



**Australian Government**

**Department of the Environment and Energy**

# **Draft National Recovery Plan for the Australian lungfish (*Neoceratodus forsteri*)**



February 2017

The Species Profile and Threats Database pages linked to this recovery plan is obtainable from: <http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

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## Acronyms

AAQ	Aquaculture Association Queensland
AMTD	Adopted Middle Thread Distance
ASFB	Australian Society for Fish Biology
BMRG	Burnett Mary Regional Group
CITES	Convention on International Trade in Endangered Species
CPUE	Catch Per Unit Effort
DAFF	Department of Agriculture Forestry and Fishing (Qld)
DEHP	Department of Environment and Heritage Protection (Qld)
FFSAQ	Freshwater Fishing and Stocking Association of Queensland
MRCCC	Mary River Catchment Coordinating Committee
NGO's	Non-government organisations
NRM	Natural Resource Management
TOWG	Traditional Owners Working Group

## 1. Summary

<b>Family:</b>	Ceratodontidae (lungfishes)
<b>IBRA Bioregion (ver. 7.0):</b>	South Eastern Queensland; Brigalow Belt
<b>Current status of taxon:</b>	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (C'th): Vulnerable  <i>Fisheries Act 1994</i> (Queensland): No take species  <i>Convention on International Trade in Endangered Species of Wild Fauna and Flora</i> (CITES): Appendix II
<b>Distribution and habitat:</b>	The contemporary distribution of Australian lungfish is limited to south-east Queensland. Populations in the Burnett and Mary are considered endemic to those river systems. Populations are also found in the Brisbane, North Pine, Logan, and Coomera Rivers, as well as Gold Creek Reservoir, Lake Manchester and Condamine River west of the Great Dividing Range (Kemp 1995). Populations in the Brisbane and North Pine rivers may be a result of translocations, although there is some uncertainty about whether those systems had endemic populations before the introductions. Populations in the other systems are thought to originate from translocated individuals.

### Habitat critical for survival:

All known Australian lungfish populations are considered under threat given the uncertainty surrounding their population status in the different river systems, and the possible long-term consequences from a range of threats. As all known populations of Australian lungfish are under threat, habitat critical to the survival of the Australian lungfish includes:

- Any breeding or foraging habitat in areas where the species occurs (as defined by the distribution map provided in Figures 1-4); and
- Any newly discovered breeding or foraging locations.

### Recovery plan objectives:

Enhance Australian lungfish populations throughout their range (particularly populations within the Burnett, Mary, Brisbane and North Pine River catchments) to a point where there can be assurance that the species no longer meets the criteria for listing and can be delisted from the national threatened species list under the EPBC Act.

### Recovery team:

Recovery teams provide advice and assistance in coordinating actions described in recovery plans. They include representatives from organisations with a direct interest in the recovery of the species, including those involved in funding and those participating in actions that support the recovery of the species. Members are committed to the conservation of the species and the achievement of recovery objectives and implementation of recovery strategies. The membership of the Australian

lungfish recovery team may include individuals with relevant expertise from Queensland State and local governments, Catchment management groups, environmental groups and Traditional Owners.

### **Recovery strategies:**

The strategies to achieve the plans' objectives are to:

- Reduce the impacts of, and remove any redundant, artificial barriers
- Manage waterways to optimise breeding and recruitment opportunities
- Limit habitat degradation and maintain or enhance water quality
- Reduce the impacts of introduced pest and weed species
- Manage the impacts of water-based recreational activities
- Address key knowledge gaps to improve Australian lungfish management
- Facilitate high levels of community participation and support in the implementation of Australian lungfish management strategies

### **Criteria for success:**

This recovery plan will be deemed successful if, within 10 years, all the following have been achieved:

- Population densities of Australian lungfish are increasing and have a healthy demographic structure.
- Instream artificial barriers have been identified, and appropriate management (including removal of redundant barriers) of barriers is occurring.
- Appropriate measures have been put in place to manage key threats affecting habitat.
- Habitat quality has been maintained or improved in key locations.
- Community awareness of, and participation in, Australian lungfish conservation has increased.

### **Criteria for failure:**

This recovery plan will be deemed to have failed if; within 10 years any of the following have occurred:

- The species has become locally extinct from key locations in the wild, or populations at these locations do not display a healthy demographic structure.
- Instream barriers remain a threat to the long term survival of Australian lungfish, and are not appropriately managed.
- Actions have not been undertaken to address key threats limiting population growth and recovery.
- Habitat quality has declined in key locations.

## **2. Introduction**

The Australian (or Queensland) lungfish (*Neoceratodus forsteri*) is an iconic and distinctive freshwater fish species endemic to south-eastern Queensland. One of only six living lungfish species found worldwide, the Australian lungfish belongs to the ancient group *Sarcopterygii*, along with the

coelacanth which lives in deep waters off the coast of Madagascar and Indonesia. The commonly used descriptor, 'living fossil', is apt for Australian lungfish as fossils identical to Australian lungfish found in northern New South Wales have been dated back to the Cretaceous Period (100 million years ago). The Australian lungfish is considered one of, if not, the oldest known extant vertebrate species. It is a more primitive species than the other extant species of lungfish (Kemp 1986, Berra 2007, Cavin and Kemp 2011). The fossil record shows up to eleven species may have originally inhabited Australian river systems, however by the time of European settlement only *Neoceratodus forsteri* was thought to be extant, making this species sole surviving member of the family Neoceratodontidae.

The contemporary distribution of Australian lungfish is limited to south-east Queensland. Populations in the Burnett and Mary are considered endemic to those river systems. Populations are also found in the Brisbane, North Pine, Logan, and Coomera Rivers, as well as Gold Creek Reservoir, Lake Manchester and Condamine River west of the Great Dividing Range (Kemp 1995). Populations in the Brisbane and North Pine rivers may be a result of translocations, although there is some uncertainty about whether those systems had endemic populations before the introductions. Populations in the other systems are thought to originate from translocated individuals.

The species is relatively numerous within its natural distribution but long term survival is threatened by barriers to movement, regulation of flows, habitat degradation, and pest and weed species. The August 2003 listing of Australian lungfish in the Vulnerable category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* relates primarily to the limited and patchy distribution of the species, and a decrease in available spawning and nursery habitat. Juvenile Australian lungfish are not being readily detected in surveys. It is unclear whether this is due to survey method, naturally low recruitment rates given the long lived nature of the species, or very high predation of juveniles (Mary River threatened species recovery team, 2011). Given the uncertainty surrounding apparent lack of juveniles, presence of mature individuals could be a false representation of security of the population. Long term survival of the species requires optimal recruitment conditions to be provided to ensure recruitment is occurring.

A survival strategy was prepared for this species in 2008 and this outlined the major threats in detail. The recovery plan builds on this comprehensive body of work by providing additional information, concepts and actions required to help ensure the long-term survival of this iconic Australian species.

Recovery actions summarised within this plan are grouped into six primary result areas, these being:

- Reduce the impacts of artificial barriers
- Manage waterways to optimise breeding and recruitment opportunities
- Limit habitat degradation and maintain or enhance water quality
- Reduce the impacts of introduced pest and weed species
- Manage the impacts of water-based recreational activities
- Pursue key knowledge gaps to improve Australian lungfish management
- Facilitate community participation and support in management strategies and their implementation

Due to the long lifespan of this species (believed to live up to 60 – 80 years of age and thought to reach sexual maturity at 15 – 20 years of age), actions discussed within this plan to facilitate recovery of Australian lungfish are proposed for implementation over a ten year period (with a review of



performance at five years). It should be noted that with dedicated and cooperative implementation, the estimated recovery of this long-lived species is approximately 30 – 50 years.

### 3. Species information and conservation status

The Australian lungfish *Neoceratodus forsteri* is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) list of threatened species. The species is also listed as a 'no take' species in Queensland under the *Fisheries Act 1994* and is listed under Appendix II of the Convention on International Trade in Endangered Species (CITES). The Australian lungfish is also a critical priority species for the State under the Back on Track Phase I species prioritisation framework (DERM, 2010). Despite the level of protection afforded to this species, it is listed as 'Common / Secure' by the Australian Society for Fish Biology (ASFB) and has been described as locally abundant within its range (Kemp 1995).

## 4. Biological information

### 4.1. Description

Australian lungfish are characterized by a robust elongate body covered in overlapping layers of large, thick scales. The head is somewhat conical but flattened to produce a broad dorsal surface. The snout and head exhibit clusters of sensory pits or 'ampullary organs' used to detect weak electric fields emitted by potential prey items (Watt et al. 1999). The eyes and mouth are small relative to the overall body reflecting their roughly diamond shape. The dorsal fin emerges roughly half way along the length of the body and joins the caudal and anal fins to outline the broad flattened tail. There are no fin spines or other sharp surfaces on the body or gill covers. The upper body surface varies from light shades of olive-green to brown or almost black, with a series of smaller dark marks scattered in random patterns. In contrast, the underbelly is brightly coloured in various shades of orange, yellow, pink or white.

Juvenile Australian lungfish appear similar to adults, with some clear differences. Juveniles exhibit a more pronounced and slightly rounded head (Kemp 1986). Darker spots on the body are frequently clustered giving a mottled appearance and the sensory pores are more prominent on the head and snout. As noted by Kemp (1986), the dorsal fin arises further forward, close to the back of the head.

Australian lungfish can attain considerable size, with early authors reporting maximum dimensions in the order of 1.7 m and 40 kg (e.g. Krefft 1870, Spencer 1892, Longman 1928). Current evidence suggests that individuals of these proportions are now extremely rare. A sample of almost 3000 Australian lungfish collected by Brooks and Kind (2002) included individuals ranging in length from 345 – 1420 mm, with a mean total length of 906 mm.

### 4.2. Life history and ecology

While many aspects of Australian lungfish anatomy and physiology are well documented, crucial parameters such as population size and structure, recruitment rates and mortality levels remain poorly understood.

Australian lungfish complete their life cycle entirely in freshwater. The annual spawning season can commence as early as July and continue until at least January (Kemp 1986, Brooks 1995, Joss and Joss 1995). However, the majority of spawning occurs between August and November. Early authors noted that spawning activity occurs in shallow glides and along river margins in close proximity to

macrophyte beds or partially submerged riparian vegetation (e.g. Caldwell 1885, Illidge 1893, Semon 1899). Kemp (1984) collected viable eggs from submerged macrophytes and tree roots in the Brisbane River and from root masses of the noxious weed water hyacinth in Enoggera Reservoir. Following a series of similar collections, Kemp (1993) noted that Australian lungfish spawning is largely restricted to submerged plants that occur in shallow water, have dense growth forms and contain food items such as algae, protozoa, small molluscs and crustaceans. Subsequent studies (Brooks 1995, Brooks and Kind 2002) have demonstrated that Australian lungfish spawning occurs in a diverse range of aquatic, semi-aquatic and submerged terrestrial plant species. There is a strong positive correlation between macrophyte density and the intensity of Australian lungfish spawning. Water flow is not mandatory in spawning areas but influences the depth at which eggs are deposited (Kemp 1993, Brooks 1995, Brooks and Kind 2002), but highest densities of early stage embryos are typically associated with intermediate flow velocities (Arthington 2009). The unifying feature of Australian lungfish spawning sites are that they provide protection from predators such as other fish, including adult lungfish; birds; invertebrates; suitable dissolved oxygen levels for developing embryos; and abundant food supplies for recently hatched fry (Kemp 1984, Brooks 1995, Brooks and Kind 2002).

