highly variable (averaging 100 to 500 mm a year), evaporation rates are very high in comparison to precipitation (3–4 m a year), local surface run-off is highly variable and infrequent, and remote rain events periodically trigger large scale flooding which brings water into the systems from far away—a combination of factors that produces some of the most variable river systems in the world.

Inland drainage basins in Australia are typically very flat, producing meandering and **braided** water courses that include numerous shallow temporary waterholes and some deep, permanent, waterholes, surrounded by huge areas of vegetated floodplain swamps that are shallowly flooded during the wettest parts of the

inundation cycle. Within this complex hydrological system, the arid and semi-arid lakes described in this profile are considered to be those areas of natural open water greater than 8 ha in extent.

The lakes (or **lacustrine** systems) can occur at the terminus (end) of a hydrological system, receiving overflow and backflow waters from flooded rivers, and are often referred to as terminal lakes for this reason. Atypically, lakes may occur in the main flow path of a river, for example, Lakes Koolivoo and Mipia on the lower Georgina River system. Because of the complexity of the wetland systems in the **arid** and semi-arid zone, the lakes are a patchwork of varying habitat conditions at any single point in time, since they each vary in size, depth, salinity and turbidity as they cycle through periods of wet and dry.

The ecology of the arid and semi-arid lakes, particularly the successful recruitment and survival of their plant and animal species, is tied to this cycle.

The lakes receive their water from two main sources: remote, semi-regular monsoon rain events that cause large-scale flooding of the inland river systems and their associated downstream wetlands; and local rainfall events that sometimes provide smaller scale irregular replenishment of the lakes. In-flowing water to the lakes is invariably fresh, and many lakes remain fresh, but some may become **brackish** or saline over time as they dry out.

Some lakes are naturally saline due to the pre-existence of salts in the soil and weathered bedrock, and salinity levels range from low (**hyposaline**) to high (hypersaline). Only a few lakes are distinctly saline for most of their cycle. A single lake may exhibit a mix of both fresh and saline water conditions at one time depending on its **topography** and the location of the tributaries that carry water into the lake.

Arid and semi-arid lakes can be temporary or semi-permanent depending on the reliability of their water source. Very few arid and semi-arid lakes are considered truly permanent. The frequency of filling,

Arid and semi-arid lakes vary in size, depth, salinity and turbidity as they cycle through periods of wet and dry. The ecology of their plant and animal species is tied to this cycle.

Aerial view of a full arid zone lake.
Photo: Roger Jaensch, Wetlands International

and persistence of the arid and semi-arid lakes depend on a variety of factors: the size and run-off characteristics of the catchment, whether or not the lake is well connected to a river system, the frequency and volume of flow in that river, the position of the lake along the river course (lakes in the middle reaches are usually more likely to be semi-permanent than lakes at the far end because not all flows will reach the end of the system), the maximum depth of the lake basin (greater depth will counteract evaporation), the height of the water table, climate variation and local weather events. At times in a long-term climate cycle there will be a run of good years when many of the lakes will fill to capacity and endure for some time—1974 to 1976, for example, is recognised as the wettest period across inland Australia for the last 100 or so years.

Because the lakes can range in size from a few hectares (such as a small depression on a sand plain), to almost 90 000 ha (Lake Yamma Yamma—one of Queensland's largest arid and semi-arid lakes) they will respond differently to climatic and flood events. Small lakes may fill and dry in relatively short cycles of (for example) several weeks, because they can be filled by local rainfall events. Larger lakes can depend on periodic flooding of the inland river systems and therefore will fill less frequently though once full they can persist for longer. Depending on their depth and **evaporation rate** they can remain inundated for many months and some might be permanent, particularly if they have a groundwater source. Some lakes only receive water as backflow after the rest of the drainage system has flooded.

A typical dry playa lake between sand dunes in the Channel Country. Photo: Sue Gardiner

A shallow lake formed by a local rainfall event.
Photo: Sue Gardiner

A dry freshwater lakebed.
Photo: Sue Gardiner

Salt crust on a dry playa.
Photo: Sue Gardiner

A hardened clay lakebed.
Photo: Sue Gardiner

Vegetation response on the edge of a drying lake.
Photo: Sue Gardiner

Because of the highly variable conditions that create in-flow to the arid and semi-arid lakes, it is difficult to be prescriptive about how long they are wet or dry. In general, temporary lakes are considered to be dry for several months or years at a time, and are often very shallow (less than 0.5 m), rising to only 1–2 m deep at the peak of inundation. The smaller temporary lakes may fill one year in three to five, whereas the larger lakes might receive inflow only one year in five to 10. Semi-permanent lakes can be up to several metres deep in good years, and might contain some water in approximately eight years in 10.

The characteristic landform of an almost flat, shallow, terminal lakebed in an arid and semi-arid zone is commonly called a **playa**. In dry times, playas consist of cracking clay flats that can be crusted and hardened to varying degrees depending on their substrate and position in the landscape, and sometimes might be covered in a thin layer of soluble

salt deposits. Some lakebeds are devoid of vegetation, but others support diverse communities of **forbs** and grasses as they dry out, which make them a valuable potential grazing resource. When they contain water, arid and semi-arid lakes can also support highly productive aquatic plant beds and algal turfs that are an important component of the food chain.

Wind-borne clay, silt and sand usually form accompanying low fringing dunes, known as lunettes, around the lakes. These may support salt-tolerant fringing species such as **samphire**s, rushes, and sparse to open shrublands and grasslands on the slightly higher ground at the edges of the lakebed. Small areas of low open woodlands (commonly comprised of Eucalypt species) often occur on the sandy beaches and fringing dunal areas of these wetlands. Many of these patches of woodland are too small to be depicted on current vegetation mapping for Queensland—however they are significant habitats for a range of species.

An open gidgee woodland fringing an arid zone lake.
Photo: Sue Gardiner

Distribution

Queensland's arid and semi-arid lakes occur in inland-draining catchments including the Channel Country, Mulga Lands, Einasleigh Uplands and Desert Uplands bioregions. The Channel Country, with an average annual rainfall of 100 to 300 mm a year, is the most westerly, and driest, of the bioregions in Queensland where arid and semi-arid lakes occur. The lakes are predominantly associated with overflows, backplains and terminal areas of the **alluvial** floodplains and clay plains of the Lake Eyre **drainage division**, with a smaller number of lakes associated with the Bulloo–Bancannia drainage division. Lakes of varying sizes are scattered across much of the landscape, many of the smaller claypans being unmapped and/or un-named; the lakes are closely associated with a similarly broad spread of swamps. Some notable examples of lake complexes in this bioregion include playas and claypans associated with the Mulligan River—Wheeler Creek junction, Lakes Torquinie and Mumbleberry, Lake Phillipi, the Muncoonie Lakes, and the Lake Mipia to Lake Machattie complex—all in the Eyre Creek (lower Georgina) catchment. Farther east, and associated with the Diamantina River, is Lake Constance; while Lake Yamma Yamma and the Barrolka Lakes are fed by Coopers Creek.

Off-river, the Bilpa Morea Claypan, Moonda and Shallow Lakes and Lake Cuddapan are principally fed by local creeks. Farther south-east, nearing the Queensland/New South Wales border, Lake Bullawarra and the Bulloo Lake complex are associated with the Bulloo River catchment. Countlessbare claypans lie within sand-dune country in this bioregion.

Further east, in the Mulga Lands bioregion, rainfall is slightly higher, from 250 to 500 mm a year. Local creeks feed the Lake Bindegolly and Toomaroo complex within the Bulloo catchment. The Paroo River catchment includes the Wombah–Kungie Lake Group—a lake and claypan system in sand plain country east of the Paroo River, and perhaps best known of all, the Currawinya Lakes (Lakes Wyara and Numulla and numerous smaller lakes and claypans).

Other notable examples include Lake Dartmouth (Warrego–Paroo catchments), and the larger claypans and lakes of sand plain country in the Mungallala Creek catchment, including the Murrawondah Lakes, the Wyandra–Cunnamulla claypans, and the Myola-Mulga Downs salt lake and claypans.

