Australian Government

Queensland Government

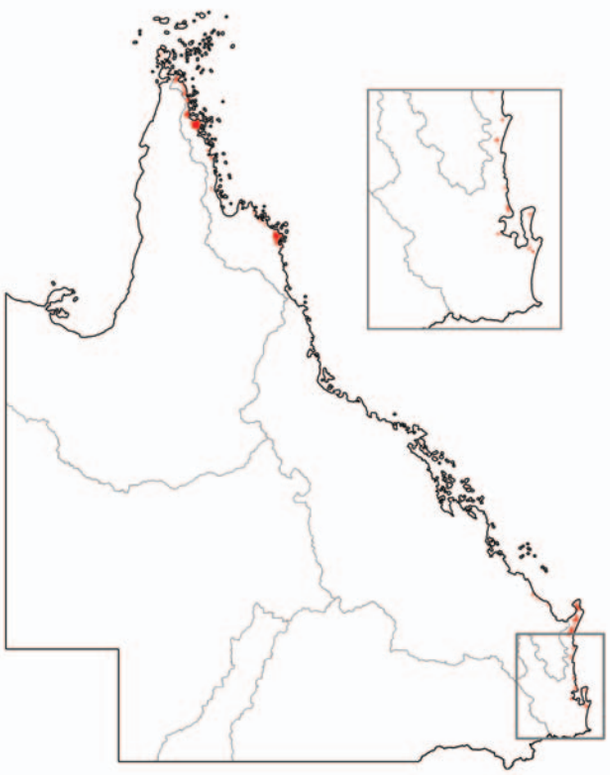
WETLAND MANAGEMENT PROFILE

COASTAL NON-FLOODPLAIN SAND LAKES

Coastal non-floodplain sand lakes occur within coastal dunefields along the east coast of Queensland, from the tip of Cape York Peninsula to New South Wales. These freshwater habitats are closed water bodies that depend on rainwater and/or groundwater for their existence. Waters of dune lakes are generally characterised by being acidic, of low salinity and have low levels of solids and nutrients. The coastal non-floodplain sand lakes are generally unproductive biologically—supporting low levels of aquatic flora and fauna, and simple food chains. Threats to these wetlands can include tourism and recreation; urban development; sand and mineral mining; forestry and land clearing; pollution, groundwater extraction; fire; weeds; grazing and feral animals.

This profile covers the habitat types of wetlands termed coastal and sub-coastal non-floodplain sand lake–perched and coastal and sub-coastal non-floodplain sand lake –window (see <www.derm.qld.gov.au/wetlandsinfo> for more information). (In this management profile, they will be referred to as coastal dune 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>.*



Map showing the distribution of coastal non-floodplain sand lakes in Queensland; grey lines indicate drainage divisions. Map: From Queensland Wetlands Mapping v2.0 (September 2009)

Description

Coastal **dune** lakes are non-tidal, freshwater wetlands that occur in **siliceous** sands along coastal dune areas of mainland Queensland and the sand mass islands in south-east Queensland (that is, Fraser Island, Stradbroke Island and Moreton Island). The origin, evolution and processes involved in the formation of coastal **dune lakes** are diverse—lakes may be formed in sand hollows

Basin Lake — one of the many dune lakes on Fraser Island. Photo: David Cameron

created by wind (known as deflation hollows); when dunes advance and form a barrier across hollows and valleys; or between parallel dunes (that is, in dune swales). These lakes depend on local **catchment** run-off (rainwater) and/or groundwater and are not considered to be part of a floodplain. They are generally permanent in nature but may be semi-permanent or temporary depending on their location and climatic conditions. The water level of coastal dune lakes may change quite markedly between seasons.

COASTAL dune lakes depend on rainwater and/or groundwater and are generally permanent in nature but may be semi-permanent or temporary depending on their location and climatic conditions.

Six main variations of dune lakes have been described for the eastern coast of Australia, classified with respect to their origins, water chemistry and **geomorphology** (Timms, 1982; 1986). However, not all dune lakes fit neatly into this classification system.

- Perched lakes — occur well above sea level and are perched above the water table by an impermeable organic layer.
- Lowland lakes on leached dunes — occur in dune swales, near the sea and close to sea level and are typically associated with swamps.
- Water table window lakes — occur between dunes and intercept the regional groundwater table. They effectively form a window to the **aquifer** below.
- Dune contact lakes—these occur between a sand dune and **bedrock**.
- Freshwater lakes with marine contact—these are distinguished from lowland lakes and dune contact lakes by a current or past connection with the sea.
- Ponds in frontal dunes—these occur in wind created hollows in frontal dunes and are often small, shallow and seasonal.

Although there is a great deal of variability between lake types, the water of dune lakes is generally characterised by being acidic (that is a pH of less than 6), of low salinity, humic, and having extremely low levels of dissolved solids, suspended solids and nutrients. These lakes can be crystal clear, clear and tea-coloured, or even opaque because of the presence of dissolved organic matter. Water that is tea-coloured or brown is also known as 'black water' and this is more typically found in perched lakes, whereas 'white

WHAT IS A PERCHED LAKE?

Perched lakes are **hydrologically** complex systems that can fill rapidly in response to local rainfall and associated infiltration through the sand mass. They are formed in depressions bounded by a layer of sand that has become cemented together with decomposed organic material (such as leaves, bark and dead plants). This layer is known as 'coffee rock'. It is semi-permeable to water and prevents rainwater from percolating through to the regional aquifer, thus these lakes create their own local groundwater systems where free water can accumulate in the soil profile. The topography, stratigraphy (layering), permeability and other properties of the local semi-permeable layer can be complex and heterogeneous, making these systems highly diverse, complex and difficult to predict. They are generally more acidic (they have a lower **pH**) than window lakes because they tend to contain more organic matter. The water level, pH and size of perched lakes can vary from year to year or even dry out completely during times of drought. Many perched dune lakes are tea-coloured because of their high organic content.

Sunset over Brown Lake on Stradbroke Island—a perched lake. Photo: Nicholas Saunders

water' that is clear and colourless arises from regional groundwater aquifers—this is more commonly associated with window lakes. Factors that contribute to the physical variation between lakes include lake age and size, how it was formed, proximity to the sea, surrounding vegetation, and the extent to which leaf litter accumulates and decays within it.

Coastal dune lakes are usually well oxygenated, naturally **oligotrophic** (because of low nutrient levels in the surrounding infertile sands) and unproductive biologically in that they usually support low levels of **aquatic** flora (including algae) and fauna, and support relatively simple aquatic food chains. The term 'dystrophic' is often used to describe tea-coloured perched lakes, and to describe bodies of water that contain stained, acid water with low biological productivity. Oligotrophic lakes are unusual both in Australia and the world in general, even though they were naturally common in the past. Over time, many lakes have become **eutrophic** due to the natural lake ageing process and also as a result of human activity.

This profile focuses on the coastal dune wetlands that are considered to be **lacustrine** or 'lake-like' in form. However, coastal dune lakes do not occur in isolation. They may be fringed by dense stands of **sedges** (particularly *Lepironia articulata*), wet heath vegetation, or occur alongside dunal swamps that are dominated by species such as *Melaleuca quinquenervia*. Further information on these surrounding wetland types and how they should be managed can be found in the wetland management profiles (see <www.derm.qld.gov.au/wetlandinfo>).