During courtship individuals separate into pairs or small groups (Grigg 1965b, Brooks 1995). There are no visible external features that reliably distinguish the sex of adult Australian lungfish. However, sex was determined for 586 individuals. For those fish where sex was determined through internal examination, there was an overall sex ratio close to 50:50. Males appear to mature at an earlier age than females, reaching maturity at between 15 and 17 years, compared to between 20 and 22 years in females (Arthington 2009). The average length of mature males for the subset of fish where sex was determined was 767 mm compared to 834 mm for females (Brooks and Kind 2002). In keeping with its slow growth, Australian lungfish are likely to be a long-lived species and may regularly reach 50+ years in the wild (Brooks and Kind 2002). No parental care is evident after the eggs have been deposited. The negatively buoyant eggs have an outer membrane that remains sticky for a short period allowing the eggs to adhere to the spawning substrate (Kemp 1986).

Fertilised Australian lungfish eggs are hemispherical, green or brown in colour and 2 – 3 mm in diameter (Kemp 1982). Kemp (1994) reported that a proportion of eggs are infertile or suffer mortal physical damage. In most cases where the egg or embryo is damaged, bacterial or fungal infection follows, the rate of infection varies between locations and can exceed 30% (Kemp 1994, Brooks and Kind 2002). Because the eggs are laid in shallow water, even small fluctuations in water level can expose the eggs or inundate them to unsatisfactory levels. Kemp (1981) also demonstrated that extreme temperatures (< 10°C or > 30°C) can be lethal to cleaving eggs. The extent of predation on early Australian lungfish life history stages is poorly understood. However, a range of potential predators including fish, birds, invertebrates and even other Australian lungfish are believed to prey on Australian lungfish eggs, larvae and juveniles. Newly hatched Australian lungfish are essentially defenceless and avoid predation only by lying motionless on their side in dense cover. The hatchlings do not begin feeding for a period of 2 – 3 weeks during which they rely on remaining yolk supplies for nutrition.

Juvenile Australian lungfish are rarely encountered in the wild. Late stage eggs and hatchlings can be easily collected from spawning habitat using push nets or active searches amongst the macrophytes (Kemp 1984, 1986, 1993, Brooks 1995). After this point, Australian lungfish rarely appear in fisheries surveys until they are approximately 300 mm in length (Brooks and Kind 2002). On the basis of

available evidence it seems likely that juveniles remain in the natal habitat for long periods. Records collated by Kemp (1986) provide sporadic peaks in recruitment.

Because so few specimens have been collected from the wild, growth rates of juvenile Australian lungfish are poorly understood. Laboratory studies such as Kemp (1981) report extremely slow growth in keeping with small enclosures and individual feeding. Notwithstanding some uncertainty regarding juvenile growth rates, the Australian lungfish is a slow-growing species across the bulk of its life span. Mark/recapture data from the Burnett River indicates that growth may be as slow as 5 mm/yr after individuals reach sexual maturity (Brooks and Kind 2002). There is also good evidence of resource mediated variability in growth patterns across the range of Australian lungfish (DPI&F unpublished survey data).

Australian lungfish are a predominantly nocturnal species (Dean 1906, Longman 1928, Grigg 1965a, Kemp 1986, Kind 2002). Subadults follow a similar daily rhythm to adults, leaving daytime refuges in the late afternoon to forage during the night (Kind 2002). In flowing river sections Australian lungfish exhibit largely localised movements around a distinct home range, typically 1 – 1.5 km in length (Kind 2002). The home range is typically centred on a small number of regular refuges, where individuals shelter during the day. Movements outside of the home range are rare and only observed in a small proportion of the population. In contrast, Australian lungfish in impounded waters can be highly mobile. During late autumn and winter Australian lungfish tagged by Brooks and Kind (2002) moved out of instream impoundments on the Burnett River to seek out suitable spawning habitat in shallow pools and glides. This included reaches upstream of the impoundments and in tributary streams, up to 35 km from the impoundment. Following the spawning period, return movements occurred on a staggered basis with individuals often utilizing small flow events to assist their downstream passage (Brooks and Kind 2002). Berghuis and Broadfoot (2004) reported that Australian lungfish downstream of Ned Churchward Weir also made upstream movements during minor flow events, taking advantage of increased connectivity to move between pools.

The diet of Australian lungfish changes over time reflecting a progression from larval to adult dentition (Kemp 1986). Recently hatched Australian lungfish possess isolated conical tooth cusps, which are used to catch and hold tiny crustaceans and worms, occasionally supplemented by filamentous algae (Kemp 1977, 1995). Adults are opportunistic omnivores with individuals foraging amongst macrophytes, along the banks and on the river bed. Large quantities of plant material and silt are ingested during feeding, much of which passes through the digestive system in a relatively intact state. Food items such as small molluscs, crustaceans and worms are gleaned from the plant material and broken down by the crushing action of the mouthparts (Kemp 1986). There are also reports of Australian lungfish ingesting the fruits and seed pods of terrestrial plants such as *Eucalyptus* sp., *Ficus* sp., prickly pears and lilly pilly (*Waterhousia floribunda*) (Whitley 1927, Spencer 1892, A. Berghuis pers. obs. 2012).

## 5. Distribution and human introductions

The current natural, self-sustaining distribution of the Australian lungfish is generally accepted to be limited to the Mary and Burnett River systems. Populations in the Brisbane and North Pine rivers may be a result of translocations, although there is some uncertainty about whether those systems had endemic populations before the introductions. Populations in the other systems are thought to originate from translocated individuals.

Prior to European colonisation the distribution of the Australian lungfish is thought to have been limited to the Mary and Burnett Rivers (De Vis 1885, Illidge 1893), which are geographically isolated from one another by a catchment divide. Within the Burnett River Catchment, Brooks and Kind (2002) describe the distribution of Australian lungfish as occurring from the tidal barrage at 25.9 km upstream to at least Three Moon Creek near Monto, with the majority occurring within the main river channel downstream from the township of Ceratodus. The species is also reported to be present in the Boyne River to the wall of Boondooma Dam, the Auburn River to Auburn River Gorge and Barambah Creek to the Barambah Gorge, though is not known from ephemeral tributaries such as the Nogo and Perry River (Brooks and Kind 2002). Fisheries surveys in Cania Dam have also reportedly recorded Australian lungfish believed to be translocated from drying waterholes in the upper Burnett (A. Hamlyn, DAFF unpublished data, cited in Brooks & Kind 2002).

Brooks and Kind (2002) reported that the core Australian lungfish population in the Burnett system exists between Ben Anderson Barrage and approximately AMTD 275 km and possibly also within the lower Boyne River. Surveys indicate that Australian lungfish are also widely distributed throughout the Mary River and its tributaries (DAFF, unpublished data). In the main river channel, the Australian lungfish occur from the tidal barrage upstream to the township of Conondale. Little is known about the relative abundance of the Australian lungfish between these two points, or within adjacent tributaries. Australian lungfish are also common in the Tinana/Coondoo Creek system, Obi Obi Creek, Six Mile Creek, Yabba and Little Yabba Creek, and Wide Bay Creek (Simpson 1994, Kind 2002). A small number of individuals have been observed in Borumba Dam and some other minor tributary streams (DAFF unpublished data).

Upstream of Wivenhoe Dam, Australian lungfish inhabit Lake Wivenhoe, Lake Somerset, the Brisbane River and the Stanley River. The distribution and abundance of Australian lungfish in these areas is poorly understood. Very little is known about the North Pine River population, however some suggest it exists as a result of artificial translocation but some recent genetic data suggests a natural origin (Kemp, unpublished data).

A collection of one hundred and nine Australian lungfish, most from Miva on the Mary River were collected for translocation (Welsby, 1905). They were all large adult fish, 39 that were 45 inches (approximately 1.1 m) in length and between 9 and 14 pounds in weight (4 – 6.35 kg). Of the 109 fish collected from the Mary River, eleven escaped and twelve died soon after capture. Nine died during transit to their temporary home in a farm dam where they were held for six months. Of the remaining 77 fish, 8 more died, leaving 69 fish for translocation experiments. Of these fish, three went to the North Pine River. Four fish were placed in a lagoon near the Albert River (at Messrs). Eight were put in a farm dam near Cressbrook (although 3 died), on a property near the Upper Brisbane River. Eighteen fish were placed into Enoggera reservoir and 21 directly into the Condamine River. Two fish were introduced into the Brisbane Botanic Gardens (which both died 6 months later) and 16 were released into the upper Coomera River (O'Connor in Welsby, 1905). A small number of Australian lungfish were also believed to have been translocated into Blue Lake and Eighteen Mile Swamp on North Stradbroke Island (Thompson 1975, Kemp 1990).

Introductions of Australian lungfish to North Stradbroke Island and the Brisbane Botanic Gardens appear to have been unsuccessful. Johnson (2001) has questioned the validity of including Condamine and Coomera Rivers, Lake Manchester or Gold Creek Reservoir within the known distribution of the species, stating that no recent museum records exist for these waterways. However, the museum stopped keeping Australian lungfish records in the early 1980's. A small number of Australian lungfish

were recently collected in the Coomera River and Lake Manchester (DAFF unpublished data), and an interaction with two Australian lungfish by a recreational fisher on the Condamine River was supported by photographic records and recently confirmed by Department of Agriculture, Fisheries and Forestry (DAFF) staff (S. Brooks pers. comm. 2012).

## 6. Populations

The Australian lungfish is known to occur within six catchments (Kemp 1995, Figure 1). Populations in the Burnett and Mary River systems are considered endemic. There is some uncertainty about populations in the other systems, in particular, whether they are endemic to the system; come from introduced fish; or a mixture of both introduced and endemic fish.

### 6.1. Burnett River population

The Burnett River flows approximately 420 km from its source to the sea. The total area of the Burnett river catchment is approximately 33,000 square kilometres. The Ben Anderson Barrage pool is the closest water storage to the sea, at AMTD 25.9 km. The pool is generally steep sided, and slowly transmits impounded waters along its length (Kind 2002). There is a section of river approximately 7 km long upstream of Ben Anderson Barrage pond consisting of flowing water with shallow runs and riffles up to Ned Churchward Weir (formerly called Walla Weir). Ned Churchward Weir is 74.5 km from the river mouth, and impounds water 34.5 km upstream to a point 109 km from the mouth of the Burnett River.