To the north-east of the Channel Country and Mulga Lands is the Desert Uplands bioregion, with rainfall of 500–600 mm a year, notable for two large, internally drained playas with relatively small catchments, Lakes Buchanan and Galilee. Other smaller lakes include Lakes Dunn, Huffer, Powlathanga and Moocha, and saline pans also occur in the south and south-west of this bioregion.

The Wetland*Info* website provides in-depth data, detailed mapping and distribution information for this wetland habitat type.

Queensland status and legislation

Wetlands have many values – not just for conservation purposes – and the range of values can vary for each wetland habitat type and location. The Queensland Government maintains several processes for establishing the significance of wetlands. These processes inform legislation and regulations to protect wetlands, for example, the status assigned to wetlands under the **regional ecosystem** (RE) framework.

A comprehensive suite of wetlands assessment methods for various purposes exists, some of which have been applied in Queensland. More information on wetland significance assessment methods and their application is available from the Wetland*Info* website <www.derm.qld.gov.au/wetlandinfo>. Queensland has also nominated wetlands to *A Directory of Important Wetlands of Australia* (DIWA), see the appendix.

The Queensland Government has direct responsibility for the protection, conservation and management of wetlands in Queensland, a responsibility shared with local government and the Australian Government (for some wetlands of international significance). These responsibilities are found in laws passed by the Queensland parliament, laws of the Commonwealth, international obligations and in agreements between state, local and the federal governments. More information on relevant legislation is available from the Wetland*Info* website <www.derm.qld.gov.au/wetlandinfo>.

National conservation status

The Currawinya Lakes Ramsar site (a Wetland of International Importance under the **Ramsar Convention**) contains arid and semi-arid lakes. A framework and guidelines for the management of the Currawinya Lakes has been set out in the Currawinya National Park Management Plan (QPWS, 2001).

A number of migratory shorebirds listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (that is, they are listed under the Japan-Australia and China-Australia Migratory Bird Agreements (**JAMBA/CAMBA** respectively) and/or the **Bonn Convention**) use the arid and semi-arid lakes in Queensland. A small number of arid and semi-arid lake flora and fauna species are listed as threatened under the EPBC Act and/or the NC Act and/or the **IUCN Red List** (see Species of conservation significance for more details). Recovery plans which set out research and management actions to support the recovery of threatened species under the EPBC Act are available for some of these species (see http://www.environment.gov.au/biodiversity).

Ramsar wetlands, listed migratory species and threatened species are matters of national environmental significance under the EPBC Act and as such are afforded protection under the Act. Any action that is likely to have a significant impact on a declared Ramsar wetland, listed migratory species or threatened species will be subject to an environmental assessment and approval regime under the EPBC Act.

Cultural heritage values

All wetland ecosystems are of material and cultural importance to Indigenous people and many will have profound cultural significance and values. The Indigenous peoples of inland Queensland have strong cultural associations with arid and semi-arid lakes (fresh and salt) dating back thousands of years. Lakes were important for Indigenous peoples of the arid and semi-arid interior, providing seasonal water, food and other material resources, as well as having ceremonial and spiritual values. There are more than 80 Indigenous cultural heritage sites recorded in association with arid and semi-arid lakes in Queensland. However, most arid and semi-arid zone lakes have not been systematically surveyed or assessed for cultural heritage significance.

Due to the often **intermittent** nature of arid and semi-arid lakes, traditional occupation would generally correspond with seasonal flooding events and the associated rapid expansion in resource species available, particularly vegetation, crustaceans, fish, reptiles, mammals and waterbirds (particularly their eggs). Almost all plant and animal species had some form of traditional use or cultural significance (for example totemic significance). Some of the better known plant species associated with arid and semi-arid lakes which were traditionally used for food include nut-grass *Cyperus* spp, pepper grass *Panicum laevinode, Sporobolus* spp. such as katoora grass *S. actinocladus*, rat's tail couch *S. mitchelli* and saltwater couch *S. virginicus*. Many other species were also used traditionally for food and shelter, for making implements, bags and nets, and for medicinal purposes.

Because of the transitory nature of the vast majority of arid and semi-arid lakes, there might be a lower density and more dispersed distribution of archaeological evidence of traditional occupation and use, therefore there is a lesser likelihood of encountering cultural heritage sites within arid and semi-arid lake areas. However, sites are more likely to be visible during dry periods when vegetation cover has decreased and soils are exposed, particularly soils displaced through erosion.

THE Indigenous peoples of inland Queensland have strong cultural associations with arid and semi-arid lakes (fresh and salt) dating back thousands of years, as they provide seasonal water, food and other material resources, as well as having ceremonial and spiritual values.

The information available suggests that there is a greater diversity of evidence of traditional occupation and use associated with temporary arid and semi-arid zone freshwater lakes than with arid and semi-arid salt lakes. The site recorded within arid and semi-arid salt lake areas (such as hearths and stone scatters), are indicative of temporary occupation, whereas sites found within arid and semi-arid freshwater lake wetlands suggest more permanent occupation. Along with hearths and stone scatters, these areas also include sites such as burials, scarred trees, quarries, dwellings, and places of particular significance including story places, landscape features and cultural sites. The presence of coolabah *Eucalyptus coolabah* and river red gum *E. camaldulensis* in association with some arid and semi-arid lake regional ecosystems, means that there could be scarred trees in those areas. Scarred trees may be found along lake margins and in areas of higher ground adjacent to arid and semi-arid lakes, particularly in the vicinity of more permanent water.

Some arid and semi-arid lakes also have historic cultural heritage significance, although most have not been surveyed or assessed for historic heritage values. The historic heritage values of arid and semi-arid lakes can demonstrate evidence of their past and present use by the pastoral industry, including stock camps, stockyards, huts, watering points for cattle and sheep grazing, and overland transport (for example, roads and inns/coach change stations), as well as evidence of recent occupation and traditional use by Indigenous people.

Erosion along the margin of this salt lake has exposed a large stone artefact scatter.
Photo: Rob Neal, DERM

Ecological values

An arid and semi-arid wetland complex of lakes and swamps includes a broad spectrum of habitat types, forming a richly biodiverse oasis in the otherwise dry landscape. The source of the inflowing water, either from periodic flooding from remote monsoonal activity or from local rainfall events, influences the types of species that can be present in a particular lake at any given time. For example, if a dry lake bed is filled by a local rainfall event, then fish species will largely be absent; however, the same lake filled from a regional flood event which connects it to a river system may contain a variety of fish species including catfishes, gudgeons, gobies, rainbow fishes, and hardyheads. The presence or absence of fish within the system will subsequently affect the assemblage and numbers of micro-organisms, **macroinvertebrates** and **vertebrates** (such as fish-eating birds) to be found within the lake.

THE cycling of arid and semi-arid wetlands through periods of wet and dry sustains a 'boom or bust' ecology. When flood or rainwater enters a dry lake it can trigger a chain of biological events over a very short time period

The cycling of arid and semi-arid wetlands through periods of wet and dry is critical for the recruitment and survival of many species, and sustains a 'boom or bust' ecology. When flood or rainwater enters a dry lake it can (depending on the time) trigger a chain of biological events over a very short time period. Micro-organisms (both **phytoplankton** and **zooplankton**), and larger aquatic plants (**macrophytes**), grow and reproduce at great speed to complete their life cycles while good conditions prevail, and provide an abundant food resource for macroinvertebrates such as insects and crustaceans, and also for vertebrates such as fish, frogs, turtles, reptiles and birds. Some lakes, such as Wyara, Bindegolly and Galilee have **hyposaline** rather than freshwater conditions for much of their cycle, with clear rather than turbid water, which (between critical salinity levels) triggers especially large peaks in populations of several macroinvertebrate species that in turn support high numbers of certain waterbird species such as the pink-eared duck *Malacorhynchus membranaceus*.