Coastal dune lakes can be tea-coloured due to the presence of dissolved organic matter. Photo: DERM

COASTAL dune lakes generally occur in high rainfall areas, and are oriented with their long axis aligned in a south-east to north-west direction—in line with prevailing winds.

Distribution

The coastal sand dune areas of eastern Queensland, from the tip of Cape York to the New South Wales border, contain hundreds of freshwater lakes. Most of these occur in high rainfall areas and are oriented with their long axis aligned in a south-east to north-west direction, in line with prevailing winds.

Perhaps the most well known coastal dune lakes are those that occur on Fraser Island in south-east Queenland. Fraser Island contains over 40 perched dune lakes (for example lakes Birrabeen, Allom, McKenzie, Bowarrady and Benaroon)—half of the world's perched dune lakes occur here. Lake Boomanjin on Fraser Island is recognised as the world's largest perched lake. In the south-east Queensland **bioregion** (bioregion 12) coastal dune lakes are also found on Moreton Island (for example Blue Lagoon and Lake Jabiru), Stradbroke Island (such as Blue Lake, Brown Lake and Tortoise Lagoon), and within the Cooloola sand mass (for example Poona, Freshwater and Deepwater Lakes).

Further north, coastal dune lakes and swamp wetlands are found in the Dismal Swamp section of the Shoalwater Bay dunefield area/Shoalwater Bay Military Training Area (near Byfield) of the Central Queensland Coast bioregion (bioregion 8). This area is recognised for its diverse landscape and vegetation types and relatively undisturbed wilderness areas.

The tropical dunefields on Cape York Peninsula bioregion (bioregion 3) also contain numerous dune lakes and wetland habitats. These are similar both biologically and chemically to the dune lakes of south-east Queensland. However, unlike south-east Queensland dune lakes, which are situated on deep sand dunes, those in the Cape York Peninsula bioregion are associated with ancient dunes that are thinly covered with sand and have basement rocks (**laterite** and **Mesozoic** sandstones) close to the surface.

Cape York Peninsula dune lakes occur in four main areas (located from north to south):

- between Somerset and Ussher Point, around Orford Bay (for example the perched lakes, Lake Wicheura and Lake Bronto)
- adjacent to Shelburne Bay, around Olive River
- around Cape Grenville
- in the Cape Flattery — Cape Bedford dunefields, north of Cooktown.

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

Sach Waterhole is an example of a coastal dune lake on Cape York Peninsula. Photo: John Neldner

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 coastal dune lakes of Queensland are widely recognised and valued at the state, national and international level. Many of the coastal dune lakes are found in three of the five Queensland sites recognised as Wetlands of International Importance under the Ramsar Convention (Ramsar wetlands)—Shoalwater and Corio Bays Area, Great Sandy Strait and Moreton Bay. In addition Fraser Island, which is on the World Heritage List, maintained by the World Heritage Convention, is recognised as being the largest sand mass island in the world and contains over 40 perched lakes and numerous other lakes. The Shoalwater Bay Military Training Area (Byfield) is a Commonwealth heritage place under the Commonwealth Heritage List.

Ramsar wetlands, World Heritage properties, Commonwealth heritage places, threatened species, and migratory species are listed as matters of national

Lake Birrabeen is a coastal dune lake on Fraser Island—a World Heritage Area, renowned for its many dune lakes. Photo: DERM

environmental significance (NES) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and as such, are afforded protection under the Act. The EPBC Act recognises all species listed under the Japan-Australia and China-Australia **Migratory** Bird Agreements (**JAMBA/CA MBA** respectively) and/or the **Bonn Convention** (see Species of conservation significance and Appendix 2). Any action that will, or is likely to, have a significant impact on a NES matter will be subject to an environmental assessment and approval regime under the Act.

There are at least eight fauna species associated with coastal dune lakes in Queensland that are listed as threatened under the Queensland *Nature Conservation Act 1992* (NC Act) and/or the EPBC Act, and/or on the IUCN Red List (see Appendix 2). Recovery plans, which set out research and management actions, to support the recovery of some of the threatened species listed in Appendix 1 may be available or being prepared.

Management plans or similar documents are in place for each of the Ramsar wetlands, although in some instances they may not apply to the entire Ramsar site.

SOME coastal dune lake areas are of particular significance to Indigenous people as story places, landscape features and as sites for cultural activities.

Cultural heritage

All wetland ecosystems are of material and cultural importance to Indigenous people and many will have profound cultural significance and values. More than 100 Indigenous cultural heritage sites have been recorded within coastal dune lakes in Queensland—concentrated on Stradbroke, Moreton and Fraser Islands and coastal dune areas at Cooloola in southeast Queensland and Cape Flattery, in North Queensland. However, most coastal dune lakes have not yet been systematically surveyed or assessed for cultural heritage significance.

There is a high likelihood of cultural heritage sites occurring within and adjacent to coastal dune lakes. Evidence of traditional occupation and use recorded within these areas include burials, ceremonial earth arrangements, pathways, scarred trees, hearths, shell **middens**, quarries, stone scatters, fish traps, food and fibre resources and historic contact sites. Some coastal dune lake areas have particular significance as story places, landscape features and as sites for cultural activities.

The most commonly recorded sites associated with coastal dune lakes are shell middens and stone artefact scatters associated with open camp occupation sites. Archaeological evidence of cultural activity, such as shell middens and stone artifact scatters, are often concentrated along ecotones around the margins of coastal dune lakes, and in association with neighbouring regional ecosystems. The clustering of sites along **ecotone**s reflects the concentration of traditional occupation and use within areas of greatest **biodiversity**.

Some coastal dune lakes also have historic cultural heritage significance of both Indigenous and non-Indigenous origin, although most have not been surveyed or assessed for historic heritage values. DERM has records of six historic sites associated with coastal dune lakes, all located within the Cooloola and Fraser Island areas. The historic heritage values of coastal dune lakes demonstrate evidence of their past occupation and use associated with the pastoral, timber and forestry industries. Sites include timber camps, a homestead, loading jetty, sawmill and settlement and an historic landscape area. For further information refer to the *Coastal fringe wetlands—cultural heritage profile* <www.derm.qld.gov.au>.

Archaeological evidence of occupation (such as shell middens) may be found in dunal areas—often concentrated along the margins of lakes.
Photo: DERM

Ecology and ecological values

Coastal dune lakes and their surrounding wetlands are a unique and aesthetically valued component of the Queensland landscape and provide **ecosystem services** that include:

- **regulating services** — including sediment and nutrient retention
- **cultural services** — such as Indigenous cultural values and sites, tourism and recreation
- **supporting services** — such as being important as habitat for fauna at a particular stage of their life cycle (for example, breeding)
- **provisioning services** — dune lakes and their surrounding dunes are a source of groundwater and resources (for example sand and minerals).

DUNE lakes can support specialised animal species that survive in low nutrient, acidic water and/or species that are widespread and tolerant of a wide range of conditions.

Coastal dune lakes within Queensland are diverse in size, form, depth and degree of permanency (that is, seasonally drying to permanent). Given that they occur from the tip of Cape York Peninsula to New South Wales, and beyond, a diverse range of flora and fauna species are supported by these habitats. In their natural state coastal dune lakes can support both specialised animal species that survive in the low nutrient, acidic water characteristic of dune lakes, and/or animals that are widespread and tolerant of a wide range of conditions. Differences in species composition between lakes are due to their geographical isolation from each other and may occur opportunistically (for example the chance arrival of a particular fish species).