Despite the installation of a fishway that successfully passes other fish species, the successful upstream movement of Australian lungfish from the estuarine waters downstream of the Ben Anderson barrage is restricted by the current fishway design (Stuart and Berghuis 2002). Other structures including two redundant weirs (Bungera and Walla Gauge) are partial barriers during low water levels. Causeway Road at Booyal is a complete barrier at low to moderate river flows. Fishways installed at Ned Churchward Weir, Paradise Dam and Claude Wharton Weir have been documented as capable of providing upstream passage for Australian lungfish (DAFF data) but operation is not optimal and the structures are prone to mechanical failure and flood damage.

Pre-construction modelling of a stepped spillway design for Paradise Dam indicated a low risk of injury to downstream moving fish during a spillway overtopping event. Assessment by DEEDI (2012) found that fish mortalities occurred during all flow rates over the Paradise Dam stepped spillway. Fish injury and mortality was also documented for fish that passed through the environmental release tower and the irrigation flow intakes.

There are two irrigation storages further upstream (John Goleby Weir and Jones Weir) that are impassable to Australian lungfish in normal flow conditions. Kind et al. (2008) report Australian lungfish distribution within the Burnett catchment as extending from the Ben Anderson Barrage upstream to around 10 km upstream of the John Goleby Weir at AMTD 335 km (Figure 2). Brooks and Kind (2002) reported that highest densities of Australian lungfish occurred between Ben Anderson Barrage and a point approximately 275 km upstream, and reported that Australian lungfish were less likely to be found in impounded reaches than in flowing stretches of the Burnett River, based on Catch per Unit Effort (CPUE) data. Tait (2009) reported the majority of Australian lungfish occurred downstream of the township of Ceratodus.





Figure 1 Distribution of Australian lungfish

The Australian lungfish also occurs in tributaries of the Burnett River with perennial flow, including Three Moon Creek near Monto to around Mulgildie, Barambah Creek to the Barambah Gorge, the lower reaches of the Auburn River to Auburn River Gorge, and the Boyne River to the wall of Boondooma Dam (Brooks and Kind 2002) (Figure 2). Anecdotal reports indicate the species once inhabited the Boyne River above Boondooma Dam, however recent surveys have failed to record samples from this area (A. Hamlyn DAFF unpublished data cited in Brooks and Kind 2002). Australian lungfish have been sampled from Cania Dam which was apparently translocated to this location from drying waterholes in the upper Burnett (A. Hamlyn DAFF unpublished data cited in Brooks and Kind 2002). Tait (2009) also report the presence of an isolated population in Splitter Creek, which joins the Burnett River below the Ben Anderson Barrage. Australian lungfish are noted to be absent from ephemeral tributary basins such as the Perry or Nogo Rivers (Brooks and Kind 2002).

#### **6.1.1. Burnett River - population status**

The Burnett River Basin is regarded as one of the most developed catchments in Queensland in terms of water infrastructure (Kind 2002). The Australian lungfish population in the Burnett River is largely dominated by adult fish but some juveniles are occasionally observed. Exactly 2888 Australian lungfish were sampled during a 3 year (1997 – 2000) study of the Burnett River (Brooks & Kind 2002) and 1387 Australian lungfish were collected during 2006 – 2007 sampling conducted at 6 sites in the vicinity of Paradise Dam as part of the Burnett Dam Baseline Australian Lungfish Monitoring (Kind and Brooks, unpublished data in Tait 2009). The species performs large scale spawning in several reaches but it is unknown what proportion of eggs and larvae survive and recruit to the adult population. Grey's Waterhole, a deep permanent pool on the Burnett River (AMTD 182.8 km) has been identified as a special feature with high conservation value (Clayton et al. 2006), likely to represent an important breeding group. In the main river channel, the majority of Australian lungfish occur downstream from the township of Ceratodus. Brooks and Kind (2002) reported that CPUE was highest in river reaches 50 – 100 km from the river mouth.



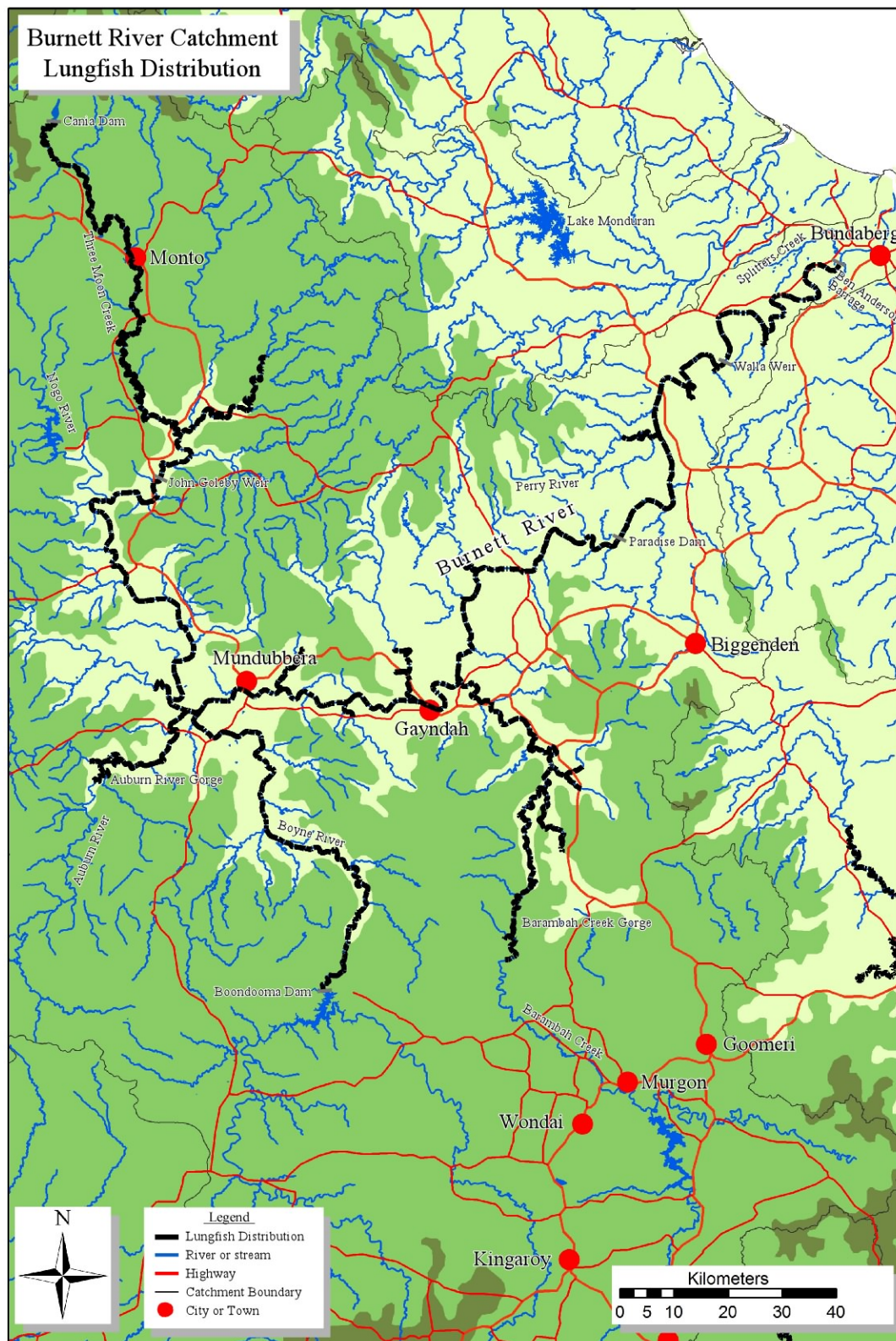


Figure 2 Map of the known distribution of Australian lungfish in the Burnett River catchment.



## 6.2. Mary River population

The Mary River Catchment has approximately 3000 km of waterways, many of which contain communities of remnant riparian vegetation of conservation significance (Stockwell 1999), which provide habitat for a diverse range of flora and fauna some of which has been identified as rare, vulnerable and endangered under the *Environment Protection and Biodiversity Conservation Act 1999* and/or the *Queensland Nature Conservation Act 1992*. The estuarine riparian communities in the lower Mary are of international significance for wader birds, added to the Ramsar list in 1999 (Stockwell 1999). Of the 9400 square kilometres of the catchment, 67% has been subjected to moderate land clearing and 28% of this has been extensively cleared, primarily for beef and dairy cattle grazing (Kelly 1997). This clearing of the fertile alluvial floodplains has significantly reduced native riparian vegetation cover and contributed to the alteration of the natural dynamics of river processes in the Mary River Catchment (Kelly 1997). Water quality in the Mary River is impacted by surrounding land use, discharge from a sewerage treatment plant, meatworks effluent, and pesticide and herbicide runoff (EPA 2001). The main channel of the Mary River remains largely unregulated aside from tidal barrages in estuarine reaches, and is less regulated in comparison to the Burnett system, with 11 storages supplying water for both urban and irrigation requirements (QDPI 1990).

Tidal barrages on the Mary River and Tinana Creek were fitted with fishways that have been found to provide passage for most fish species but remain unproven for the successful passage of Australian lungfish (Berguis and Piltz 2004, DAFF unpub data). The Kidd Bridge Gauging Weir on the Mary River Gympie is a barrier to fish migration during all flows lower than 6,125 ML<sup>day<sup>-1</sup></sup> or approximately 97% of all flows in the Mary River at Gympie (Berguis 2012). An unauthorized weir installed on the Mary River upstream of the Gympie town reach is a barrier under most flows and several defunct road crossing and gauging weirs on the Mary River mainstream constitute migration barriers during low flows. On Tinana Creek the Teddington Weir and Tallegalla Weir are complete barriers to fish migration; stream gauging weirs and road crossings also serve to fragment stream connectivity during low to moderate flows.

### 6.2.1. Mary River - population status

Despite a range of catchment impacts, the Mary River Australian lungfish population is considered relatively healthy throughout its range. Kind et al. (2008) report that recent surveys indicate Australian lungfish are widely distributed throughout the Mary River and its tributaries. In the main Mary River channel, Australian lungfish are believed to occur from the tidal barrage upstream to the township of Conondale (Figure 3), however little is known about the relative abundance of Australian lungfish between these two points. Australian lungfish are also believed to be common in tributary creek systems including the Tinana/Coondoo Creek system, Obi Obi Creek, Six Mile Creek, Yabba and Little Yabba Creek, and Wide Bay Creek (Simpson 1994; Kind 2002). A small number of individuals have also been observed in Borumba Dam and some other minor tributary streams (DAFF unpublished data cited in Kind et al. 2008).