ICONIC WETLANDS OF THE ARID ZONE: THE CURRAWINYA LAKES

The Currawinya Lakes were proclaimed a national park in 1991, and are also listed as a Ramsar site. The park contains a mosaic of dunefields, fresh and saltwater lakes, claypans and swamps, and is a diverse and important wetland system. The two largest lakes, Numalla and Wyara, provide a significant water source and refuge for local and migratory species.

More than 180 species of birds have been sighted at the lakes, including approximately 60 waterbird species. During dry periods in the inland of eastern Australia, if Lakes Wyara or Numalla have retained plenty of water they commonly support over 20 000 waterbirds and occasionally over 100 000 waterbirds. Currawinya is also one of the most important refuges in Australia for the freckled duck *Stictonetta naevosa* (rare, NC Act) with several thousand birds present at some times.

The two principal lakes are less than 3 km apart but are distinctively different: Lake Numalla contains freshwater supplied mainly by a channel from the Paroo River, whereas Lake Wyara is supplied by local creeks from an independent catchment and is saline. A connection between Lake Wyara and the Paroo River can occur during exceptional floods. Lake Numalla is almost permanent and is fringed by black box *Eucalyptus largiflorens* woodland, belalie *Acacia stenophylla* and lignum *Muehlenbeckia florulenta* shrublands, and sedgelands of *Cyperus gymnocaulos*. Wyara often dries to a glaring saltpan, surrounded by samphire shrubs such as *Halosarcia pergranulata*, and fringed by shallow crescent dunes on its eastern side.

Up to 10 times as many waterbirds are usually found on saline Lake Wyara, because the water is generally shallower, and being saline, is clearer than Numalla, providing excellent conditions for the rapid growth of the water plants, insects and crustaceans upon which the birds feed. When Lake Wyara is dry but Numalla still has plenty of water, the latter can also support huge numbers of waterbirds. Waterbirds breed on both lakes and in associated wetlands, pelicans, cormorants and swans nest on islands or spits when Lake Wyara is at the right depth, and ducks and spoonbills nest in trees and shrubs around Lake Numalla.

Saline Lake Wyara, Currawinya Lakes.
Photo: Adam Creed, DERM

Freshwater Lake Numulla, Currawinya Lakes.
Photo: DERM

Many lake-inhabiting species tolerate a range of environmental conditions as their habitats vary with fluctuations in water depth and salinity, and use a diverse range of mechanisms to survive in variable environments. Many species have short life cycles that can be completed while the lakes are full of water and at their lowest salinity. Some, such as the water flea *Daphiniopsis queenslandensis* and brine shrimps *Artemia* spp. produce drought-resistant eggs or larvae that will only hatch when water is present, and can survive for years through dry conditions. Others, such as the crayfish *Cherax destructor* and some species of water snails and frogs, take shelter in burrows, underground, or under stones to avoid **desiccation** as wetlands dry out; and mobile species such as waterbirds fly between waterholes as water levels fluctuate, but may have boom and bust cycles in response to periods of drought.

Plants of the arid and semi-arid lakes also show adaptations to variable conditions, with some aquatic plants such as *Ruppia* **spp.** and *Lepilaena* spp. being able to thrive in conditions of 100 parts per 1000 (ppt) salt, and algae such as *Dunaliella* spp tolerating 300 ppt salt (seawater has a salinity level of 35 ppt). A range of **halophytic** shrubs that fringe the lakes survive harsh conditions by excreting excess salt through their leaves.

Vegetation of the arid and semi-arid lakes

Typical vegetation occurring in and around the arid and semi-arid lakes includes fringing shrubs such as belalie *Acacia stenophylla*, sally wattle *Acacia salicina*, creek wilga *Eremophila bignoniflora*, clustered lawrencia *Lawrencia glomerata*, silver leaf cassia *Senna phyllodinea*; chenopods including old

Vegetated fringe of a drying freshwater lake, showing typical forb and herb layer with samphires and lignum. Photo: Sue Gardiner, DERM

PLANTS OF THE ARID AND SEMI-ARID LAKES: THE CHENOPODS

Chenopods are a family of plants generally referred to as saltbushes or bluebushes. They survive well in the hot, dry conditions of the arid and semi-arid zone, having succulent leaves covered in scales or silver, hairy down, and a deep root system. The leaves of many chenopods have pores that are able to excrete salt, making these plants salt tolerant as well as drought adapted.

Two well-known examples of chenopod shrubs are the Queensland bluebush *Chenopodium auricomum* and old man saltbush *Atriplex nummularia*, which grow on the fringes of some arid and semi-arid lakes. There is also a range of smaller chenopods, including small saltbush *Atriplex eardleyae*, pop saltbush *Atriplex spongiosa*, and red burr *Sclerolaena calcarata* that grow on the drying lakebeds. All are known for their rapid growth after flooding, and their free seeding, which allows them to quickly revive after periods of drought and grazing. They are important plants in the cattle fattening regime of the Channel Country, and an important food source for granivorous birds, such as parrots and pigeons, as well as some native rodent species.

Old man saltbush.
Photo: David Akers, DERM

man saltbush *Atriplex nummularia*, small saltbush *Atriplex eardleyae*, pop saltbush *Atriplex spongiosa*, thorny saltbush *Rhagodia spinescens*, ruby saltbush *Enchylaena tomentose*, blue bush *Chenopodium auricomum*, and cotton bush *Maireana* spp; lignum *Muehlenbeckia florulenta* and flowering lignum *Eremophila polyclada*; and samphires such as blackseeded samphire *Halosarcia pergranulata* and brownheaded samphire *H. indica*.

A range of forbs and grasses can be present on lake shores and margins, or sometimes across dry lake beds, including *Eragrostis* species such as swamp cane grass *E. australasica*; *Sporobolus* species, such as katoora grass *Sporobolus actinocladus*, rat's tail couch *Sporobolus mitchellii* and saltwater couch *S. virginicus*; other grasses such as couch *Cynodon dactylon*, comb chloris *Chloris pectinata*, red Flinders grass *Iseilema vaginiflorum* and small Flinders grass *I. membranaceum*, pepper grass *Panicum laevinode*, brown beetle grass *Leptochloa fusca* and button grass *Dactyloctenium radulans*; desert sneeze weed *Centipeda thespidiodes*; soft roly-poly *Salsola kali*; red burr *Sclerolaena calcarate*; *Teucrium racemosum* var. *racemosum*; spreading nutheads *Epaltes australis*; red spinach *Trianthema triquetra*; *Cullen* spp.; *Sesbania* spp.; Cooper clover *Trigonella suavissima*; *Solanum* spp.; *Frankenia* spp.; *Mimulus* spp.; and sedges such as spiny flat sedge *Cyperus gymnocaulos*, common finger rush *Fimbristylis dichotoma* and *F. vagans*.

Submerged and floating aquatic plants may flourish when lakes and clay pans are flooded, and include algal turf *Chara australis*, green alga *Ulothrix* spp, sea tassel *Ruppia maritima*, red water-milfoil *Myrophyllum verrucosum*, water mat *Lepilaena bilocularis*, foxtail stonewort *Lamprothamnium papulosum*, *Polygonum* spp, *Ludwigia* spp and *Azolla* spp.

Scattered trees and open woodland such as coolabah *Eucalyptus coolabah*, belalie *Acacia stenophylla*, beefwood *Grevillea striata*, northern boobialla *Myoporum acuminatum*, river red gum *Eucalyptus camaldulensis*, poplar box *Eucalyptus populnea, poplar gum Eucalyptus platyphylla, Molloy red box Eucalyptus leptophleba, bluegum Eucalyptus tereticornis, Reid River box Eucalyptus brownii, long-fruited bloodwood Corymbia polycarpa* and gidgee *Acacia cambagei* or *A. georginae* may also occur around lake margins at or above high water mark.

Wetland*Info* provides full species lists of wetlands animals and plants.

THE arid and semi-arid lakes support a wide variety of micro-organisms (both phytoplankton and zooplankton), and macroinvertebrates such as insects and crustaceans, which are key elements of the food chain.