In general, coastal dune lakes are considered to be unproductive biologically in that they are naturally oligotrophic, have low concentrations of essential plant nutrients, are high in dissolved oxygen and support relatively low amounts of aquatic plants (including algae) and animals. Oligotrophic lakes are often surrounded and if shallow, invaded by dense strands of sedges and rushes such as *Lepironia articulata*, *Eleocharis* **spp.**, *Baumea* spp., *Schoenus* spp., *Juncus* spp. and *Gahnia* spp.. The deeper areas of lakes are generally vegetation free. Throughout Queensland *L. articulata* is commonly associated with

COASTAL DUNES AND SAND MASSES CONTAIN LARGE QUANTITIES OF WATER

Coastal dunes and sand masses are an important source of groundwater and most coastal dune lakes (particularly window lakes) are dependent on groundwater for their formation. The source of this groundwater is the dunes and sand masses themselves, which hold vast quantities of freshwater (from rain) in groundwater aquifers.

For example, Fraser Island which has sand dunes up to 220 m above sea level contains a massive groundwater aquifer that stores an estimated 10 to 20 million **megalitres** (ML) of water, of which almost 6 million ML is above sea level. Water can remain in a sand mass for many years, sometimes as long as 70 to 100 years. Where the ground surface dips below the watertable, the exposed groundwater forms a window lake. Aquifers play an important role in preventing saltwater from the ocean seeping into groundwater and the land itself. It does this because gravity from the groundwater mound exerts an outward pressure on seawater and freshwater naturally floats on top of saltwater.

Sand dunes hold vast quantities of water in groundwater aquifers. This groundwater plays an important role in maintaining the ecological integrity of dunes. Photo: DERM

coastal dune lakes. However, species such as *Baumea teretifolia*, *Eleocharis sphacelata*, *Leptocarpus tenax*, which are common in south-east Queensland, are more commonly replaced with the species *B. rubiginosa*, *E. brassi* and *Dapsilanthus ramosus* in Cape York coastal dune lake areas (Timms, 1986).

Coastal dune lakes can occur alongside a diverse range of wetland habitats and vegetation types including beaches, mangroves, salt flats, swamps, sedgelands, heathland and rainforest depending on their exact location. Where lake levels fluctuate, vegetation surrounding the lake is highly water tolerant and may include species such as sundews (genus *Drosera*) and bladderworts (genus *Utricularia*).

Littoral vegetation, which is vegetation that occurs around the lake's edge, provides habitat for a variety of aquatic **invertebrates** and both food and shelter for higher order organisms such as fish, frogs and turtles. Damage to this vegetation is likely to be detrimental to the feeding and breeding activities of the threatened fish species, the honey blue eye *Pseudomugil mellis* (Arthington, 1994). This species extends only as far north as the Shoalwater Bay region. Food sources for coastal dune lake-dwelling organisms may be either allochthonous (that is externally derived) or autochthonous (internally derived). Three simple food webs have been described for coastal dune lakes (Arthington, 1994). These include a:

1) grazing food chain — this involves **phytoplankton** being grazed by zooplankton, and **zooplankton** being grazed by fish and/or turtles
2) **detritus** food chain—whereby dissolved humic acids (from leaves and other organic matter) provide nutrients for bacteria, which in turn feed zooplankton and fish
3) terrestrial organic food chain—in this case allochthonous food sources in the form of pollen or insects provide food for fish directly.

Studies have shown that human activities on Fraser Island can influence the relative importance of allochthonous and autochthonous carbon sources for dune lake consumer organisms (that is, invertebrates and fish) (Hadwen & Bunn 2004, 2005).

Some coastal dune lakes do not contain fish, and where this is the case, food chains may be even simpler with aquatic insects (of the Orders **Hemiptera**, **Odonata**, **Coleoptera**, **Chironomidae**) being the top of the food chain. Coastal dune lakes support large populations of invertebrates, most notably the copepod *Calamoceia tasmanica*, which is a species of zooplankton characteristically associated with these ecosystems.

Coastal dune lakes are often surrounded and invaded by grass-like vegetation. Photos: DERM

ALTHOUGH the lakes are not overly productive in terms of vegetation biomass they are an important seasonal refuge for birds as they move from dry inland areas or during times of drought.

The coastal dune lakes and surrounding swamps and sedgeland provide important habitat for a variety of species including rare and threatened ones (see Species associated with coastal dune lakes). Although the lakes are not overly productive in terms of vegetation biomass, they provide an important seasonal refuge for birds, including migratory species, as they move from dry inland areas or during times of drought.

Coastal dunes lakes are highly susceptible to pollution and nutrient enrichment. Nutrient enrichment may result from urban runoff, sewage, agricultural activities, clearing and/or burning and in response to recreational use (see Managing coastal dune lakes).

The northern sedgefrog *Litoria bicolor* is found in coastal dune lake areas of northern Queensland. Photo: DERM

DESCRIBING THE NUTRIENT STATUS OF LAKES

Lakes are often classified according to their nutrient or trophic status. Oligotrophic lakes, like healthy coastal dune lakes, are characterised by having low levels of nutrients (such as phosphorus and nitrogen) and plant growth and high oxygen concentrations, while eutrophic lakes have high levels of nutrients and plant growth and low oxygen concentrations. Between these extremes are mesotrophic lakes.

Factors that contribute to the nutrient status of a lake include:

- climate—this includes temperature, amount of sunlight, rainfall and hydrology of the lake
- lake morphometry—this is based on the depth, volume and surface area of the lake, and the lake surface area to catchment size ratio
- nutrient supply—dependent on soil type, geology of the landscape, vegetation, and land use and management.

The process by which a lake moves from an oligotrophic to eutrophic condition is known as **eutrophication**. Lakes that occur in catchments that have rich organic soils or agricultural areas enriched with fertilisers are likely to be more eutrophic than those that occur on infertile soils or sand dunes.

The water of coastal dune lakes is often clear and low in nutrients and algae. Photo: DERM

Eutrophic lakes are also susceptible to algal blooms—a condition where the number of **algal cells** has increased to such an extent that water quality is reduced. Algal blooms can discolour water, form scums on the lake surface and produce unpleasant odours. While they are not always toxic, algal blooms can also harm aquatic life (such as fish and frogs) and be a human health issue.

Since harmful algal blooms can have detrimental economic, environmental and social impacts the Queensland Government has developed a multiagency response plan to aid State and local governments and water storage operators manage them (find more information on the DERM website <www.derm.qld.gov.au>).

Species associated with coastal dune lakes

Preservation of coastal dune lakes is vital to protect species that are dependent on these wetlands for nesting, breeding and/or feeding habitat, particularly species threatened with extinction. A number of species associated with Queensland's coastal dune lakes are listed as threatened under State (NC Act) and Commonwealth (EPBC Act) legislation and/or recognised under international conventions or agreements such as the IUCN Red List. Some of the species associated with coastal dune lakes are listed below.

Note: Fauna and flora species more commonly or exclusively occurring in northern or southern Queensland are denoted by an (N), or (S) respectively, after the species name.