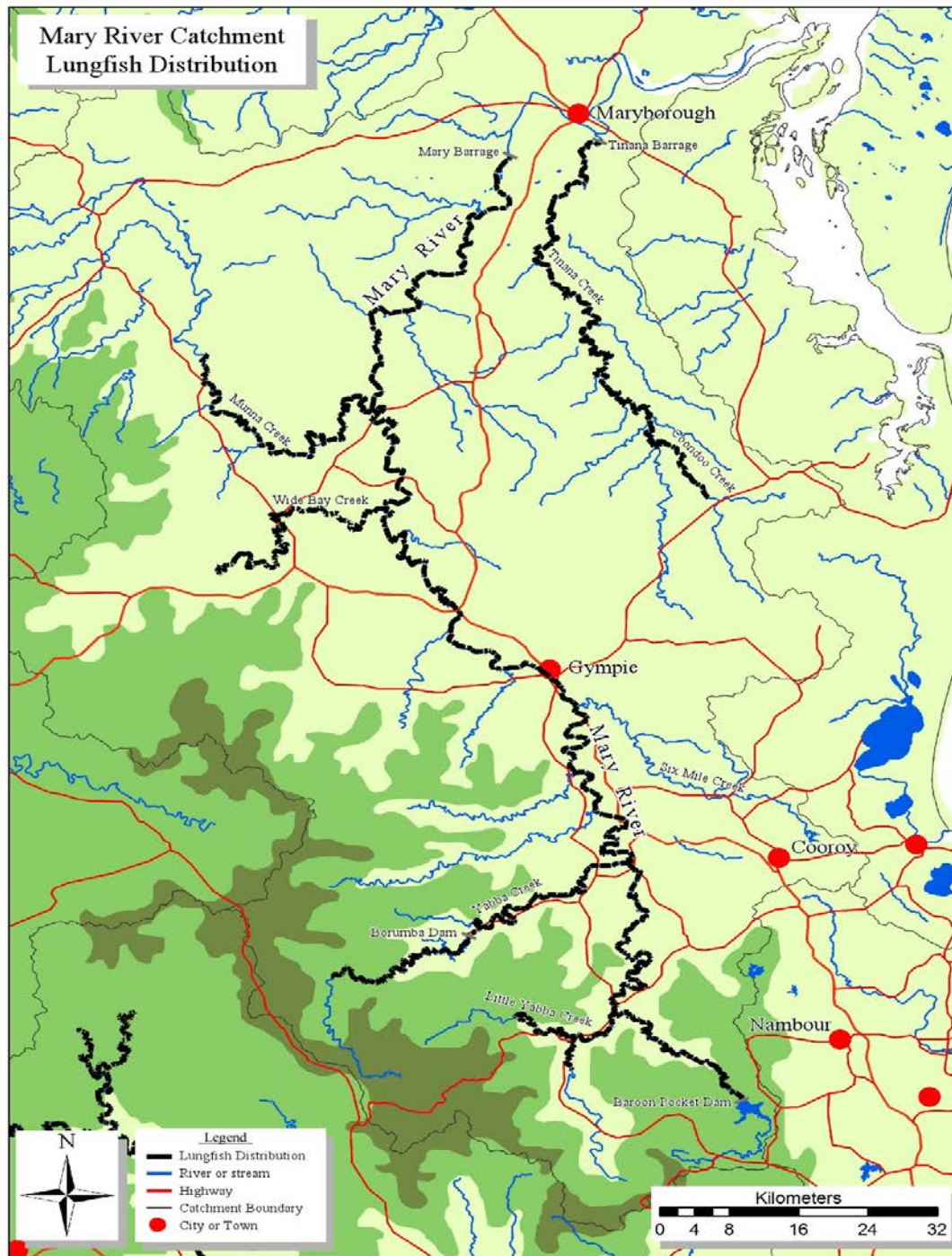


Figure 3. Map of the known distribution of Australian lungfish in the Mary River catchment.

### 6.3. Brisbane River population

The upper catchment of the Brisbane River is dominated by two large water storages: Somerset Dam that subsequently flows directly into the headwaters of Wivenhoe Dam (Kemp 1986). Downstream of these impoundments the river known as the middle Brisbane River, becomes wide and slow flowing, with occasional shallow riffles and runs. Thick native riparian vegetation lines the banks, contributing to spawning and shelter habitat for Australian lungfish, and aquatic macrophytes were previously abundant (Kemp 1986). This middle Brisbane River system is influenced by regulated flows as part of

the water supply system for the broader Brisbane region, and consequently receives consistent flows ideal for Australian lungfish (Kind 2011). The densest population of Australian lungfish in the Brisbane River is believed to occur between Wivenhoe Dam and the Mt Crosby Pumping Station (Hydrobiology, 2007). Australian lungfish populations have also been established in artificial impoundments on tributary streams within the Brisbane catchment including Lake Manchester, the Gold Creek Reservoir, and the Enoggera Reservoir on Enoggera Creek.

The persistence of Australian lungfish in Lake Manchester, and the Gold Creek Reservoir was unable to be confirmed through a review of available literature but were verbally confirmed by fisheries scientists.

Mount Crosby Weir is a barrier to the passage of Australian lungfish from the saline waters downstream of the weir under most flow conditions. Although the weir was fitted with a fishway in 1941 it is considered ineffective for the passage of most fish species during low to moderate flows. The passage of Australian lungfish beyond the weir would be limited to high flood flows that submerge the Mount Crosby weir crest.

### **6.3.1. Brisbane River - population status**

CPUE information suggests that populations in the Brisbane River catchment is equivalent to that recorded from confirmed endemic populations in the Mary and Burnett River systems (Hydrobiology 2007). Upstream of Wivenhoe Dam, Australian lungfish inhabit Lake Wivenhoe, Lake Somerset, the Brisbane River and the Stanley River (Figure 4). Kind et al. (2008) report the distribution of Australian lungfish within these areas as being poorly understood. Hydrobiology (2007) reported lowest CPUE values from reservoirs within the Brisbane River and noted that the population was skewed towards larger individuals, indicating low abundance of younger individuals (potential indications of low spawning/recruitment). Australian lungfish populations in the Brisbane River between Wivenhoe Dam and the Mt Crosby Pumping Station (middle Brisbane River) have been subject to long-term biological studies (e.g. Kemp 1984, 1986, 1993). Length frequency information for the middle Brisbane River population show a wider range of size classes indicating periodic recruitment is occurring (Seqwater unpublished data).

Whilst the Enoggera Creek Reservoir population was once described as thriving (Thompson 1975), later surveys indicated that the population was dominated by larger specimens (Pusey et al. 2004), and the population is now believed to be extinct within the reservoir (Kemp 2008, 2011). No specimens were obtained by Hydrobiology (2007) in a survey of the reservoir. It is suggested that the decline in this population may have been caused by efforts to control water hyacinth by spraying of herbicides in 1974 (Kemp 1995, 2008). Anecdotal reports indicate there are still Australian lungfish inhabiting the reaches of Enoggera Creek below the dam.

Australian lungfish populations in Lakes Wivenhoe and Gold Creek Reservoir are poorly understood and have never been subject to rigorous survey (Kind 2002). With the exception of early reports



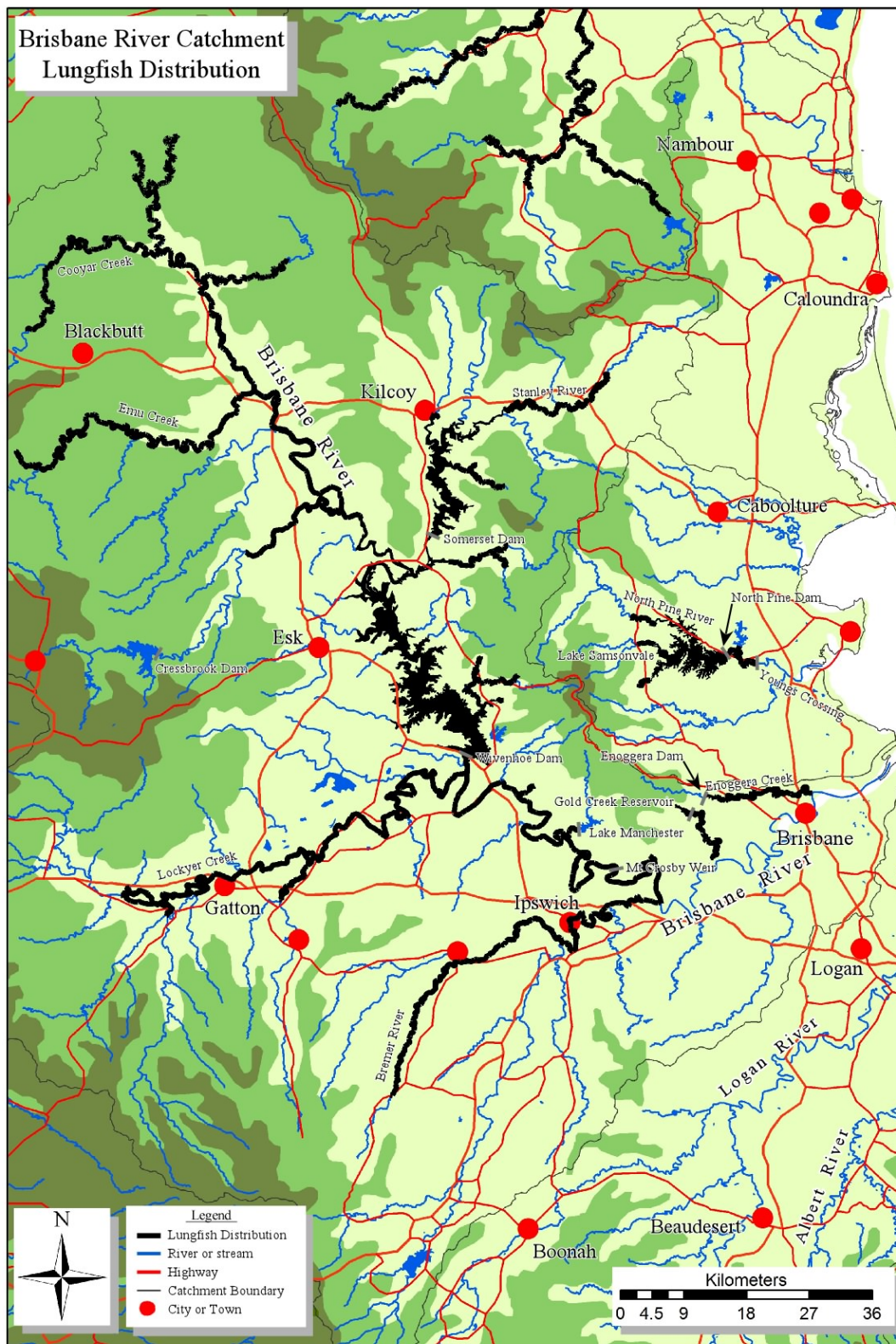


Figure 4 Map of the known distribution of Australian lungfish in the Brisbane and North Pine River catchments.

from Enoggera Reservoir, Australian lungfish recorded in these impoundments have invariably been adults. Despite observed spawning events within Lake Wivenhoe (Roberts et al., in Prep) there are currently no confirmed records of juvenile Australian lungfish collected from within the impoundment, although few detailed surveys have been undertaken of impoundment habitats.