PLANTS OF THE ARID AND SEMI-ARID ZONE LAKES: SWAMP CANEGRASS

Swamp canegrass *Eragrostis australasica* is a characteristic tussock grass of arid and semi-arid wetlands. Its stiff cane-like stems, up to 2 m tall, and dense growth habit, made it a valuable thatching material when lush, often used for meat houses and **bower sheds** in the past.

Canegrass commonly grows on the margins of claypans that have been inundated for several months, and sometimes occurs in almost pure stands as canegrass swamps.

Lignum and canegrass are the preferred habitats of the grey grasswren *Amytornis barbatus*, a regionally **endemic** species of the lower Bulloo, Cooper, Diamantina and Georgina catchments.

Canegrass wetland.
Photo: Sue Gardiner, DERM

The Bulloo subspecies *A. barbatus barbatus* is listed as vulnerable under the EPBC Act.

Fauna of the arid and semi-arid lakes

Information about the fauna that use the arid and semi-arid lakes is generally scarce, with the notable exception of birds, and to a lesser degree fish. The following describes some of the better-known faunal groups—but further survey work and research are needed to better understand the details of these biodiversity habitats in the arid and semi-arid landscape, and the species that use them.

The arid and semi-arid lakes support a wide variety of micro-organisms (both phytoplankton and **zooplankton**), and macroinvertebrates such as insects and crustaceans, which are key elements of the food chain. Examples include **phyllopods** such as shield shrimps *Triops australiensis* (see box Survivng dry times: the shield shrimp), *Ranchilla* spp. and *Cyzius* sp.; **ostracods** or seed shrimps; **copepods** such as *Boeckella triarticulata*; **cladocerans** such as the water flea *Daphiniopsis queenslandensis*; **anostracans** such as brine shrimp *Artemia* spp.; and **isopods** such as *Haloniscus* sp.. **Molluscs** including large mussels, freshwater snails, and the salt lake snail *Coxiella* sp. are also common.

Fish associated with the lakes include two species of catfish—Hyrtl's tandan *Neosilurus hyrtlii*, and moonfish *Porochilus argenteus*. Bony bream *Nematolosa erebi*, spangled perch *Leiopotheropon unicolour*, gudgeons *Hypseliotris* spp., Lake Eyre hardyhead *Craterocephalus eyresii*, desert goby *Chlamydogobius eremius*, desert rainbowfish *Melanotaenia splendida tatei*, Australian smelt *Retropinna semoni*, western chanda perch *Ambassis* sp., and banded grunter *Amniataba percoides* (recorded in Queensland in the Georgina River and Warburton River systems) can occur.

Amphibians associated with arid and semi-arid lakes include the water holding frog *Cyclorana platycephala*, eastern snapping frog *C. novaehollandiae*, grassland collared frog *C. cultripes*, greenstripe frog *C. alboguttata*, northern snapping frog *C. australis*, rough collared frog *C. verrucosa*, desert burrowing frog *Limnodynastes spenceri*, desert shovelfoot *Notaden nichollsi*, holy cross frog *N. bennettii*, chirping froglet *Crinia deserticola*, trilling frog *Neobatrachus centralis*, broad palmed rocket-frog *Litoria latopalmata*, and ruddy treefrog *L. rubella*.

SURVIVING DRY TIMES: THE SHIELD SHRIMP

Shield or tadpole shrimps are ancient creatures that evolved over 200 million years ago and are perfectly adapted to surviving in temporary wetland habitats. Two genera occur in Australia, with *Triops* species found in hot arid and semi-arid areas such as western Queensland.

Adults are up to 35 mm long, and have a characteristic shield covering most of their body, with two 'tails' protruding from the last segment of their abdomen, and up to 60 pairs of feathery legs. They are found in freshwater or slightly saline lakes, and claypans and puddles of even the most temporary duration, usually where there are no fish predators. They usually live under submerged water plants to protect themselves from the sun, and feed on decaying plant and animal matter.

Shield shrimps have a short life cycle—their eggs hatch in just a few days, and the larvae develop into mature adults able to reproduce within a week or two. Shield shrimp eggs are highly resistant to desiccation, so that if their wetland habitat dries out before the shrimps can hatch, the eggs (cysts) remain viable, surviving in the dried mud for years, and in some known cases, decades, awaiting the return of more favourable conditions.

Shield shrimp *Triops australiensis*.
Photo: Richard Johnson, DERM

SURVIVING DRY TIMES: THE WATER HOLDING FROG

The water holding frog *Cyclorana platycephala* only comes to the surface to feed and breed after a rain or flood event moistens the ground enough for it to dig its way out. The above-ground lifecycle from tadpole to frog takes four weeks, and must be completed before the wetland dries out so that the adult frogs can burrow again to protect themselves from the desiccating effects of the arid and semi-arid surface environment.

The water holding frog has specially adapted spade-shaped projections on its heels to help it burrow efficiently. Once underground it forms a cocoon around itself by shedding a layer of its own skin, and slows down its body processes to conserve the water it has stored in its bladder and in pockets under its skin. In this way the frog can survive underground for a number of years with no further moisture. When rain or floods return, the frog eats its protective cocoon, and digs its way to the surface, where the cycle of reproduction and survival begins again.

Traditionally, burrowing frogs such as the water holding frog, were prized by Indigenous peoples as a valuable source of water. The frog releases some of its stored water when subjected to slight pressure and can be released unharmed after providing a drink to a thirsty traveller, which could mean the difference between death and survival in desert conditions.

The water holding frog *Cyclorana platycephala*.
Photo: DERM

Potential threats to burrowing frog populations in the arid and semi-arid lakes include reduced or altered water flow conditions, leading to loss of breeding sites, and physical disturbance of habitat by cattle and feral animals.

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The arid and semi-arid lakes of inland Queensland form a network of feeding and breeding habitats for migratory and non-migratory waterbirds, which integrates with other networks across the continent. In favourable conditions, particular lakes may support populations of tens to hundreds of thousands of waterbirds, of which non-migratory species form by far the largest proportion.

Typical non-migratory representatives of the major waterbird groups include swans, geese and ducks such as plumed whistling-duck *Dendrocygna eytoni*, black swan *Cygnus atratus*, pink-eared duck *Malacorhynchus membranaceus*, Pacific black duck *Anas superciliosa*, grey teal *Anas gracilis* and hardhead *Aythya australis*; grebes such as hoaryheaded grebe *Poliocephalus poliocephalus* and great crested grebe *Podiceps cristatus*; fish eaters such as pied cormorant *Phalacrocorax varius*, little black cormorant *P. sulcirostris* and Australian pelican *Pelecanus conspicillatus*; herons and allies such as white-faced heron *Egretta novaehollandiae*, strawnecked ibis *Threskiornis spinicollis* and yellow-billed spoonbill *Platalea flavipes*; brolga *Grus rubicundus*; Eurasian coot *Fulica atra*; shorebirds such as blackwinged stilt *Himantopus himantopus*, red-necked avocet *Recurvirostra novaehollandiae* and red-capped plover *Charadrius ruficapillus*; and gulls/terns such as silver gull *Larus novaehollandiae*, gull-billed tern *Sterna nilotica* and whiskered tern *Chlidonias hybridus*.

Little black cormorants and yellow-billed spoonbill.
Photo: Roger Jaensch, Wetlands International

Also present, but most often recorded from the Currawinya and Bindegolly lakes, is the blue-billed duck *Oxyura australis*, a relatively rare species in Queensland, being principally a temperate zone species.

Migratory shorebirds recognised under the JAMBA, CAMBA and/or the Bonn Convention that occur at arid and semi-arid lakes include the common greenshank *Tringa nebularia*, red-necked stint *Calidris ruficollis*, sharp-tailed sandpiper *C. acuminata* and whitewinged black tern *Chlidonias leucopterus*.

Though not proven to be truly migratory, several birds of arid and semi-arid lakes, notably the great egret *Ardea alba*, glossy ibis *Plegadis falcinellus* and Caspian tern *Sterna caspia*, are listed as migratory under the EPBC Act because they are included in the lists of JAMBA and/or CAMBA.

Promontories and low islands within some lakes are significant nesting sites for waterbirds such as pelicans, black swans, red-necked avocets, Caspian terns, pied cormorants and silver gulls.