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

Fauna

Birds

- ground parrot *Pezoporus wallicus*

Fish

- Oxleyan pygmy perch *Nannoperca oxleyana* (S)
- honey blue eye *Pseudomugil mellis* (S,)
- ornate rainbowfish *Rhadinocentrus ornatus* (S)
- poreless gudgeon *Oxyeleotris nullipora* (N)
- onegill eel *Ophisternon bengalense* (N)
- northern purplespotted gudgeon *Mogurnda mogurnda* (N)

Amphibians

- wallum froglet *Crinia tinnula* (S)
- Cooloola sedgefrog *Litoria cooloolensis* (S)
- wallum rocketfrog *Litoria freycineti* (S)
- wallum sedgefrog *Litoria olongburensis* (S)
- northern sedgefrog *Litoria bicolor* (N)
- white lipped treefrog *Litoria infrafrenata* (N)
- shrill whistlefrog *Austrochaperina gracilipes* (N)
- tawny rocketfrog *Litoria nigrofrenata*. (N)

THE HONEY BLUE EYE

The vulnerable (NC Act) honey blue eye *Pseudomugil mellis* fish is endemic to Queensland, occurring in slow flowing, slightly acidic, tannin-stained coastal dune lakes as well as streams, swamps and heath areas of south-east Queensland, extending north as far as Shoalwater Bay. It is often found within or near emergent or submerged sedge and rush vegetation (for example, *Lepironia articulata*, *Gahnia seiberiana*, *Juncus* spp., *Eleocharis* spp.). At 3 cm long, it is one of the smallest threatened species in Queensland. In addition to its characteristic blue eyes, the honey blue eye is a distinctive amber to orange colour.

Threats to the honey blue eye include residential and industrial development, forestry, mining, aquarium use and agriculture. The introduced mosquito fish *Gambusia holbrooki* also threatens the species where the two co-exist, because its larvae compete with it for food and habitat.

Honey blue eye *Pseudomugil mellis*.
Photo: Gunther Schmida

Habitat protection is vital for ensuring survival of the honey blue eye. It is also important to maintain genetic diversity of the species by protecting individual populations and ensuring that breeding can occur between adjoining populations. Small breeding populations are being maintained in captivity.

Reptiles

- Fraser Island short-neck turtle *Emydura macquarii nigra* (S)
- estuarine crocodile *Crocodylus porosus* (N)

Microcrustaceans

- *Calamoecia tasmanica*
- *Calamoecia ultima* (N)

Insects

- Order Hemiptera
- Order Odonata
- Order Coleoptera
- Order Chironomidae.

ACID FROGS

A group of four amphibians called 'acid frogs' inhabit the temporary or permanent still waters of lakes, creeks and swamps of south-east Queensland and New South Wales. These species undergo tadpole development in soft waters of high acidity (low pH) and low nutrient content—conditions commonly found in coastal dune lakes and their surrounds.

The four acid frog species are the wallum froglet *Crinia tinnula*, Cooloola sedgefrog *Litoria cooloolensis*, wallum rocketfrog *Litoria freycineti* and wallum sedgefrog *Litoria olongburensis*. Recent records indicate all of these species continue to occur throughout their pre-European range. However populations have suffered habitat loss and disturbance because of land clearing.

Acid frogs have specialised breeding requirements and are particularly susceptible to changes in water chemistry. Exotic pine plantations with their associated road construction, and changes to burning practices have led to alterations in hydrology and water chemistry and these have been detrimental to the frogs' breeding success. The clearing of native vegetation to establish exotic pine plantations has now ceased but habitat loss, a result of increased urban development, continues to threaten acid frog habitat. Damage to microhabitats (reed beds and sedges) by too frequent fire, human trampling and recreation activities have also been identified as detrimental.

The wallum rocketfrog *Litoria freycineti*—one of four frog species commonly referred to as 'acid frogs'.
Photo: DERM

Other potential threats have been identified (for example the use of chemicals to control mosquitoes and weeds, grazing and predation by feral pigs) but so far their effects have been poorly studied.

A number of actions to protect the habitat of the acid frogs have been identified. These include: establishing minimum protective buffers around known breeding sites (for example, 100 m; refer to Managing alterations to hydrology/drainage) that exclude a range of routine uses including timber harvesting and chemical use; maintaining natural drainage patterns, water tables and water quality when conducting activities adjacent to or upslope of known breeding sites; and monitoring and managing grazing, feral pigs and pine wildings. Handling frogs should be avoided, to reduce the risk of disease transfer.

ESTUARINE (SALTWATER) CROCODILE

The estuarine crocodile *Crocodylus porosus* is most commonly found in the tidal reaches of rivers and marine habitats from Rockhampton and north to the Queensland–Northern Territory border. However, they are also found in freshwater sections of lakes, lagoons, swamps and waterways up to hundreds of kilometres from the sea, including the freshwater coastal dune lakes of north Queensland. Therefore, despite its name, an estuarine crocodile can be found in locations that might be more commonly associated with the relatively harmless freshwater crocodile *Crocodylus johnstoni*. The estuarine crocodile can be distinguished from the freshwater crocodile by having a broader snout, thick teeth and not having large, prominent scales (known as scutes) directly behind its skull.

Although coastal dune lakes are not an obvious place to find estuarine crocodiles (because they generally support low amounts of aquatic flora and fauna and simple food chains), the species can utilise these freshwater habitats as they make their way around the landscape. Crocodiles play an important part maintaining the overall health and balance of wetland ecosystems. They are at the top of the food chain, preying on a variety of animals including fish, frogs, prawns, crabs, insects and (if large enough) even feral pigs, wallabies and other crocodiles. Estuarine crocodiles are most active at night.

Estuarine crocodile *Crocodylus porosus*. Photo: DERM

All crocodiles in Queensland are protected by legislation. This means that interfering with crocodiles or their eggs and possessing or taking parts of crocodiles is illegal without a licence. The estuarine crocodile is also recognised as being threatened and is listed as 'vulnerable' under the Queensland NC Act. Threats to the species include loss of breeding habitat and illegal shooting. In addition, less than 1 per cent of eggs laid by an estuarine crocodile reach adulthood, and sexual maturity occurs relatively late at around 12 years for females and 15 years for males, meaning that populations are slow to recover. Other threats to the species include the destruction of nests by flood and predation of crocodile eggs by feral pigs, goannas and even other crocodiles.

Estuarine crocodiles are potentially dangerous so unnecessary risks should not be taken in crocodile habitat. Guidelines on how to be 'croc wise in croc country' can be found on the DERM website <www.derm.qld.gov.au>.