#### **6.4. North Pine River population**

The North Pine River is disrupted mid-catchment by North Pine Dam approximately 5 km upstream of Petrie, forming the 2000 hectare Lake Samsonvale. The dam provides water supply to Brisbane, Pine Rivers and Redcliffe. Australian lungfish are present in Lake Samsonvale, and downstream to Young's crossing (generally considered to be the limit of tidal influence) (Figure 4). Below the wall of the reservoir the creek is depauperate, and while Australian lungfish may survive here they are in poor condition and have little food. Very little has been published to date on the Australian lungfish population in North Pine River. Surveys of the North Pine population have been conducted by South East Queensland Water (Seqwater), however these are currently not publicly available. Preliminary results indicate that Australian lungfish may be relatively abundant and dominated by adult specimens, but this will require further research, reporting and investigation. This population is the subject of ongoing research by Seqwater to better understand population demographics.

##### **6.4.1. North Pine River population status**

Flood releases from North Pine Dam are known to have adverse impacts. During releases in 2009, more than 50 Australian lungfish were found stranded, dead or injured in one short section of river bank downstream of the dam wall. Many fish were subsequently translocated back to Lake Samsonvale to prevent further mortality. It is unclear whether juveniles are being recruited to adult populations and the lack of fish passage on North Pine Dam provides little opportunity for downstream-displaced fish to recolonize upstream habitat and leads to decreased survival. Since the deaths in 2009 Seqwater has implemented a range of improved management procedures to prevent Australian lungfish deaths during flood operations. These procedures have been very successful and have reduced fish mortality during flood events.

#### **6.5. Logan/Albert, Coomera, and Condamine River Populations**

Both the Logan-Albert and Coomera River Systems originate in the McPherson Ranges near the Queensland-NSW border, with the Logan/Albert then heading north to the Logan City - Beenleigh area, and the Coomera River passing around Canungra, Coomera and Oxenford. The Condamine River forms part of the Murray-Darling Basin, originating on Mount Superbus on the inland side of the Great Dividing Range, flowing northwest across the Darling Downs, then west. Similarly for the Logan River, a recent confirmed recapture of a relatively small specimen indicates they are still present in that river.

##### **6.5.1. Logan/Albert/Coomera and Condamine population status**

Whether the Australian lungfish persists in the Logan/Albert and Coomera River systems remains uncertain. Johnson (2001) suggested the species was almost certainly absent from the Condamine River, however a recent reported capture of two individuals from the Condamine system in 2011 (species was later verified with the use of photographic records by DAFF staff, S. Brooks, pers. comm. 2012) may indicate the species occurs in low numbers within this river, though precise location of capture could not be confirmed.

## 6.6. Population structure

Genetic studies on Australian lungfish populations are limited and the little data that exists has focused on identifying broad population differences between existing populations. The level of diversity within populations, and the minimum effective population size remains unresolved. Allozyme and mitochondrial DNA samples were taken from 278 individuals from Mary, Burnett and Brisbane River populations. Limited genetic differentiation was detected among rivers suggesting that the Mary and Burnett populations mixed during periods of low sea level when the drainages may have converged before reaching the ocean. The status of the population in the Brisbane river is less certain, with some data indicating the Brisbane River population originated from individuals taken from the Mary River (Frentiu et al. 2001) while other evidence suggests there has always been a population of Australian lungfish in the Brisbane River (Lissone 2003).

Kemp (1986) argued that the Brisbane and North Pine populations are unlikely to have expanded from such a small number of translocated fish, and therefore probably form part of the historical distribution. A study investigating genetic variation at allozyme and mitochondrial DNA loci (Frentiu et al. 2001) reported that Australian lungfish were likely to be introduced to the Brisbane River from the Mary River. Conversely Randomly Amplified Fingerprints (RAF) on the total genomic DNA of Australian lungfish revealed evidence indicating the Brisbane River population had unique sequences (Lissone 2003).

Given persisting uncertainty regarding origin of a number of populations, a key research priority should be to confirm which populations are natural and which are translocated. This is based largely on the assumption of likely low expected levels of genetic variation within translocated populations, and consequent assumed low conservation value. Given the inconsistency in findings regarding origin of the Brisbane River population, and possibly also the North Pine River population (Frentiu 2001), it is considered precautionary to view these populations as natural populations until this can be confirmed.

Frentiu et al. (2001) suggests that post-bottleneck recovery of Australian lungfish populations was most likely slow given the long generation time of the species (Brooks & Kind 2002) and the high predator vulnerability of juveniles (Bancroft 1928). Low genetic variation may lead to inbreeding depression, population decline, reduced evolutionary potential and high extinction risk (Frankel and Soulé 1981, cited in Arthington 2009). Brooks & Kind (2002) further suggested the species may potentially be vulnerable to introduced diseases and recommended that in order to achieve the goal of preserving the limited amount of genetic variation still evident in Australian lungfish populations, management actions should aim to maintain high adult survival, limit the loss of suitable spawning habitat and provide for suitable passage throughout the Burnett River system.

## 6.7. Spatial management units

Several populations within each catchment could be defined as spatially distinct enough to justify separate management requirements. At a broad scale, genetic information has demonstrated some degree of structuring or distinctiveness among catchments but the degree of within catchment variation is unknown. Much of the spatial isolation within catchments is artificial and results from dam construction which has isolated important refuge habitats. Certain characteristics of each management unit include areas of known spawning sites, areas of critical habitat, unregulated reaches or sites of recent recruitment.

A number of actions within this plan relate to identifying Spatial Management Units, as well as gaining an understanding of their structure and dynamics with a focus on species rehabilitation. The most obvious of these is the need to identify the degree of genetic structuring among the two (possibly three) endemic Australian lungfish populations in the Mary and Burnett Rivers (and possibly also Brisbane River). Present management of populations in the Mary, Burnett and Brisbane River catchments therefore focuses on several mitigation programs aimed at the catchment level and include:

1. Construction and maintenance of fishways to facilitate movement;
2. Targeted pest species eradication programs;
3. Protection of critical habitat areas;
4. Protection of spawning sites; and,
5. Water management practices.

Australian lungfish populations in other catchments have unique attributes that require preservation because of the unique threats located in each catchment. Spatial management of existing populations should therefore occur within each catchment within the known distributional range.

### **6.8. Populations under threat**

All known Australian lungfish populations are considered under threat given the uncertainty surrounding their population status in the different river systems, and the possible long-term consequences from a range of threats. Many active threats are contributing to population declines and most occur at the catchment scale such as land clearing, pesticide use and irrigation abstraction which influence water quality. Others threats such as large dams, migration barriers, pest species introduction, river regulation and stepped spillways occur at the reach scale and could put isolated populations at risk. Identification of threatened populations allows for the development of targeted management interventions to minimise risks associated with each threat. Many of the threats identified impact on many/all known populations (Table 1).



**Table 1 Summary of Australian lungfish populations under serious threat**

Catchment	Most significant threats
Burnett	Flow regulation, barriers to movement and potentially introduction of predatory species are the key threats to this population. Inappropriately-operated fishways have been identified as a potential cause of restricted population mixing and the construction of stepped spillways has been demonstrated to kill fish attempting downstream migrations during high flow events (DEEDI 2012). Introduced predatory species such as gambusia ( <i>Gambusia holbrooki</i> ) and tilapia ( <i>Tilapia mariae</i> and <i>Oreochromis mossambicus</i> ) prey upon eggs and recruits. Chemical runoff and siltation from surrounding farms is also a potential problem in the Burnett River (Tucker et al. 1999). Limited availability of suitable spawning habitat may also be a factor over time.
Mary	Habitat degradation and flow regulation are key threats for this population, in addition to possible future increases in fragmentation from damming. Stocking of predatory species may also be a threat, however supporting information is not available to confirm this. Proliferation of aquatic weed species, which can out-compete natural species, is a further threat which could modify important natural habitat.
Brisbane and North Pine	Low genetic diversity, lack of appropriate spawning habitat (within specific reaches), competition/predation by introduced species (especially Tilapia and Banded grunter ( <i>Amniataba percoides</i> )), marine stranding (below North Pine Dam) are key threats for these populations. An increased threat arises from controlled flood mitigation measures which cause rapid changes in water levels and stranding. These pose the greatest risks in the Brisbane and North Pine.
Logan/Albert, Coomera and Condamine Rivers	These populations are not well understood, however likely threats would include habitat degradation and introduction of pest species.

## 7. Habitat

Australian lungfish are potamodromous, meaning that they complete their lifecycle entirely within freshwater habitats and are known to occupy tributary, river mainstream, and impounded reaches. The species is restricted to areas of permanent water (Brooks & Kind 2002) and cannot live in saline waters or migrate through sea water (Pusey et al. 2004, Gunther 1871).

Structural complexity is an important habitat characteristic for both juvenile and adult lifestages (Kemp 1984, 1987, 1995, Brooks and Kind 2002, Kind 2002). Submerged aquatic plants are an important habitat feature for breeding grounds, nursery areas and adult foraging zones (Kind 2002). Australian lungfish are reported to show particular preference for shallow, dense beds of species including *Vallisneria spiralis*, *Vallisneria gigantea*, *Hydrilla verticillata*, *Ludwigia peploides*, *Nymphaea* and *Nymphoides* (Kind 2002). Woody debris is also believed to be important to Australian lungfish, particularly sub-adult individuals (Kind 2002), though are not utilized as extensively as macrophytes habitats. Partially-submerged riparian vegetation, undercut banks, and rocks also offer shelter in heavily populated reaches (Brooks and Kind 2002, Kind 2002, Kemp 1995).



Australian lungfish appear particularly selective of spawning habitat. Breeding occurs from August through to December in shallow runs and along river margins in close proximity to aquatic vegetation. Eggs are laid amongst dense beds of submerged macrophytes, with highest densities reportedly requiring intermediate flows (0.2 metres per second), low turbidity, high dissolved oxygen, depths of 40 – 60 cm (Brooks and Kind 2002). These preferred spawning habitats are highly susceptible to changes in flow and water quality and can vary in geographical location among years.

Steep banks and deep water typical of impoundments do not provide suitable conditions for Australian lungfish (Kind 2002) because these conditions do not favour growth of extensive macrophyte beds, which are the key habitat feature necessary for foraging and reproduction in Australian lungfish (Kind 2002; Brooks and Kind 2002). It should be noted that woody debris and deep water does appear to provide suitable refuge sites for adults, and spawning has even been observed within impoundment habitats. These few documented examples do not appear to have resulted in successful recruitment (Brooks and Kind, 2002; Kemp 2011).