The freckled duck *Stictonetta naevosa*, one of Australia's least abundant ducks, is periodically found congregating in large numbers on freshwater lakes such as Numalla, Muncoonie and Machattie, and saline lakes such as Torquinie and Mumbleberry, after breeding in lignum swamps. Some of the samphire, saltbush, herbfields and dune woodlands associated with the margins of the lakes are also important habitat for a range of more common species such as finches and fairy-wrens. The green herbage on the drying beds of the arid and semi-arid lakes are also used by nomadic species such as the orange chat *Epthianura aurifrons* and the vulnerable (NC Act) yellow chat *E. crocea*.

FAUNA OF THE ARID AND SEMI-ARID LAKES: THE AUSTRALIAN PELICAN

Pelicans *Pelecanus conspicillatus* are found in lakes throughout Australia. Weighing up to 13 kg, they are a heavy bird but, with a wingspan of up to 3 m, pelicans are very good soarers, using **thermals** to rise to altitudes of 1000 m or more, and can remain in the air for up to 24 hours. They travel long distances to suitable breeding and feeding grounds and often appear on arid and semi-arid lakes after flooding events.

Pelicans breed in colonies, the largest of which (up to 50 000 pairs) occur in lakes in the Lake Eyre Basin, which are therefore vital for sustaining this species. They prefer to nest at isolated sites such as small islands or spits. Both the male and female birds build the nest, which consists of a hollow scraped in the ground, sometimes lined with plants and feathers. When the chicks are about a month old they gather together in crèches of up to 100 individuals, where they stay for a further two months until they become independent and are able to fly and follow the rains and floods as their parents do.

Australian pelicans on an arid zone lake.
Photo: Roger Jaensch, Wetlands International

FAUNA OF THE ARID AND SEMI-ARID LAKES: THE FLOCK BRONZEWING

Formerly abundant throughout the semi-arid and semi-arid inland of Australia, populations of the flock bronzewing, or flock pigeon *Phaps histrionica* declined markedly in the last century. It is thought that reduction or loss of favoured seed-bearing grasses, and predation by both native and feral animals are its biggest threats. The distribution and requirements of this species are currently being researched, with the assistance of inland communities.

The life cycle of this nomadic pigeon is strongly influenced by rainfall, with the birds travelling great distances to feed on the seeds and shoots of the grasses and forbs which appear after good rain and flood events in the arid and semi-arid. Breeding times are also linked to rainfall, with most nesting occurring after good wet seasons.

In Queensland the pigeons principally occur in short tussock grasslands, such as those dominated by *Astrebla* spp. This habitat is extensive in the Mitchell Grass Downs bioregion and smaller areas occur in the Channel Country bioregion. Like many seed-eating birds, the pigeons routinely drink water and their common name is derived from their habit of congregating in large flocks at water sources, which creates a unique spectacle. They drink at small sites such as natural tree-less ponds and stock dams and in dry periods the open shores of some arid and semi-arid lakes.

Flock bronzewing.
Photo: Martin Armstrong

MIGRATORY FLYWAYS

A number of shorebirds found on Queensland's arid and semi-arid lakes migrate across the world between their breeding grounds in the Arctic and non-breeding grounds in the southern hemisphere. The routes that the birds follow are known as flyways, and eight main flyways can be identified across the world. Australia lies at the southern end of the East Asian–Australasian Flyway, which originates in Russia and Alaska, crossing 22 countries along its path. Flyways contain chains of wetlands which provide abundant food such as aquatic worms, molluscs and crustaceans, enabling the travelling birds, which may take two months to commute between their two homes, to make stopovers to feed and rebuild their reserves of fat for the next stage of their journey.

Caring for the wetlands along the flyways, and the migratory birds that use them, needs international cooperation, hence the development of migratory bird agreements such as JAMBA and CAMBA, to which Australia is a signatory.

Species of conservation significance

A number of species associated with the arid and semi-arid lakes in Queensland are listed as threatened under State (NC Act) and Commonwealth (EPBC Act) legislation and/or recognised under international conventions or agreements such as JAMBA, CAMBA and the IUCN Red List. Most abundant are the migratory shorebirds.

The arid and semi-arid lakes apparently support rather few **vascular** plants of conservation significance. However Lake Buchanan is known for a number of newly discovered, and probably endemic, species such as Lake Buchanan button grass *Dactyloctenium* sp. (Yarrowmere J.Kemp+ 338411), as well as the rare (NC Act) fringing rush *Fimbristylis vagans* and endemic Lake Buchanan fringe rush *Fimbristylis* sp. (Lake Buchanan). The endemic Lake Buchanan bluebush *Lawrencia buchananensis* is listed as vulnerable under the NC and EPBC Acts.

Buchanan's fairy shrimp *Branchinella buchananensis* is a species of very restricted distribution, known only from one arid and semi-arid lake in Queensland and two lakes in north-west New South Wales, none of which are under protected land management. Threats to its survival in NSW include the development of gypsum or other mining, which could disturb the hydrology of the lakes. Given that the same threats are not identified in Queensland, Lake Buchanan may well become a significant refuge for this species in the future.

The vulnerable (EPBC Act; rare, NC Act) grey grasswren *Amytornis barbatus barbatus* (Bulloo subspecies) is a resident species associated with the arid and semi-arid lakes and swamps, where it breeds in the lignum and canegrass communities. The vulnerable (NC Act) yellow chat *Epthianura crocea crocea* (gulf/inland subspecies) is also found in lignum swamps, particularly in the Georgina River—Eyre and Diamantina floodplains.

Small mammals such as the kultarr *Antechinomys laniger* (rare NC Act) utilise dry claypans and margins to forage. Although generally regarded as inhabiting dunes, dusky hopping-mouse *Notomys fuscus* (vulnerable EPBC, endangered NC Act) can be found on claypans between dunes along with the fawn hopping-mouse *Notomys cervinus*.

Further survey work is needed in these remote and difficult to access areas to comprehensively determine the conservation status of rare and threatened species.

ADOPTING appropriate strategies that consider stock and water management, and the control of weeds and feral animals, will ensure that the exceptional ecological and cultural values of arid and semi-arid zone lakes are maintained.

Managing the arid and semi-arid lakes

Most of Queensland's arid and semi-arid lakes are on leasehold land managed predominantly by the grazing industry, with some representation in national parks in the Channel Country (Simpson Desert, Welford and Diamantina National Parks) and Mulga Lands (Currawinya, Bindegolly and Culgoa Floodplain National Parks). Successful long-term management of the arid and semi-arid lakes for conservation outcomes as well as production therefore relies heavily on an integrated approach involving all stakeholders.

Land managers are using a range of tools to integrate ecologically sustainable pastoral grazing practices with nature conservation. Adopting appropriate strategies that consider stock and water management, and the control of weeds and feral animals, will ensure that the exceptional ecological and cultural values (including tourism) of these wetlands are maintained. The final outcome will depend on the individual management decisions of the pastoral grazing company or property manager.

The key management issues are outlined below.

Water regulation and extraction

Water regulation or extraction affects local and regional hydrology and is arguably the highest priority issue for management of arid and semi-arid lakes. Catchment-based planning for water allocation, led by the Department of Environment and Resource Management (DERM) is now addressing water flow issues in a number of catchments. Water Resource Plans, and where necessary Resource Operational Plans, are being prepared under the Queensland *Water Act 2000* in catchments where human consumptive needs have had a measurable impact or where rivers and wetlands have significant ecological or social values.

A water resource plan details what the government aims to achieve for a catchment's social, economic and environmental needs, while a resource operational plan details how water resources will be managed from day to day to meet these objectives.

Water resource plans are in place for the Warrego/Paroo/Bulloo/Nebine, Condamine/Balonne, Cooper Creek and Georgina/Diamantina catchments. Resource operation plans have been declared for the Warrego/Paroo/Bullo/Nebine, Georgina/Diamantina catchments, and Condamine/Balonne catchments. These will regulate the use of water for stock, domestic, urban and large-scale use such as irrigation, aquaculture or mining; and the placement of structures such as dams, weirs and ring tanks that affect the natural flow regimes of inland catchments. This is of vital importance because many lakes are only filled by peak flows in the catchments, and any modification of these flows could result in failure of lakes to fill, resulting in the loss of their biodiversity and production values. For further information on water resource planning in Queensland, see the DERM website <www.derm.qld.gov.au>.