Flora

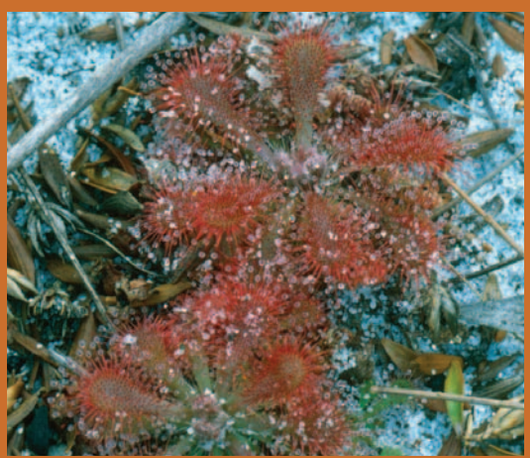
Some of the flora species associated with coastal dune lakes and their surrounding area include:

Herbs

- sundews, for example *Drosera auriculata*, forked sundew *D. binata*, *D. spatulata*–bladderworts, for example moth bladderwort *Utricularia biloba*, floating bladderwort *U. gibba*, asian bladderwort *U. uliginosa*

Sedges/rushes

- *Lepironia articulata*
- *Baumea* spp. (*B. rubiginosa* (N), *B. teretifolia* (N)(S))
- *Juncus* spp.
- *Gahnia* spp. (including *G. sieberiana* (N))
- *Eleocharis* spp. (including *E. brassii* (N), *E. sphacelata* (S))
- *Schoenus* spp. (including *S. scabripes* (S), *S. calostachyus* (N), *S. sparteus* (N))
- *Dapsilanthus elatior* (N)
- *Dapsilanthus ramosus* (N)
- *Leptocarpus* spp. (including *L. tenax* (S))



The sundew *Drosera spatulata*, is found in land adjacent to some coastal dune lakes, and is covered in sticky, glandular hairs which are used to capture small insects. Photo: DERM

Trees/shrubs

– *Asteromyrtus lysicephala* (N)
– *Melaleuca arcana* (N)
– broad-leaved tea-tree *Melaleuca leucadendra* (S)
– swamp paperbark *Melaleuca quinquenervia* (S)
– swamp tea-tree *Melaleuca dealbata* (S)
– *Melaleuca* sp. aff. *viridiflora* (S)
– *Thryptomene oligandra* (N)
– broad-leaved banksia *Banksia robur* (N)
– red bottlebrush *Callistemon polandii* (N)
– tantoon *Leptospermum polygalifolium* (N).

Lepironia articulata

The sedge species, *Lepironia articulata* is commonly found in association with coastal dune lakes. This species, which is sometimes referred to as grey sedge, is a perennial, grass-like plant that forms clumps and dense thickets around the edges of lakes, lagoons and swamps. It can also grow in water to a depth of approximately 1.5 m. *L. articulata* has hollow, blue-grey erect stems that reach a height of 2 m. The inflorescence, which refers to the group of flowers and the stalks and branches that support them, is reddish-brown in colour, cylindrical in shape, points sideways and is found about 5 cm below the stem tip. The submerged parts of *L. articulata* provide habitat for microinvertebrates and macroinvertebrates, fish, frogs and other species. Decaying *L. articulata* and other plant matter also provides a valuable food source for aquatic invertebrates and other fauna.

Clump of *Lepironia articulata*.
Photos: Queensland Herbarium

Close-up of *Lepironia articulata* showing its inflorescence.

Managing coastal dune lakes

The location of coastal dune lakes, along with their naturally restricted distribution and dependence on maintaining an oligotrophic water status, makes them highly susceptible to threats such as tourism and recreation; urban development; sand and mineral mining; forestry and land clearing; military training impacts (only in the Shoalwater Bay area); groundwater extraction; fire; weeds; grazing and feral animals. The impact of each of these threats depends on the lake's location within the landscape and the adjacent land use. For example, urban development and tourism and recreation is a relatively greater threat to the dune lake ecosystems of south-east Queensland than they are to the Cape York Peninsula dune lakes—where inappropriate/unmanaged grazing is a relatively greater threat.

Permits, state and federal legislation and industry guidelines regulate how land managers should manage resources and the coastal dune lake landscape. Conditions of use and permits required for activities are determined by the wetland's tenure (freehold, leasehold, and local, state and Australian Government land), its location and environmental value or uniqueness. Within the category of private owners/stakeholders, Indigenous ownership applies to some coastal dune lakes on Cape York Peninsula.

To maintain the integrity of coastal dune lake wetlands land managers and state and local governments must ensure that businesses and industries (including recreation and tourism) are sustainable and environmentally sound.

A BUFFER zone of intact native (or other) vegetation is an effective way of maintaining the ecological and hydrological functioning of a wetland—it also reduces impacts from adjacent land uses.

Managing alterations to hydrology/drainage

Coastal dune lakes are dependent on rainwater and groundwater for their existence and if the natural flow of this water is altered, so are the characteristics or existence of the lake. Changes to the hydrology of dune lakes can occur naturally through climatic events (that is drought and flooding) or through human activities such as drainage for urban and industrial development; road building; land clearing; sand and mineral mining; and groundwater extraction for mining or domestic use. While many of these activities may have already affected some lakes, or be seen as necessary in the future, further impacts can be minimised by considering the full hydrological and environmental impact prior to undertaking an activity.

An effective way of maintaining the ecological and hydrological functioning of a wetland is the provision of a buffer zone of intact native or other vegetation. Buffer zones can maintain ecological functionality and reduce impacts from adjacent land uses. DERM is currently investigating buffer zones to assist best practice management.

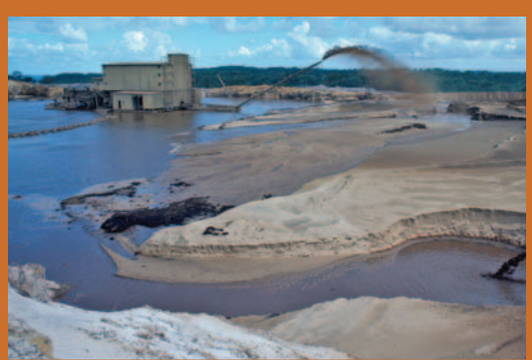
A buffer around a wetland can help maintain the environmental values of the wetland and protect it from current and future threats from adjacent land uses.

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.

Mining is one of the greatest threats to coastal dune lakes. The coastal sand dunes and masses along Queensland's coast are a rich source of sand for building materials, and heavy minerals such as rutile, ilmenite, monazite and zircon. Major deposits occur on Fraser Island, Moreton Island, Stradbroke Island, and in the dune systems of Shoalwater/Byfield, Shelburne Bay and Cape Flattery. Mining can have many adverse environmental impacts such as the loss of native flora and fauna, pollution, excessive withdrawal of water, and the draining or loss of lakes caused by changes in groundwater levels or rupturing the base of the groundwater aquifer. This can lead to the intrusion of saltwater where there was previously freshwater, and cause permanent changes to the ecology of the landscape. In an attempt to minimise some of the impacts of mining, companies can be required to rebuild sand dunes and undertake rehabilitation and monitoring programs that endeavour to restore the natural flora and fauna to the landscape. Public concern over the adverse impacts of mining in some areas of Queensland led to the cessation of mining at some locations (for example Fraser Island and Shelburne Bay). The Queensland *Water Act 2000*, administered by DERM regulates the taking of groundwater for mining and other purposes.

The clearing of vegetation for sand mining results in the loss of flora and fauna habitat and exposes the landscape to erosion.



An artificial freshwater pond created for sand mining operations.

Revegetation of affected areas may be required to minimise the impacts of mining. Photos: DERM

COASTAL dune lakes are closed systems so even minor additions of nutrients can have significant ecological impacts—potentially irreversibly altering water quality and the composition of lake flora and fauna.

Managing water pollution

Coastal dune lakes are characterised by being naturally oligotrophic and because they are closed systems even minor additions of nutrients can have significant ecological impacts, potentially altering the lake and composition of its flora and fauna irreversibly. This process is known as eutrophication, and most of the threats to coastal dune lakes described in this profile, either directly or indirectly cause this to occur.

A wide range of activities (and their associated chemicals and nutrients) can lead to the eutrophication of coastal dune lakes, if not planned and managed correctly, including:

- tourism and recreation
- urban and industrial development
- mining
- military training exercises
- land clearing
- forestry
- grazing
- feral animals
- fire.