Availability of suitable spawning habitat appears to be a significant factor limiting recruitment which is always reported to be low. Poor recruitment is known to be associated with limited macrophyte abundance following high flow (Arthington, 2009). Aquatic macrophyte presence and density can vary significantly within any given catchment both between and among years, in response to variables such as flow, turbidity, and season. It is therefore not considered appropriate to map critical habitat for Australian lungfish. Rather, it is more useful to identify specific reaches where critical habitat is known to be present most frequently and could contain critical habitat given suitable environmental conditions.

## 8. Habitat critical to survival

As all known populations of Australian lungfish are considered under threat, habitat critical to the survival of the Australian lungfish includes:

- Any breeding or foraging habitat in areas where the species occurs (as defined by the distribution map provided in Figures 1-4); and
- Any newly discovered breeding or foraging locations.

## 9. Risk assessment for potential threats to Australian lungfish

Assessment of risk involves consideration of the range of potential consequences presented by a given threat, and how likely those consequences are to occur. Consequence and likelihood are combined to produce an estimated level of risk associated with the particular threatening process in question. The risk assessment process used for this plan was developed in accordance with the Australian Standard AS/NZS 4360:2004 Risk Management, HB 436:2004 Risk Management Guidelines and HB 203:2006 Environmental Risk Assessment – Principles and Process.

### Likelihood Assessment (defining the likelihood of an event occurring)

Terms used to describe the likelihood of an event occurring and an interpretation of their meaning are tabled below:

Likelihood term	Event is known to occur or would be expected to occur
Occasional	Event may occur
Possible	Event would be unlikely to occur (evidence to suggest it is possible)
Unlikely	Event would occur rarely (uncommon but known to occur elsewhere)

Rare	Event would occur very rarely (in exceptional circumstances)
Remote	Chance of event occurring is so small it can be ignored in practical terms (never heard of but not impossible)

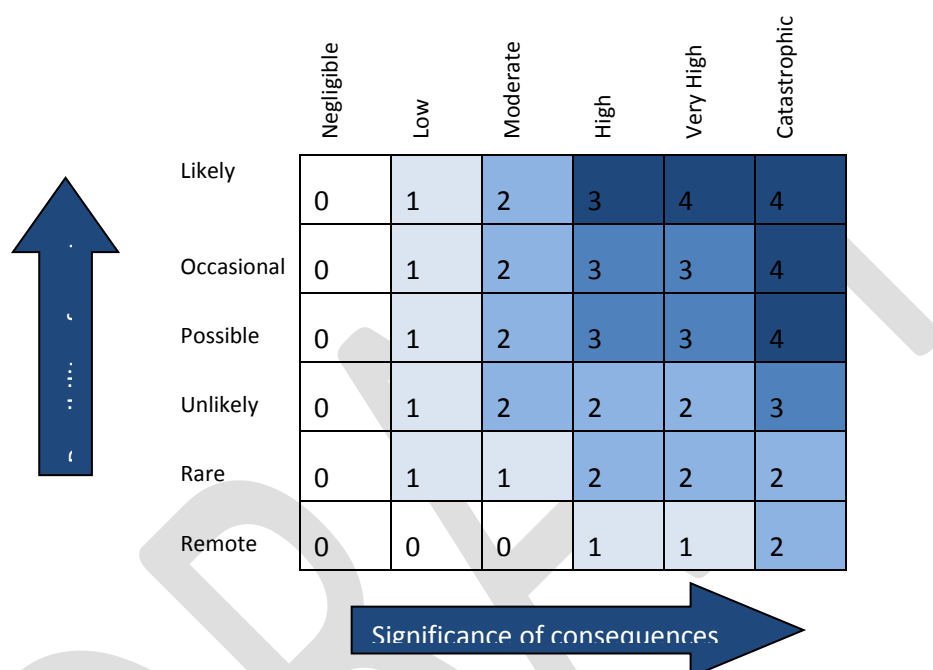
### Consequence Assessment (defining the consequences of an event occurring)

Terms used to describe the severity of the expected impacts (level of significance) are tabled below:

Level	Ecological Consequence
Negligible	Insignificant impacts to populations. Unlikely to be measurable against background variability. Interactions may be occurring but it is unlikely that there would be any change outside of natural variation. No recovery time needed.
Low	Possibly detectable but little impact on population size and none on dynamics. Rapid recovery would occur if stopped, measured in months.
Moderate	Level of interaction/impact at maximum acceptable level. Long-term recruitment/dynamics not adversely affected. Recovery probably measured in months to years if stopped.

High	Level of impact above maximum acceptable level. Would affect recruitment levels of the species or their capacity to increase in numbers. Recovery measured in years if stopped.
Very High	Likely to cause local extinctions if continued. Recovery period measured in years to decades if stopped.
Catastrophic	Local extinctions are imminent/immediate. Long-term recovery period to acceptable levels will be greater than decades or never, even if stopped.

### Risk evaluation matrix – potential impacts



### Risk analysis for the activity

A risk analysis was undertaken for each threat identified. This involved assessing available information to determine the likelihood and consequence of each threat according to the Risk Assessment Matrix. The results from the Risk Assessment Matrix (0 to 3) are summarised and discussed below.

### Risk Ranking Outcomes

Risk	Level of impact	Management response
0	Negligible	Nil
1	Low	None specific/manage by routine procedures
2	Moderate	Continue current arrangements/management responsibility must be specified
3	High	Probable increase to management/senior management attention required
4	Extreme	Substantial additional management required/immediate action required

(Source Kind et al. 2008)

## 10. Threats

### 10.1. Instream barriers

**(Threat Ranking: High)**

Man-made barriers to Australian lungfish movement such as dams, weirs and culverts are common throughout the distribution of Australian lungfish but only a small proportion are fitted with suitable fishways which are yet to be demonstrated as fully effective for Australian lungfish. Barriers to fish movement prevent individuals from accessing suitable spawning habitat and restrict the potential for gene flow within catchments. Dams and weirs featuring design characteristics including stepped spillways and steep faces with shallow associated plunge pools are known to result in physical damage to Australian lungfish as they move over these structures during flow events (DEEDI 2012, Kind 2002, Brooks and Kind 2002, Stuart and Berghuis 2002). Australian lungfish are known to move over weir and dam walls and become stranded in estuarine waters or separated from preferred habitats (for details refer to description of threats). Stranding of adults, juveniles, eggs and larvae can also occur as a result of water drawdown. In the case of stepped spillways, mortalities have been reported during all flows (DEEDI 2012). DEEDI (2012) suggest that the cumulative effect of mortalities of Australian lungfish passing over the stepped spillway on Paradise Dam is likely to be major over the longer term. Further, large spillways at Lake Wivenhoe, Samsonvale and Enoggera, which are not stepped, are also known to lead to substantial Australian lungfish mortality events. Whilst the extent of damage to Australian lungfish populations caused by large barriers within other catchments is unknown, it is also likely to be significant.

Tidal barrages that divide fresh and saline water also lead to stranding of Australian lungfish in estuarine waters and other isolated river sections. Marine stranding is a common occurrence in the Burnett River (Brooks and Kind 2002, Stuart and Berghuis 2002), Mary River (Berghuis 2001), Enoggera Creek (Kemp 1986) and the North Pine River (DAFF unpublished data). Australian lungfish are intolerant of elevated salinity and rarely survive in this situation. There is also evidence that Australian lungfish accumulating below migration barriers experience substantial declines in condition (DAFF unpublished data).

### 10.2. Regulated flows

**(Threat Ranking: High)**

Flow regimes within the natural distribution of Australian lungfish have been significantly altered by river regulation. Numerous dams and weirs have been built, particularly within the Burnett, Mary, North Pine and Brisbane catchments. The construction and operation of water storage infrastructure has altered the volume, frequency, duration and timing (seasonality) of riverine flows. Permanently flooded and fluctuating water levels make it difficult for macrophytes to establish within impounded areas. Altered flow can also significantly impact on growth and condition of macrophyte beds downstream of barriers. It should be noted however that provision of consistent flows can also provide ideal conditions for proliferation of submerged macrophytes downstream, and consequently suitable habitat for Australian lungfish (e.g. Brisbane River downstream of Lake Wivenhoe, S. Brooks pers. comm. 2012). But it is also important to provide sufficient flow during periods of drought. In general however, there is evidence that flow regulation has led to increased fluctuations in water level, reduced water volumes, reduced habitat for fish, stranding of adults, exposure and desiccation of eggs, permanent inundation of critical habitat and changes in Australian lungfish movement patterns.

Many of these impacts to Australian lungfish populations associated with regulation of flows are also likely to be further exacerbated under future climate change scenarios (Hobday and Matear 2005).

Australian lungfish are also physically-extracted from the river by pumps and injured in the process, particularly at the Mount Crosby Pump Station Intake. Extraction by pumps is known to occur with other species elsewhere such as the Murray-Darling Basin where significant losses of native fish have been documented (Baumgartner et al., 2006).

### **10.3. Habitat degradation/reduced water quality**

**(Threat Ranking: High)**

Juvenile and adult Australian lungfish rely on complex underwater habitat, predominately macrophyte beds, woody debris and undercut banks for foraging and shelter (Kemp 1986, Kind 2002, Brooks and Kind 2002). Degradation of these habitats can occur via numerous causes including livestock trampling, de-snagging, erosion, flow modification, increased sedimentation, and land clearing. Livestock watering and drinking in shallow reaches can trample Australian lungfish eggs and breeding habitat (DAFF unpublished notes). Stock access is widespread throughout the distribution of Australian lungfish, in both impounded and riverine areas. This is a cause of significant bank slumping, erosion, increased turbidity and degraded habitat. Reduced habitat availability is likely to expose juveniles to increased predation. The distribution of high quality Australian lungfish habitat and potential breeding sites is documented to some extent for some sections of the Burnett and Brisbane Catchments, but poorly understood elsewhere.

Australian lungfish also have highly specialised breeding requirements incorporating shallow waters with dense macrophyte cover. The construction of water storages has resulted in the loss of breeding habitat and current evidence suggests that habitat within impoundments is sub-optimal for Australian lungfish breeding (Brooks and Kind 2002, Kemp 2011). Loss of breeding habitat has the potential to impact on recruitment levels and the capacity for Australian lungfish to increase in numbers. All extant populations are dominated by mature individuals with few smaller recruits recorded.

A reduction in water quality from changes to parameters such as dissolved oxygen, temperature, pH, salinity and waterborne toxins can negatively impact on Australian lungfish growth and egg development. Increased salinity is an issue for many inland river catchments and the Burnett and Mary Rivers have been identified in the National Action Plan for Salinity and Water Quality as one of the 21 areas most affected by salinity and water quality problems in Australia. Increased salinity could have major effects on Australian lungfish due to their intolerance for saline conditions. The sub-lethal impacts of salinity and effects on early stages are poorly understood. Increasing river salinity could therefore be expected to have a detrimental effect on Australian lungfish populations. Water drawn from the lower levels of impoundments is often low in oxygen, substantially cooler and in new impoundments or those that have recently filled may be acidic with high levels of hydrogen sulphide. Poor water quality during releases is known to impact on fish and habitat downstream of many impoundments throughout the world and has impacted on spawning habitat within the Burnett River.