In general, maintaining the natural variation in frequency of flooding and persistence of arid and semi-arid lakes will protect their conservation values. Even with wise planning of water allocation this will become an increasing challenge, as reduced rainfall and higher temperatures are predicted to occur through much of arid and semi-arid Australia.

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Management of grazing

The Channel Country has highly productive and valuable fattening pasture. This, coupled with the fact that the area is relatively free of introduced pests such as cattle ticks or exotic plants, means the area has become an important area for organic beef production, particularly for a cooperative of pastoralists that is one of the nation's largest organic beef exporters.

The importance of the lakes in the beef production system varies. The chenopod herbfields (for example *Atriplex* spp. and *Sclerolaena* spp.) that flourish on the beds of some large lakes are probably the most valuable forage from a grazing perspective, and lake beds dominated by rat's tail couch *Sporobolus mitchellii* are also productive. Some trampling may occur along lake fringes but because the deep alluvial soils become boggy, cattle generally tend not to venture far onto the lake surface until it has dried out. Mosquitoes and sandflies may discourage cattle from coming to the lakes while the perimeters are still wet. This may limit **pugging** and trampling, and minimises impact on natural processes.

Grazing pressure from native animals is variable, but often minimal. Kangaroo populations are not large in the Channel Country, but can be high in the Mulga Lands.

Vegetated lakebeds are a highly valued grazing resource.
Photo: Roger Jaensch, Wetlands International

Feral camels graze the lakebeds occasionally, but pigs are the most damaging of the feral species present, as they root for food and wallow at the lake edges.

Physical disturbance

Excavation in the lakebed to create a deeper, longer-term water supply has occurred in some arid and semi-arid lake areas in the past. This had the effect of extending or increasing grazing pressure on the lakebeds. It is an offence under the Queensland *Water Act 2000* to excavate a watercourse, lake or spring without a permit.

Disturbance and physical damage to the landscape and ecology by animals, humans or vehicles scars the lake flats and their surrounds until the next rains—which may be many years away. Some plants, such as samphires, are easily destroyed by physical trampling even though they are capable of withstanding harsh climatic conditions. Samphires are important because they act as sediment and nutrient traps and also stabilise the lake edge. Wherever possible humans should endeavour not to create new tracks with their vehicles or from other activities.

Vehicle and animal tracks create scars on dry arid zone lakes that last for many years. Above is a photo of recent scarring on a claypan. The track in the bottom photo has not been used for several years but the samphire plants have not recovered.
Photos: Sue Gardiner, DERM and Richard Johnson, DERM

Tourism/recreation

Management of tourism and recreation impacts to protect arid and semi-arid wetlands will be an increasingly significant issue. The resident human population of the arid and semi-arid lakes area is very small, but there is significant and increasing tourist visitation. This has a number of effects, which can be direct, such as on-site impacts, or indirect, for example decline of downstream water quality and associated species decline.

The most preferred campsites are on the edges of persistent lakes and waterholes. Using the riparian timber for campfire fuel, especially hollow branches and logs, can over a long period totally degrade habitat for hollow-dwelling fauna such as ducks, parrots, owls, bats and reptiles. Disturbance of nesting birds by human activity in the heat of a summer's day can result in the death of unhatched chicks. The activity of unleashed pet dogs can also be devastating to ground-nesting waterbirds and disturbing to wading birds and ground-dwelling fauna.

Issues such as the inappropriate disposal of rubbish and human excrement, and damage to vegetation has caused some towns to ban or restrict camping at popular spots, causing campers to look further afield and thereby extend the degraded area. Some tourists also create new vehicle tracks, which tend to draw others to continually expand their presence and impact.

In order to minimise adverse impacts on arid and semi-arid lakes, tourists should use designated camping areas where available and dispose of waste appropriately in bush camps. Local timber, including fallen material, should not be taken for fires unless it has been provided for that purpose. Existing tracks should be followed to avoid wider degradation of the landscape. Dogs should be kept under control to avoid disturbance to wildlife.

Lignum management

Inundated lignum *Meulenbeckia florulenta* shrublands support waterbird breeding colonies, and provide habitat for the grey grasswren *Amytornis barbatus*, and other species such as small marsupials, reptiles, crabs and snails throughout the year. Burning of lignum shrubland is a relatively common practice in the Channel Country, to encourage growth of preferred fodder plants and reduce areas where cattle may hide during mustering.

There has been no systematic scientific investigation of an appropriate managed fire regime (in terms of frequency, intensity and pattern) for wetlands in the arid and semi-arid zone. Collaborative research projects developed by scientists and graziers would be beneficial to determine whether this preferred fire regime is the best way to achieve ecologically sustainable grazing.

Weeds

The most frequently encountered weed species are parkinsonia *Parkinsonia aculeata* (mainly in the Desert Uplands, Mitchell Grass Downs and Channel Country bioregions) and mesquite *Prosopis velutina* and hybrids in the Mulga Lands (two of 20 Weeds of National Significance—see <www.weeds.gov.au> for further information). Water movement is the main seed dispersal mechanism for parkinsonia; mesquite seeds are moved by water but to a much larger extent by cattle, sheep, feral pigs and emus.

Both these thorny shrub species form dense thickets in riparian areas and if large-scale infestations were to develop unchecked in the Channel Country wetlands there is potential to alter the ecology of the entire bioregion. Fortunately this has not yet occurred; the diligence of the region's pastoralists, supported by education programs and assisted with finance for on-ground activities by state and Australian governments and community initiatives has been an effective control combination.

WEEDS such as parkinsonia and mesquite, if left untreated, can replace native plant species, reducing habitat quality in arid and semi-arid zone lakes. The diligence of pastoralists, supported by education programs and funding from government and community initiatives, has been an effective control combination.

Both parkinsonia and mesquite, if left untreated, can replace native plant species, reducing habitat quality. They can take over large areas and lead to increased costs to landholders through increasing the difficulty of mustering stock, a reduction in stock access to watering points and a decrease in primary production of grasses that they replace. Infestations can also provide refuges for feral animals, especially pigs.

Controlling parkinsonia and mesquite is expensive. Prevention of spread is more cost-effective. Any weed outbreaks on watercourses, particularly in upper catchments, should be controlled. Soil or sand from infested catchments should not be transferred into uninfested catchments, and machinery used in infested catchments should be thoroughly cleaned before moving to other areas. Cattle should be quarantined before transport into uninfested areas, and animals should be excluded from existing infestations.

An integrated approach using several weed management techniques is the most effective way of tackling dense infestations, however control methods should be tailored to suit the landscape. Fire may be used as a control option, particularly after mechanical or chemical control (however it must be managed carefully to minimise the impact on other vegetation and the potential for erosion if heavy rains follow

COMMUNITY ACTION PROTECTS CATCHMENTS

From an initiative developed by the Cooper Creek Catchment Committee grew the Cross Catchments weed and feral animal initiative. In collaboration with state and local governments and supported by the regional natural resource management group, Desert Channels Queensland, the initiative has facilitated aerial and ground weed survey work; digital mapping and prioritisation of infestations and weed free areas across the Channel Country, Mitchell Grass Downs and Desert Uplands; and financial support of strategic on-ground weed control projects. This has resulted in an accurate knowledge of weed distribution, an understanding within the rural community of what needs to be done and a much-reduced risk of weed invasion, especially of the Channel Country wetlands.