Tourism and recreation are extremely popular activities in coastal dune lake areas because the lakes' water can be clear and their surrounds picturesque. Given high visitation rates in some areas, particularly in south-east Queensland, direct nutrient enrichment (known as nutrification) in the form of urine, soaps, detergents, shampoos, sunscreen and other chemicals can lead to an increase in the amount of algae (known as an algal bloom) and cause water quality to decline. In coastal dune lakes blooms of algae are an obvious indication of an unbalanced ecosystem. This is not only a concern for maintaining the ecological integrity of the lake but also a human health issue. Unhygienic camping practices in the lake's proximity can also lead to nutrification. To reduce the impact of human-induced pollution, land managers need to educate visitors about the susceptibility of coastal dune lakes to nutrification, and where necessary, conduct regular water and soil monitoring procedures. If conditions are severe or unsafe it may be necessary to close or restrict a lake's use. Other practices that should be adhered to include:

- not using detergents, soaps, toothpastes, shampoos or other chemicals in lakes or waterways—wherever possible the use of sunscreen should be limited
- not urinating in or near coastal dune lakes
- not burying human faecal waste within 100 m of a lake, or 40 m from the defining bank, whichever is greater
- not littering or burying rubbish near a lake—it should be taken off-site.

Lake McKenzie on Fraser Island is a popular swimming and sunbathing location.
Photo: Wade Hadwen, Griffith University

Increased pollution, **sediment** and nutrient concentrations in coastal dune lakes can also result from land use activities in adjacent areas. For example, chemicals such as oils, pesticides, fertilisers, septic tank seepage and heavy metals can be introduced into lakes through urban, industrial and military training uses, forestry, mining and grazing. Over time, a build up of these chemicals can cause a reduction in the visual amenity of the lake environment, an imbalance in natural nutrient cycles within the lake, the proliferation of algae, death of sensitive flora and fauna (or a change in the composition and relative abundance of species within the lake environment), and cumulative impacts on fauna that feed on dune lake invertebrates and fish.

Increased sediment and nutrient loads in coastal dune lakes can also result from fires in adjacent areas, land clearing, feral animals and grazing (see Managing fire, Managing weeds and Managing grazing and feral animals for more information).

INCREASED pollution, sediment and nutrient concentrations in coastal dune lakes can result from activities on adjacent land—chemicals such as heavy metals, oils, pesticides, fertilisers and septic tank waste can be introduced through urban, agricultural, military or industrial uses.

To preserve the pristine nature of coastal dune lakes, land use and activities within lake catchments should be planned and conducted in a manner that prevents or minimises soil disturbance, erosion and maintains water quantity and quality. Wherever possible, vegetation cover should be retained (see Managing alterations to hydrology/drainage). It is also essential that any activity, such as mining and forestry, occurring at or adjacent to a coastal dune lake comply with the appropriate legislation and industry codes of practice and guidelines (see <www.derm.qld.gov.au>).

Managing fire

Coastal dune lakes (like all lakes) are naturally fire tolerant, provide natural firebreaks and are a refuge for animals during bushfires. However, bushfires and hazard reduction burning in adjacent areas can affect coastal dune lake **biota** (that is plants, animals and micro-organisms) by raising temperatures, altering **microhabitat**s, and also by increasing the level of **siltation** and amount of organic matter (such as leaf litter and ash) that enters the lake. This in turn can alter nutrient cycles, and in particular increase the biological oxygen demand (BOD) of the water body. BOD, which can be directly quantified from a water sample, is a measure of the oxygen used by micro-organisms to decompose the nutrients (in this case fire-induced) entering the lake. As nutrient levels can increase after fire, the number of micro-organisms required to decompose the nutrients also increases. This leads to a decrease in available oxygen and is an indication of lake eutrophication. In addition, raised water temperatures such as that caused by fire, increase the rate of chemical processes (for example processes related to growth, **photosynthesis** and bacterial decomposition) and results in less dissolved oxygen being available for fish and other aquatic organisms. The pollution of coastal dune lake habitat can also result from fire fighting chemicals and alterations in the volume of water in lakes used as reservoirs to fight bushfires.

BUSHFIRES and hazard reduction burning can affect coastal dune lake plants, animals and microorganisms by raising temperatures, altering micro-habitats, and by increasing the level of siltation and amount of organic matter entering the lake.

As the effects of fire on the coastal dune lakes are not obvious it is important that land managers carefully consider and plan for the full spectrum of impacts a prescribed burn or naturally occurring bushfire could cause on both coastal dune lakes and the surrounding vegetation and landscape, including coastal and sub-coastal wet heath swamps and coastal and sub-coastal tree swamps. Researchers studying coastal and sub-coastal wet heath swamps have found that plant productivity and the abundance of birds tends to peak between four and eight years post-fire. As such, fire frequency intervals of between seven and 20 years have been recommended to maintain overall biodiversity in the coastal heaths of south-east Queensland. However it should not be assumed that fire regimes suited to vegetation communities in south-east Queensland are also appropriate for vegetation communities further north. In addition, it is recommended that planned burns in coastal and sub-coastal wet heath swamps should be conducted when the soil is wet, to avoid the risk of destructive peat fires, and an extended period of post-fire monitoring is required to ensure re-ignition does not occur because **peat** layers can smoulder for several weeks before re-igniting wildfires where there is a suitable fuel load.

Fire on land adjacent to coastal dune lakes can have impacts on flora, fauna and water quality. Photos: DERM

Factors that need to be considered when planning a prescribed burn are:

- the vegetation types
- fire frequency (that is, time since the last burn)
- fire intensity
- season
- wind speed
- temperature
- terrain
- soil and air moisture.

For further information about local requirements, restrictions and responsibilities with respect to prescribed burns and fire management land managers should consult with their local council or rural fire brigade <www.ruralfire.qld.gov.au>. Additional information for south-east Queensland can be found on the Southeast Queensland Fire and Biodiversity Consortium website <www.griffith.edu.au/environment-planning-architecture>.

WEEDS can be spread by vehicles, native, domestic and feral animals, and by flowing water and wind.

Managing weeds

Certain locations, particularly those that are used intensively for recreation, grazing or have been cleared of vegetation, may be susceptible to exotic weed invasion. For example, disturbance activities (such as military activities and mining) in the Shoalwater Bay coastal dune lake areas have caused weed infestations of lantana *Lantana camara*, corky passion flower *Passiflora suberosa* and *Emilia sonchifolia*.

Weeds displace native flora by competition and shading and alter vegetation fuel loads, and subsequently change the ecology and threaten the character of coastal dune lake areas. They can be spread as live fragments or seed by vehicles, native, domestic and feral animals, and by flowing water and wind.

Control methods for weeds vary, depending on the characteristics of the plants being targeted, and include manual or mechanical removal, chemical application, biological control (if available) and fire. Integrated weed control programs using more than one of these methods are likely to be the most effective.

The flower and leaf of Lantana *Lantana camara*—a serious environmental weed.
Photo: DERM

Although fire can be a highly effective control method the costs and benefits of its use need to be thoroughly considered before implementation (see Managing fire). Similarly, it is important that land managers are well informed about chemicals used for weed control as they are toxic and may be harmful to non-target species. Penalties can apply if native plants and animals are harmed, particularly around wetland areas. Herbicides that only target the weed species and do not contaminate the area are preferred. All methods require follow-up and ongoing monitoring to ensure that weeds remain under control and that there are not unforseen effects.