Increased sedimentation and turbidity due to erosion and runoff can affect river productivity and thereby reduce macrophyte growth that is important breeding habitat. Increased suspended particles can lead to smothering of eggs and substrates essential for spawning, refuge and feeding. Observational data suggests that no eggs are found on macrophytes that are covered in fine sediment (S. Brooks pers. comm. 2012).

## 10.4. Introduced native and non-native invasive species

### (Threat Ranking: Medium)

Native fish have been introduced widely throughout the distribution of Australian lungfish to enhance recreational fishing opportunities (Hollaway and Hamlyn 2001). In most areas stocking occurs annually for Australian Bass (*Macquaria novemaculeata*), Saratoga (*Scleropages jardinii*), Golden Perch (*Macquaria ambigua*), Silver Perch (*Bidyanus bidyanus*) and Barramundi (*Lates calcarifer*). The impacts of stocked fish on Australian lungfish are poorly understood. Many recreationally-valued stocked species are predatory and may prey on juvenile Australian lungfish or eggs, however there is no conclusive evidence to demonstrate the extent of this threat. Introduced species also increase the threat of competition for food and habitat or disturbance to spawning habitat and spread of disease and parasites.

The noxious, non-native *Oreochromis mossambicus* (a species of Tilapia) occurs widely in the Brisbane River Catchment, where it coexists with Australian lungfish. The species has also become established in Boondooma Dam within the Burnett River Catchment. Tilapia are a highly invasive group of species and disturb macrophyte beds when making their nests, which could reduce the availability of suitable Australian lungfish breeding habitat. However, no evidence is currently available to confirm negative impacts of Tilapia on Australian lungfish populations. The noxious European carp (*Cyprinus carpio*) is also widespread in parts of Queensland, but has not yet established any populations within the distribution of Australian lungfish outside the Brisbane River.

Noxious aquatic weeds such as water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*) and cabomba (*Cabomba caroliniana*) and others are already present within the distribution of Australian lungfish and are widespread in some sections. Floating weeds cover the water surface, leading to reduced temperature and oxygen levels in the water below, inhibiting the growth of submerged plants used for spawning by Australian lungfish. Likewise, submerged weeds with dense growth forms such as cabomba and dense water weed (*Egeria densa*) are not suited to Australian lungfish spawning. Limited weed removal programs are currently in place.

## 10.5. Fishing and boating activities

### (Threat Ranking: Medium/Low)

Australian lungfish are listed as a 'no take' species under the *Fisheries Act 1994*. Despite this status, fishing competition data and other reports confirm that incidental capture of Australian lungfish occurs in the recreational fishery (S. Brooks pers. comm. 2012). Interviews with local residents indicate that some Australian lungfish may still be taken illegally for human consumption or for use as pet food (S. Brooks pers. comm. 2012). Discarded carcasses have been found on river banks at popular angling sites (Kind 2002, DAFF unpublished data). The extent of illegal take has not been quantified, and no data are currently available on the post-release survival rate of Australian lungfish taken by recreational anglers.

Australian lungfish deaths from boat strike have been observed in the lower reaches of the Burnett, Mary and Brisbane Rivers (DAFF unpublished data). This artificially increases adult mortality rates, however the extent of mortality from this occurrence is currently poorly understood.

## **10.6. Specific threats impacting on Burnett population**

There are currently 25 instream water storages in the Burnett catchment (Brooks and Kind 2002). Three threats specific to damming were recently highlighted as a substantial conservation concern for Australian lungfish. Firstly, stepped spillways are known to increase mortality during downstream passage (DEEDI 2012). Secondly, the provision of a fishway to provide passage for Australian lungfish was deemed inappropriate under certain operation conditions. And thirdly, there is a need to ensure appropriate operation and maintenance of fishways post construction, to maximise benefits to target species provided fish can locate the entrance.

Marine stranding is a common occurrence in the lower Burnett River following flow events where fish are flushed downstream and trapped by tidal barrages (DAFF, Sun Water unpublished data). There is also little suitable Australian lungfish breeding habitat between the Ben Anderson Barrage (AMTD 25.9 km) and Ned Churchward Weir (Brooks and Kind 2002). Australian lungfish apparently struck by boats suggests that high boat traffic in this region may impact local populations.

Changes in aquatic macrophyte populations were described with respect to the effects of water level fluctuations and possible impact (Duivenvoorden, 2008). Severe water level fluctuations were observed to destroy natural vegetation stands, thus eliminating the required cover for Australian lungfish to spawn. The two major causes of vegetative die back were inundation for extended periods (causing decomposition) or exposure which caused recruitment failure of seedling plants. Monitoring vegetation cover prior to the spawning season and then using this information to essentially manage water levels within the Burnett River was discussed as a potential mechanism to protect spawning habitat at critical times of year.

## **10.7. Specific threats impacting on Mary population**

The major threat to connectivity in the Mary population is the future construction of main channel barriers. At present the Mary River main channel is largely undeveloped; 11 storages were present within the Mary River system in 2002, with most barriers located on tributaries. The Mary River tidal barrage at AMTD 59.3 km and Gympie Control Weir at AMTD 179.5 km are currently the only major barriers on the main river channel (Kind 2002). Installation of additional barriers throughout the system would increase threat of population fragmentation for this species.

Marine stranding is a common occurrence following flow events where fish are flushed downstream and trapped in marine sections.

Habitat throughout much of the Mary River catchment has been degraded as a result of various land use practices, with the State of the Rivers report for the Mary River catchment (Johnson 1997) describing riparian vegetation as very poor for 40% of the stream length, and poor for a further 23%. The majority of streams in the catchment were also ranked as moderate to poor in terms of channel diversity and aquatic habitat (Johnson 1997). Loss of riparian vegetation has a number of consequences. Firstly, overhanging riparian vegetation has been identified as one of the preferred habitats for Australian lungfish in the Mary River, with individuals of all lifestages noted to utilise the structural complexity of partly submerged vegetation and the shadow offered by riparian vegetation (Kind 2002). Reduction of this important habitat is consequently thought to increase intraspecific competition within the remaining patches (Kind 2002). Secondly, loss of vegetation results in increased soil erosion and land slippage, and this has been identified as a particular issue for this catchment (Johnson 1997), with riverbank and gully erosion identified as the source of 87% of



sediment entering the Mary River (DeRose et al. 2002). The State of the Rivers survey found that the two predominant human factors affecting bank stability were stock (57% of sites) and clearing of vegetation (43% of sites) suggesting that riparian restoration involving removal of stock and re-vegetation would mitigate soil erosion. Land clearing has increased siltation and loss of optimal spawning habitat in the Mary catchment.

Stocking of recreationally-important fish species may pose a threat to Australian lungfish populations, with regular introductions of piscivorous (fish eating) species such as Barramundi and Australian bass potentially increasing predation impacts on juvenile Australian lungfish. There is currently no data available to indicate the likely frequency of predation, preventing consideration of potential population impacts. Given that these species co-exist under normal circumstances it is most likely that any adverse interactions would arise from instances where densities of stocked fish are increased to unnatural levels. Further research is required.

### **10.8. Specific threats impacting on Brisbane River population**

Managed flow released into the Brisbane River provides constant flows (to supply water to Brisbane), which facilitates macrophyte growth and high natural recruitment of Australian lungfish downstream of Wivenhoe Dam. Constant releases from Wivenhoe Dam, in conjunction with active control efforts from councils and Seqwater, prevent large infestations of Water Hyacinth and provide sufficient conditions for native vegetation to grow. A major threat to this Australian lungfish population is flood mitigation, post flood stranding and low flows during drought periods. Given the middle Brisbane River receives flows from the heavily-utilised Lockyer Valley agricultural area and also has salinity hot spots that drain directly into the river channel, flooding may result in decreased water quality and impact negatively upon the species.

Food availability in Wivenhoe Dam may be limited during periods of variable water levels which may impact viability of spawning adults (Kemp 2011). In addition, refuges for young fish do not exist when water level fluctuates, especially in spring when Australian lungfish are spawning. Lack of small fish refuges has been identified as a possible danger to recruitment of young Australian lungfish to the adult population. Eggs and embryos found in unaltered reaches of the Brisbane, when compared to those collected in Lake Wivenhoe were atypical to fish collected in previous decades (Kemp, 2011). Inability to provide conditions to suit optimal development of eggs in broodstock is therefore considered a potential threat to upstream populations.

### **10.9. Specific threats impacting on North Pine River population**

A major threat for the North Pine population is a lack of suitable spawning habitat upstream and downstream of the dam itself. In the long term this may lead to population extinction arising from recruitment failure. Recent surveys conducted at the end of a drought period suggest that upstream populations are dominated by large individuals and juveniles are never collected (S. Brooks pers. comm. 2012). Whether this is a persisting issue or artefact of drought conditions is unresolved but warrants further monitoring to ascertain long term population changes. Kemp (Unpublished data) suggests that similar processes impacting upon the Lake Wivenhoe population also exist in Lake Samsonvale.

The North Pine Dam is known to impact adult fish that move downstream with spillway flows and cannot return. The amount of available habitat for Australian lungfish downstream of the dam is limited by increasing salinity, and adult fish are known to congregate in extremely high densities below



the dam wall. These threats could be mitigated by improving downstream habitat or providing an upstream migration pathway, possibly through the construction of a fishway.

Tilapia is an invasive species which has recently invaded the Pine River catchment. Strategies to limit the spread of Tilapia and prevent further incursions would limit potential impacts on Australian lungfish.

## **11. Recovery objectives and strategy for recovery**

### **Overall Objective**

Enhance Australian lungfish populations throughout the range of the species (particularly naturally occurring populations within the Burnett, Mary, Brisbane and North Pine River catchments) to a point where there can be assurance that the species no longer meets the criteria for listing and can be delisted from the national threatened species list under the EPBC Act.

### **Specific objectives**

1. Reduce the impacts of, and remove any redundant, artificial barriers
2. Manage waterways to optimise breeding and recruitment opportunities
3. Limit habitat degradation and maintain or enhance water quality
4. Reduce the impacts of introduced pest and weed species
5. Manage the impacts of water-based recreational activities
6. Address key knowledge gaps to improve Australian lungfish management
7. Facilitate high levels of community participation and support in the implementation of Australian lungfish management strategies

The overall strategy for recovery of Australian lungfish will be to investigate its status in the context of key biological and ecological attributes such as current distribution and population structure, recruitment, movement, habitat and flow requirements. Existing mitigation programs which are being developed at the catchment level must then seek to gain institutional and community support for conservation efforts through education and awareness, and targeted rehabilitation programs involving community groups (such as Landcare).