EXPENSIVE SHADE TREES

Mesquite *Prosopis velutina* were planted as shade trees around stockyards at a property on the Bulloo River floodplain around the middle of last century. By the late 1980s two freshwater lakes and thousands of hectares of floodplain and drainage lines were totally colonised with mesquite. To date, more than $4 million has been spent on this mesquite infestation by landowners and local, state and Australian governments. While the distribution and density has been greatly reduced, the infestation is far from eradicated and remains a potential threat to the entire Bulloo floodplain.

closely to burning, and to prevent loss of stock and property). Regardless of the method/s used, follow-up will be required to control seedlings. For more detailed information on the management of parkinsonia and mesquite, see www.weeds.gov.au.

Feral animals

Feral pigs *Sus scrofa* are present throughout the arid and semi-arid zone of Queensland. The damage caused by their presence includes predation on frogs, turtle eggs and mussels; rooting up lakebed and riparian vegetation; and their role as a host or vector for diseases of cattle such as leptospirosis; hence control of pigs is desirable to landholders and the wider community. As both wetlands and pigs can occur across several properties, effective control of pigs depends on coordinated management by networks of land managers. The Cross Catchment weeds and feral animal initiative referred to above has also contributed to knowledge and control of the feral pig population in the region.

Red fox *Vulpes vulpes* are also found throughout the area, but are most prevalent in the Mulga Lands. Cats *Felis catus* are also present throughout the region and may reach extremely high numbers in the Channel Country following peaks in the population of native long-haired rats *Rattus villosissimus,* which are a major prey item. The diets of individual animals have been well documented (consumption of frogs, reptiles, young and adult birds) but the cumulative effect of their presence is difficult to define.

Camels *Camelus dromedarius*, donkeys *Equus asinus*, horses *Equus caballus*, rabbits *Oryctolagus cuniculus*, goats *Capra hircus* and chital deer *Axis axis* can all be found in certain parts of the arid and semi-arid lake region but their effect on lake ecology is mainly indirect through increased erosion in catchments.

For further information on weed and pest animal management, see the Department of Employment, Economic Development and Innovation (DEEDI) website <www.deedi.qld.gov.au>.

Exotic fish are relatively few in number and diversity compared to other river systems. Exotic fish species are found mainly in arid and semi-arid waterholes, persistent terminal lakes and/or artesian bore overflows, but they can spread into arid and semi-arid lakes during and after floods where they can compete with indigenous fishes. Gambusia (plague minnow or mosquitofish) *Gambusia holbrooki* is a declared species that is reported to cause declines in indigenous fish populations in non-riverine wetlands. Noxious fish are listed in the Queensland *Fisheries Regulation 1995*. Substantial penalties can be imposed on persons who release such fish into the wild or who have noxious fish in their possession without a permit.

Local residents and visitors to these regions should also not use live bait, to minimise impacts on the health and integrity of wild fish populations. An example of an escapee is the redclaw crayfish *Cherax quadricarinatu*, which is now present in the Georgina and Cooper river systems. Endemic to Gulf Country rivers, large populations have established in the Channel Country, and have the potential to out-compete the endemic blue crayfish *Cherax destructor*. Redclaw must not be returned to the water or used as fishing bait (dead or alive) and may not be introduced to or relocated within the Lake Eyre drainage system. The only exception is a registered aquaculture farm, which must demonstrate appropriate security measures prescribed in the Queensland *Fisheries Act 1994*.

LIVING WITH A LAKE

Having a lake as part of a property has production benefits, but there are less tangible benefits too. A couple who have a Desert Uplands property with frontage to a large saline lake enjoy taking friends to view the peaceful scene. At times there are hundreds of brolgas performing their mating dances, and pelicans, black swans, seagulls, avocets, egrets and ducks come there to breed. When interviewed the couple were emphatic that 'we really appreciate the lake for what it is and our appreciation is not only commercially driven'.

Although the lake fringes are highly productive, being good fattening country when spring or early summer rain falls, they need to be cared for. The owners realised that constant grazing was taking a toll on forbs and grasses that grow on the lake fringes, creating a buffel grass *Cenchrus ciliaris* monoculture.

A change in stock grazing management was introduced to avoid this. It was also found that fencing to control grazing on old man saltbush allowed the resource to become more sustainable in the long term.

Areas of lignum *Muehlenbeckia florulenta* on the property harbour feral pigs, sometimes in large numbers. Hunting and baiting reduce numbers to some degree, but because of the large area and number of neighbours involved, it is not easy to coordinate control efforts. The landholders have found that the extreme drought years have the biggest reducing effect on pig numbers.

The introduced thorny shrub parkinsonia *Parkinsonia aculeata* germinates freely on the moist edges of the lake. A determined effort over a six-year period has brought the infestation under control, but the landholders continue to undertake annual patrols to control new seedlings.

BEEF PRODUCTION AND NATURE CONSERVATION

Two adjoining leases under one ownership have extensive saline lakes and chenopod herbfields associated with the Mulligan River system. The area has diverse flora and fauna including a number of endangered and of concern regional ecosystems.

The company owning the properties entered into a nature refuge agreement with Queensland's (then) Environmental Protection Agency (now DERM) over two paddocks, totalling 200 000 ha. The agreement enables the continued use of the land for production, at the same time maintaining the ecological values of the lakes, riparian areas and floodplains.

Under the terms of the agreement the owners continue to use the area for sustainable grazing of beef cattle as in the past, while undertaking not to carry out landscape modifications such as establishing introduced pastures or undertaking earthworks that interfere with the natural movement of surface water.

Grazing pressure is managed to ensure that susceptible species are not removed from the plant populations. In good seasons the area is used for 'backgrounding'—using the high production values of the chenopod herblands to grow young cattle to a specific weight, and then trucking them away to feedlots or targeted markets. In some years the property may receive no rain whatsoever. During these periods the land is destocked to protect the valuable pasture resource.

A large dry playa at Mulligan River Nature Refuge.
Photo: Sue Gardiner, DERM

The terms of the agreement ensure that any future owners of these areas abide by the conditions entered into by the current owners.

Various covenants and agreements (both binding and non-binding on title) are now available to landholders in Queensland to assist in the protection of wildlife and their habitat alongside production enterprises (for example, grazing, farming, horticulture and forestry). Where the biodiversity values on a property are particularly significant it may be appropriate to negotiate a nature refuge agreement. For further information on nature refuges, see <www.derm.qld.gov.au/wildlife-ecosystems>

THE AUSTRALIAN BUSH HERITAGE FUND IN THE CHANNEL COUNTRY

Not all arid and semi-arid properties are used predominantly for producing beef cattle. The Australian Bush Heritage Fund, a philanthropic organisation with a business charter to invest in the protection of biodiversity values, has purchased properties with extensive inland lakes. The properties produce minimal income but represent an investment by corporate and private shareholders in protecting specific natural landscapes.

One such property is Ethabuka, on the Queensland–Northern Territory border, consisting of 214 000 ha of vegetated desert dunefields, desert river floodplains, waterholes, lakes, swamps and artesian springs. The wetlands provide good habitat for waterbirds, including migratory species from time to time.

The property is used as a base for ecological research by universities, state and Australian government agencies, and individuals. It is also the site for an emerging type of ecotourism where people of all ages and skills travel to the property at their own expense, usually on holiday leave or in retirement, to engage in various activities such as flora and fauna surveys, fencing, weed and feral animal control, and property maintenance.

Bush Heritage and DERM staff discuss monitoring at Ethabuka. Photo: Sue Gardiner, DERM

Buffer zones

A buffer around a wetland can help maintain the environmental values of the wetland and protect it from current and future threats from adjacent land uses.

Designing an effective wetland buffer relies upon many factors, including the wetland's characteristics, environmental values, location, surrounding land uses, and the current and future impacts on the wetland.

Queensland already has legislative mechanisms that specify buffer distances. The Wetland*Info* website <www.derm.qld.gov.au/wetlandinfo> contains the latest information on legislation and buffer guidelines.

Glossary

Alluvial Soil that contains clay, silt, sand or gravel deposited by running water, for example by streams.

Anostracan Brine shrimp or fairy shrimp.

Aquatic Living or growing in water.

Arid zone A dry and hot area, with little rainfall (less than 300mm per annum). In some arid landscapes the vegetation cover is sparse or absent.