Extensive and widespread infestations of groundsel bush *Baccharis halimolia* and lantana *Lantana camara* occur on Fraser and Stradbroke islands. This is the result of previous and current land use (such as logging and mining) and ongoing recreational use. Lantana is one of 20 pest species classified as a Weed of National Significance <see www.weeds.gov.au>, and in Queensland both lantana and groundsel bush are listed as declared plants under the *Land Protection (Pest and Stock Route Management) Act 2002*—groundsel bush (Class 2), lantana (Class 3). By law all landholders must try to keep their land free of Class 2 pests and it is an offence to keep or sell these plants without a permit. Class 3 pests cannot be sold, and landholders can be required to use control measures if their land occurs next to 'environmentally significant areas', such as national parks and reserves but only if the reserve is still free of the weed species.

Further information about pest (plant and animal) strategies in Queensland, declared plants (pests) and guidelines on their management can be found on the DERM website <www.derm.qld.gov.au>.

Groundsel bush *Baccharis halimolia* can form dense thickets and suppress the growth of native vegetation.

Leaves of the groundsel bush are a dull green colour and have a characteristic shape.
Photos: DERM

Effective weed management requires coordinated planning at the national, state, regional, local and property level. Queensland pest management plans that are in place or being developed can be found on the DERM website <www.derm.qld.gov.au>. Under the *Land Protection (Pest and Stock Route Management) Act 2002* local governments must have pest management plans in place and are responsible for ensuring declared weeds and pest animals on all private and public land in their area are adequately controlled.

Although a comprehensive list of weed species is not available for all coastal dune lakes in Queensland, local land protection officers and local government weed and pest officers are a valuable starting point to aid land managers identify which weed species occur in their area, and can provide information about other pest plant and animal issues in Queensland. Greening Australia may also be able to provide advice <www.greeningaustralia.org.au>.

COASTAL dune lakes are fragile ecosystems with simple food webs. It is important that land managers reduce or eliminate the likelihood of pollution and exotic plant and animal invasion.

Managing grazing and feral animals

Cattle grazing and feral animals (such as cats, foxes, rabbits, horses, pigs, goats, cane toads and mosquitofish) can threaten the water quality and ecology of coastal dune lake areas in a variety of ways including:

- competing with native animals for food and habitat
- feeding on native species associated with coastal dune lakes
- carrying and transmitting diseases (such as vibriosis and leptospirosis) that can be passed on to cattle through water
- trampling vegetation and soil
- destabilising and eroding wetland edges
- over-grazing new plant growth, preventing flowering or seed setting
- increasing water **turbidity**
- increasing nutrient levels through defecation and urination, which can foul water, favour weed invasion and potentially harm native species that depend on dune lakes or their surrounding habitat.

Given the fragile and pristine nature of coastal dune lakes and their simple food webs it is important that land managers reduce or eliminate the likelihood of pollution and exotic plant and animal invasion. Where cattle grazing occurs this may be achieved by restricting stock access to lakes at critical times, or permanently through the use of fencing or other methods and providing water troughs at a distance from lakes.

The feral pig *Sus scrofa* is a declared pest species in Queensland.

Feral pig damage at Blue Lagoon on Moreton Island. Photos: DERM

The feral pig *Sus scrofa* is a significant pest species in coastal dune lake areas, as it is for wetland areas across Queensland. The species is declared as a Class 2 pest under the Queensland *Land Protection (Pest and Stock Management) Act 2002* and under this Act land managers are required to control feral pigs on land under their management. In recognition of the severe impact of feral pigs on the Australian landscape, predation, habitat degradation, competition and disease transmission by feral pigs has also been listed as a key threatening process under the EPBC Act (listed August 2001). Under the Act the Australian Government, in consultation with the states and territories, has developed a Threat Abatement Plan which outlines control techniques and stakeholder roles and responsibilities. This plan can be viewed on the Department of the Environment, Water, Heritage and the Arts website <www.environment.gov.au/biodiversity>.

It is desirable for land owners and land managers in Queensland to have a feral pig control program in place, usually involving a combination of shooting, trapping and baiting to reduce pig numbers. Control programs may be most effective when considered as a part of a cooperative approach across a local area. A list of declared animals (pests), pest animal strategies and fact sheets to assist land managers can also be found on the DERM website <www.derm.qld.gov.au> and further information on pest animal control (including feral pigs) can be obtained from Land Protection officers. Local government weed and pest officers are also a valuable source of pest animal information as they are responsible for ensuring declared weeds and pest animals on all private and public land in their area are adequately controlled (see Managing weeds).

Other pest species of particular significance in coastal dune lake areas of Queensland are the cane toad *Rhinella marina* and the mosquitofish *Gambusia holbrooki*. Both of these species are widespread in Queensland. While the cane toad is not listed as a declared pest in Queensland and there is no legal requirement for landholders to control them, it is acknowledged that the species is a prolific breeder and a threat to native wildlife (such as the 'acid frogs'). Threats to native wildlife from cane toads include competition for food and habitat, poisoning and predation. The Brisbane City Council in south-east Queensland established a committee that urged all residents to take responsibility for controlling the pest. Freezing the animals is considered to be a humane form of euthanasia. Further information about the cane toad can be found on the DERM website or directly from land protection officers and local government weed and pest officers.

The cane toad *Rhinella marina* is a threat to native wildlife. Photo: DERM

The mosquitofish has also been implicated in the decline of frog and native fish species (such as the 'acid frogs', honey blue eye and the oxleyan pigmy perch) commonly associated with coastal dune lakes. Like the cane toad, mosquitofish have a high reproductive rate, flexible feeding and habitat requirements, prey on tadpoles and fish eggs, and compete with native fish for habitat and food. The species is listed as a noxious fish in the Queensland Fisheries Regulation 1994. Under this regulation it is an offence to possess, rear, sell or buy mosquitofish, which are also commonly known as gambusia. It is also an offence to release them into Queensland waterways or use them as bait, whether alive or dead. Gambusia should be destroyed immediately if caught.

To maintain the integrity of coastal dune lakes land managers should ensure that activities occurring within lakes and in adjacent land are environmentally sound and sustainable.
Photos: DERM

Glossary

Algal cells These are the cells that make up algae—the simple, rootless, chlorophyll-containing aquatic plants that occur naturally in fresh or marine water. Algae provide food for fish and other small aquatic animals.

Aquatic Living or growing in water.

Aquifer/aquifers Layer of rock (predominantly sandstone) that holds water and allows water to percolate through it.

Bedrock Solid rock that lies beneath soil, clay, gravel or other unconsolidated material.

Biodiversity The variety of plants, animals and other living organisms that occur in a particular area or region. Biodiversity includes habitat diversity, species diversity and genetic diversity.

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.

Biota All of the organisms (including plants, animals, fungi and micro-organisms) that occur in a particular region or location.

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.

CAMBA The Agreement between the Government of Australia and the Government of the Peoples 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 that collects rain that then flows into a waterway.

Chironomidae Non biting or true midges of the taxonomic order Diptera. This insect family are commonly found in freshwater environments. Their larvae are found in the sublittoral (below tide level) or profundal (deep water) zones of lakes.

Coleoptera The order of insects made up of beetles and weevils—characterised by hard wing covers, chewing mouthparts, and complete metamorphosis.

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

Cultural services Non-material benefits derived from ecosystems such as recreational, spiritual, religious benefits.

Detritus Dead or decaying plant or animal matter.

Dune A ridge of sand created by wind-related (aeolian) processes. The action of wind on sand may increase the size of the dune or shift its location.

Dune swales Linear depressions found between dunes or beach ridges. Dune swales are generally marshy or swampy, or may contain small lakes.

Ecosystem services The benefits people obtain from ecosystems including regulating, cultural, provisioning and supporting services.

Ecotone A transition zone between two or more ecological communities.

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 <see www.legislation.qld.gov.au>.

Eutrophic The term used to describe a nutrient rich body of water that has a high level of dissolved plant (or other) nutrients, high biological productivity and a low oxygen content.

Eutrophication The process by which lakes and ponds become enriched with dissolved nutrients, resulting in increased growth of algae and other microscopic plants.

Geomorphology The science concerned with landforms, especially the origin, evolution and processes involved in the formation of the earth's surface.

Hemiptera An order of insects comprising the two suborders, Heteroptera and Homoptera. Members of these suborders are sometimes called 'true bugs'.

Humic Material obtained from organic matter of soils, produced by the decomposition of plants or animals.

Hydrologically Pertaining to water flow.

Hydrology The science dealing with the properties, distribution and circulation of water.

Invertebrates Animals without a backbone (for example insects, worms and snails).

Invertebrates Animals without a backbone (for example insects, worms and snails).

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 Japan and the Government of Australia for the Protection of Migratory Birds and 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 may be tidal or non-tidal but ocean derived salinity is less than one part per thousand (1 ppt). 1 ppt is the equivalent of one gram of sodium chloride (salt) per litre of water.

Laterite A highly weathered red subsoil found in tropical and subtropical areas that is rich in oxides of iron and aluminium.

Macroinvertebrates Animals without a backbone that are visible to the naked eye.

Megalitres (ML) 1 million litres.

Mesozoic The geological era between 247 and 65 million years ago marked by the presence of cycads, evergreen trees, dinosaurs, marine and flying reptiles.

Microhabitats A small area where an organism lives that has different conditions from other small surrounding areas.

Microinvertebrates Animals without a backbone that cannot be seen without a microscope.

Middens An accumulation of debris and domestic refuse (such as shells and animal bones) which marks the site of prehistoric settlement or use.

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.

Odonata The insect group made up of dragonflies and damselflies.

Oligotrophic An oligotrophic lake is generally clear, low in nutrients and has only trace amounts of algae. Oligotrophic lakes tend to be enriched in dissolved oxygen but generally contain little aquatic or plant life. Their clear waters are highly valued for recreation.

Peat Partially decomposed organic matter (mostly plant material), which has accumulated in water-saturated environments, deficient in oxygen and resulting from anaerobic respiration.

pH A measure of acidity or alkalinity—a pH of seven is considered neutral, measurements below seven are acidic, and those above seven are alkaline.

Photosynthesis The process by which chlorophyll containing cells (in green plants) use water, carbon dioxide and the energy from sunlight to synthesise carbohydrates (such as sugar) and oxygen.

Phytoplankton Microscopic aquatic plants that depend chiefly upon currents for their movements. They form the important beginnings of food chains for larger animals.

Pine wildings Young pine seedlings (which develop naturally) often establishing in native bushland adjacent to pine plantations.

Provisioning services Products obtained from ecosystems such as food and water.

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).

Regulating services Benefits obtained from the regulation of ecosystems processes such as regulation of floods, drought, land degradation and disease.

Remnant A small surviving component of an original extent; remnant vegetation includes all intact and predominantly intact vegetation communities, excluding young regrowth.

Sedges Grass-like plants of the sedge family Cyperacaeae.

Sediment Sand, clay, silt, pebbles, organic material and minerals carried and deposited by water or wind. Sedimentation is the process by which sediment is deposited.

Siliceous Composed of silica or silicon dioxide (SiO2).

Siltation The process by which soil particles and small rock fragments are picked up by air or water and deposited as sediment on the beds of streams or lakes.

Soft waters Water that contains little or no calcium or magnesium salts but is highly acidic.

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.

Supporting services Ecosystem services that are necessary for the production of all other services such as soil formation, nutrient cycling and primary production.

Tannin A brown pigment found in leaves and other parts of plants. Tannin solutions are acidic and have an astringent taste.

Turbidity A measure of the cloudiness or muddiness of water due to the presence of suspended particles such as silt, clay and microscopic organisms.

World Heritage Convention The Convention Concerning the Protection of the World Cultural and Natural Heritage is an international treaty that seeks to encourage the identification, protection and preservation of cultural and natural heritage around the world considered to be of outstanding value to humanity.

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

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Appendixes

Appendix 1: Threatened fauna commonly associated with Queensland's coastal non-floodplain sand lakes

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*	IUCN Red List of threatened species status **
Fish	Oxleyan pygmy perch	*Nannoperca oxleyana*	vulnerable	endangered	endangered
	honey blue eye	*Pseudomugil mellis*	vulnerable	vulnerable	endangered
Amphibians	wallum froglet	*Crinia tinnula*	vulnerable	–	vulnerable
	wallum rocketfrog	*Litoria freycineti*	vulnerable	vulnerable	vulnerable
	wallum sedgefrog	*Litoria olongburensis*	vulnerable	vulnerable	vulnerable
	Cooloola sedgefrog	*Litoria cooloolensis*	rare	–	endangered
Birds	ground parrot	*Pezoporus wallicus*	vulnerable	endangered	–
Reptile	estuarine crocodile	*Crocodylus porosus*	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.

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

Appendix 2: Wetlands in Queensland that are listed in *A Directory of Important Wetlands in Australia (2005)* and/or are Ramsar sites and that include coastal non-floodplain sand lakes.

Bioregion	Directory reference	Directory wetlands	Ramsar wetlands
Cape York	QLD059	Cape Flattery Dune Lakes	–
	QLD060	Cape Grenville Area	–
	QLD062	Harmer Creek — Shelburne Bay Aggregation	–
	QLD069	Olive River	–
	QLD070	Orford Bay — Sharp Point Dunefield Aggregation	–
	QLD075	Somerset Dunefield Aggregation	–
Central Queensland Coast	QLD043	Corio Bay Wetlands	Shoalwater and Corio Bays Area
	QLD048	Island Head Creek — Port Clinton Area	Shoalwater and Corio Bays Area
	QLD054	Shoalwater Bay	Shoalwater and Corio Bays Area
	QLD178	Shoalwater Bay Training Area Overview	Shoalwater and Corio Bays Area
Brigalow Belt	QLD003	Broad Sound	–
	QLD005	Burdekin — Townsville Coastal Aggregation	–
Southeast Queensland	QLD019	Port Curtis	–
	QLD126	Burrum Coast	–
	QLD127	Bustard Bay Wetlands	–
	QLD131	Fraser Island	Great Sandy Strait
	QLD132	Great Sandy Strait	Great Sandy Strait
	QLD133	Lake Weyba	–
	QLD134	Moreton Bay Aggregation	Moreton Bay
	QLD135	Noosa River Wetlands	–
	QLD185	Coolum Creek and Lower Maroochy River	–
	QLD187	Lower Mooloolah River	–
	QLD189	Bribie Island	Moreton Bay
	QLD191	North Stradbroke Island	Moreton Bay

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