Bioregion (biogeographic region) An area of the continent defined by a combination of particular geology, landforms, climate and vegetation. For the definition of regional ecosystems, the bioregions of Sattler and Williams (1999) are adopted.

Bonn Convention The Convention on the Conservation of Migratory Species of Wild Animals, to which Australia is a signatory, and a Range State for many migratory species.

Bower shed An outback shade shelter constructed of natural timber and thatch.

Brackish Water with a salt content between that of freshwater (0-5 parts per thousand) and normal marine water (35 parts per thousand).

Braided Branching and rejoining repeatedly to form an intricate pattern or network of small interlacing stream channels.

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 is a treaty that aims to protect and conserve the birds and their habitat of those species that migrate between China and Australia.

Catchment The area of land drained by a creek or river system.

Cladoceran Water flea.

Copepod A member of a large group of species of tiny shrimp-like crustaceans.

Crustacean Animal with jointed legs and segmented body, that has a hardened outer shell, for example, crabs and shrimps.

Desiccation To lose water and dry up.

Drainage division A group of related drainage catchments.

Endemic A species that is native to an area or region.

Environmental value Under the Queensland *Environmental Protection Act 1994*, an environmental value is defined as (a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or (b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

Evaporation rate The volume of water evaporated per unit area in unit time.

Forbs Soft-stemmed, broad-leaved, low-growing annual or perennial herbs.

Hydrological The pattern and volume of river or stream flow.

Halophytic Plants that are tolerant of saline conditions.

Hypersaline Having a salinity greater than seawater (above 35 parts per thousand).

Hyposaline Salty water with a salinity lower than that of natural seawater (less than 35 parts per thousand).

Intermittent Ceases to flow in dry periods.

Isopod A simple crustacean having several pairs of legs.

IUCN Red List A list of globally threatened species assessed and maintained by the World Conservation Union (IUCN). The List provides taxonomic, conservation status and distribution information and highlights those species or groups of species that are facing a higher risk of global extinction.

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 is a treaty that aims to protect and conserve the birds and their habitat of those species that migrate between Japan and Australia.

Lacustrine Pertaining to lakes – includes wetlands and deepwater habitats that might be tidal or non-tidal with ocean salinity less than 1 part per thousand.

Macroinvertebrate Creatures without a backbone that can be seen without a microscope.

Macrophyte An aquatic plant that can be seen without the aid of a microscope.

Migratory (Bonn Convention definition) "migratory species" means the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries.

Mollusc Soft-bodied organisms that usually have a hard shell that may be external and obvious, for example snails (gastropods) and mussels (bivalves), or internal and small, for example squids (cephalopods).

Monsoon A seasonal wind that brings rain.

Ostracod Tiny marine and freshwater crustaceans with a shrimp-like body enclosed in a bivalve shell.

Phyllopod Crustaceans having swimming and respiratory appendages that resemble leaves.

Phytoplankton Tiny single-celled plants that form the base of a wetland's food pyramid because they transfer the sun's energy into plant matter and provide nourishment to the next level of organisms.

Playa A dried-up, flat-floored area consisting of thin, evenly layered sheets of fine clay, silt, or sand, and representing the bottom of a shallow, undrained desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

Pugging Soil damage (compaction) caused by grazing animals when their weight cannot be supported by the soil surface, such as deep footprints of cattle in muddy areas.

Ramsar Convention The Convention on Wetlands (Ramsar, Iran, 1971) is an international treaty that aims to halt the worldwide loss of wetlands and to conserve those that remain through wise use and management.

Regional ecosystem The vegetation community that is consistently associated with a particular combination of geology, landform and soil (see Sattler and Williams 1999).

Runoff Precipitation that drains or flows off the surface of the land, as opposed to that which is absorbed by the soil.

Samphire A fleshy green plant that grows on saline marshes.

Sp./Spp. Sp. is an abbreviation for "species" and is often used when the genus is known, but the species is not. For example, *Eucalyptus* sp. means an undetermined species of Eucalyptus. Spp. is an abbreviation for more than one species without naming them individually.

Topography The shapes, patterns and physical configuration of the surface of the land.

Thermal A thermal column (or thermal) is a column of rising warm air created by the uneven heating of the earth's surface from solar radiation.

Turbidity A measure of the amount of material suspended in water.

Vascular A higher plant with tissues which conduct water, mineral salts and synthesised food, and provide mechanical support.

Vertebrate An animal with a backbone; includes mammals, birds, reptiles, amphibians, and fishes.

Zooplankton Floating or weakly mobile microscopic or barely visible aquatic animals that eat algae.

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Appendix 1: Threatened and migratory fauna associated with Queensland's arid and semi-arid lakes.

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*	IUCN Red List of threatened species status**
Birds	Australian painted snipe	*Rostratula australis*	vulnerable	vulnerable	—
	grey grasswren	*Amytornis barbatus barbatus (Bulloo)*	rare	vulnerable	—
	yellow chat (gulf)	*Epthianura crocea crocea*	vulnerable	—	—
	squatter pigeon (southern subspecies)	*Geophaps scripta scripta*	vulnerable	vulnerable	—
	oriental plover	*Charadrius veredus*	—	listed migratory species#	—
	red-necked stint	*Calidris ruficollis*	—	listed migratory species#	—
	sharp-tailed sandpiper	*Calidris acuminata*	—	listed migratory species#	—
	curlew sandpiper	*Calidris ferruginea*	—	listed migratory species#	—
	marsh sandpiper	*Tringa stagnatilis*	—	listed migratory species#	—
	common greenshank	*Tringa nebularia*	—	listed migratory species#	—
	wood sandpiper	*Tringa glareola*	—	listed migratory species#	—
	black-tailed godwit	*Limosa limosa*	—	listed migratory species#	—
	white-winged black tern	*Chlidonias leucoptera*	—	listed migratory species#	—

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*	IUCN Red List of threatened species status**
Mammals	dusky hopping-mouse	*Notomys fuscus*	endangered	vulnerable	—

* Under the Queensland *Nature Conservation Act 1992* threatened wildlife are those species listed as presumed extinct, endangered or vulnerable. Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* threatened wildlife includes species listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.

\# Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* listed migratory species include those species listed in appendices to the Bonn Convention, and in CAMBA and JAMBA.

** The IUCN Red List of threatened species is an internationally recognised inventory for the conservation status of plant and animal species worldwide.

Appendix 2: Threatened flora associated with Queensland's arid and semi-arid lakes.

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*
Chenopod	Lake Buchanan blue bush	*Lawrencia buchananensis*	vulnerable	vulnerable

* Under the Queensland *Nature Conservation Act 1992* threatened wildlife are those species listed as presumed extinct, endangered or vulnerable. Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* threatened wildlife includes species listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.

Appendix 3: Arid and semi-arid lakes in Queensland included in *A Directory of Important Wetlands in Australia* (2005) and/or Ramsar listings.

Bioregion	Directory reference	Directory wetlands	Ramsar wetlands
Channel Country	QLD024	Bulloo Lake	—
	QLD031	Lake Bullawarra	—
	QLD032	Lake Constance	—
	QLD033	Lake Cuddapan	—
	QLD034	Lake Mipia Area	—
	QLD035	Lake Phillipi	—
	QLD036	Lake Torquinie area	—
	QLD037	Lake Yamma Yamma	—
	QLD038	Moonda Lake — Shallow Lake Aggregation	—
	QLD039	Mulligan River — Wheeler Creek Junction	—
	QLD040	Muncoonie Lakes area	—
Desert Uplands	QLD082	Lake Buchanan	—
	QLD083	Lake Galilee	—
Mulga Lands	QLD123	Lake Numalla Aggregation	Currawinya Lakes
	QLD124	Lake Wyara	Currawinya Lakes
	QLD125	Lakes Bindegolly and Toomaroo	—
	QLD166	Wyandra — Cunnamulla Claypans Aggregation	—
	QLD168	Lake Dartmouth Area	—
	QLD173	Myola — Mulga Downs Salt Lakes and Claypans	—
	QLD174	Murrawondah Lakes	—
	QLD175	Lake Wambah — Kungie Lake Group	—

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