Recovery actions will need to be population-based in the first instance because genetic data has suggested some degree of natural structuring among catchments. The recovery program for Australian lungfish must also involve developing and implementing target actions specific to known populations under threat, and be accompanied by a targeted monitoring and assessment program that is adaptively managed to determine the overall impact of threat abatement programs. Long-term datasets will be important for assessing the adequacy of rehabilitation efforts and plotting recovery trajectories to adaptively change strategies when required.

## **12. Recovery actions, performance criteria, actions and priorities**

Many actions are required to ensure recovery within each of the populations of Australian lungfish (Table 2). It should be noted that the list of potential contributors for each action are suggestions only, and need to be confirmed through consultation. A total of 34 actions are recommended, of which 17 have been ranked as high priority.

Prioritisation of actions was undertaken through application of a qualitative ranking system based on whether an action addresses a high priority threat, and the degree to which each action is likely to reduce the level of that threat.

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Table 2 Recovery objectives, performance criteria and actions required throughout the distribution of Australian lungfish

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
1. Reduce the impacts of, and remove any redundant, artificial barriers.	1.1. Reporting is undertaken on all new waterway barriers and details of fishway design so that this information may be accessed for the purposes of analysing progress of this recovery plan.	<p><b>1.1.1. Ensure that new waterway barrier works comply with fish passage requirements contained in the Fisheries Act 1994.</b></p> <p>The <i>Fisheries Act 1994</i> requires that a person must not construct or raise waterway barrier works without making adequate provision for fish movement across the barrier. In the case of permanent or long-term temporary barriers where fish passage is not adequately provided by other means, one or more fishways may be necessary. The proponent must demonstrate that the proposed fishway design will adequately provide for fish movement. Approval conditions may be applicable to the design or construction of a fishway; and/or, monitoring or operation of a fishway. Non-mechanical fishways are preferred over mechanical due to better withstanding flood damage.</p>	Department of Agriculture, Forestry and Fisheries (Qld) (DAFF), Coordinator General, local councils, water infrastructure operators, regional NRM groups and catchment bodies.	Burnett, Mary, Brisbane, Nth Pine.	High
	1.2. Existing barriers are described and assessed. Potential mitigation measures are documented and implemented at priority sites.	<p><b>1.2.1. Document artificial barriers to Australian lungfish movement and develop potential mitigation measures.</b></p> <p>A large number of man-made barriers to fish passage are located within the distribution of Australian lungfish. Only a small proportion of these barriers incorporate a working fishway. It is recommended that a report be compiled documenting the location and details of these barriers. The report should describe the likely impacts of each barrier and potential mitigation measures that may be applied and prioritise the areas where mitigation measures would have largest impact on the recovery of the Australian lungfish. Information supplied within the Burnett-Mary Regional Biopassage Strategy (Stockwell et al. 2008) should be used as a starting point for this action.</p> <p><b>1.2.2. Implement mitigation measures at priority sites to minimise impacts from artificial barriers as recommended by the report developed under 1.2.1.</b></p>	NRM regional bodies, consultants, water infrastructure operators, DAFF, Coordinator General, NGO's, regional NRM groups and catchment bodies.	Burnett, Mary, Brisbane, Nth Pine, Logan/Albert, Coomera, Condamine.	High

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
	1.3. The extent of injuries and mortality associated with Australian lungfish movement over barriers and stranding events has been identified and are reduced to sustainable levels.	<p><b>1.3.1. Develop and implement measures to minimise Australian lungfish stranding events.</b></p> <p>To achieve this action the following sub-actions need to be completed:</p> <ul style="list-style-type: none"> <li>• Develop a policy decision-making tree and response protocols describing options for minimising the occurrence of these events, reducing injuries and mortality associated with stranding and relocating stranded Australian lungfish. Incorporate development of suitable fish passage at the Burnett River and Mary River tidal barrages.</li> <li>• Early reporting of stranding by community members and development of practical capture methods needs to be investigated.</li> <li>• Identify natural and man-made pools that have the potential to strand Australian lungfish and implement strategies to manage them.</li> <li>• Develop irrigation water release strategies to allow for movement and spawning and recruitment requirements.</li> </ul>	DAFF, SunWater, other water infrastructure operators.	Burnett, Mary, Brisbane, Nth Pine.	High
		<p><b>1.3.2. Determine and minimise injury/mortality rates associated with stranding events and movements over weir and dam walls.</b></p> <p>Potential for more frequent flooding events and current recovery data indicates population loss to be significant, warranting mitigation and remediation as a priority. To achieve Action 1.3.2. the following sub-actions need to be completed:</p> <ul style="list-style-type: none"> <li>• Investigate the potential for injury to be modelled using Computational Fluid Dynamics.</li> <li>• Determine the need for further research and management responses using results of current studies.</li> <li>• Determine the rate of marine stranding events.</li> </ul>	DAFF, SunWater, other water infrastructure operators, universities, consultants.	Burnett, Mary, Brisbane, Nth Pine.	High

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
	1.4. The operation of fishways is optimised according to fishway and storage management plans.	<b>1.4.1. Produce detailed fishway and storage management plans</b> Produce individual fishway management plans detailing maintenance and operation requirements necessary to maximise the passage of Australian lungfish. These need to include scheduled shutdown and maintenance periods. Conditions of approval for new structures need to include the formulation of an appropriate fishway management plan. An important consideration is the development of strict operating protocols that include dam operations. An enforceable storage management plan that seeks to minimise any negative environmental impacts associated with the storage should be investigated.	DAFF, SunWater, other water infrastructure operators, universities, consultants.	Burnett, Mary, Brisbane, Nth Pine.	Med
		<b>1.4.2. Ensure compliance with fishway management plans.</b> Once fishway management plans are drafted and implemented it is important to ensure these are complied with. Collaboration of agencies responsible for management and operation of fishways is required to ensure operation is optimised to provide passage for the species at key times.	DAFF, SunWater, other water infrastructure operators, Coordinator General	Burnett, Mary, Brisbane, Nth Pine.	High
2. Manage waterways to optimise breeding and recruitment opportunities	2.1. Water resource planning processes incorporate Australian lungfish management plans and ineffective fishways are repaired so they do not impact on spawning and recruitment processes.	<b>2.1.1. Ensure that water resource planning processes recognise appropriate management plans for Australian lungfish and fishway operation.</b> Establish a technical working group to: <ul style="list-style-type: none"> <li>• ensure that water releases maintain Australian lungfish breeding habitat downstream of impoundments;</li> <li>• ensure adequate flows downstream of impoundments to prevent sediment build up on suitable breeding habitat;</li> <li>• maintain compliance; and,</li> <li>• investigate off-stream water storages as an option to help manage un-seasonal releases or provide a practical solution to water supply issues.</li> </ul>	DNRM, DEHP, DAFF, SunWater, other water infrastructure operators, Coordinator General	Burnett, Mary, Brisbane, Nth Pine.	High
		<b>2.1.2. Ongoing maintenance and repair of fishways</b> Heavy flooding frequently renders fishways ineffective due to water damage. In order to maintain the connectivity required via these structures it is essential to undertake regular maintenance and repair following flood events. Repair delays could impact spawning and recruitment processes.	DAFF, SunWater, other water infrastructure operators, Coordinator General	Burnett, Mary, Brisbane, Nth Pine.	High

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
3. Limit habitat degradation and maintain or enhance water quality	3.1. Key Australian lungfish habitat identified, protected and restored.	<b>3.1.1. Identify priority Australian lungfish breeding sites and key refugia for protection, restoration and management.</b> Describe priority Australian lungfish habitat from current knowledge and assessment criteria developed to identify priority habitat areas for protection, restoration and management.	DAFF, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.	Burnett, Mary, Brisbane, Nth Pine.	High
		<b>3.1.2. Identify and implement strategies to conserve key habitat.</b> On the basis of habitat areas identified in 3.1.1, consult relevant authorities, landholders and the community to identify potential habitat protection options and management measures for implementation. Implement feasible management measures. These may include fish habitat areas, closed areas etc. Commercial, residential and recreational stakeholder involvement is an important component of this action.	DAFF, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.	Burnett, Mary, Brisbane, Nth Pine.	High
	3.2. Damage caused by livestock in key habitat removed.	<b>3.2.1. Work with landholders/land managers to reduce livestock access to priority shallow river margin sites.</b> Explore options for reducing stock access in consultation with the community and landholders. These discussions should target priority breeding sites identified in 3.1.1 and concentrate on reducing stock access during the annual spawning season.	DAFF, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities, landholders.	Burnett, Mary, Brisbane, Nth Pine.	High
	3.3. Water parameters within storage facilities and during releases are consistent with levels required to support Australian lungfish populations.	<b>3.3.1. Maintain water quality in water storages and during releases.</b> Manage water storages to ensure that the quality of water released does not impact on either Australian lungfish or key habitat.	DAFF, SunWater, other water infrastructure operators, and Coordinator General	Burnett, Brisbane, Nth Pine.	Medium

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
4. Reduce the impacts of introduced species.	4.1. The extent of noxious aquatic weed infestations has been decreased within priority areas and areas where weeds may cause re-infestation.	<b>4.1.1. Expand existing aquatic weed removal programs.</b> Maintain and expand existing control programs for aquatic weeds. Programs should target key habitat identified in 3.1.1. but also be undertaken outside of key habitats, as they are often the source of new infestations. Identification and removal of source material through education and physical removal will help to reduce re-infestation of key habitats. Assess the impact and extent of submerged and emergent weeds and implement management practices. Restoration of natural riparian vegetation will reduce the opportunity for noxious weeds to become dominant. Involvement of all stakeholders will be important for the success of this action.	DAFF, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.	Burnett, Mary, Brisbane, Nth Pine.	Medium
	4.2. Public awareness of the impacts of pest species is increased within target areas of the Australian lungfish's distribution.	<b>4.2.1. Expand existing community education programs to target areas throughout the distribution of the Australian lungfish.</b> A number of community education programs already exist in relation to pest species management in Queensland. Expand these education programs into target areas throughout the distribution of Australian lungfish. Include information about why the Australian lungfish is a no-take species under the Fisheries Act 1994 (this links to action 5.1.1).	DAFF, Education Queensland, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.	Burnett, Mary, Brisbane, Nth Pine.	High
	4.3. Translocation of non-endemic fauna does not occur via water transfer.	<b>4.3.1. Control or screen water releases to prevent the translocation of non-endemic and pest species between and within catchments where feasible.</b> Ensure that all future pipelines and irrigation supplies are screened to reduce the risk of translocating non-endemic flora and fauna. A full range of control measures should be investigated including treatment as part of storage management plans.	SunWater, other water storage operators, DAFF, NRM regional bodies.	Burnett, Mary, Brisbane, Nth Pine.	Medium

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
	4.4. The impacts of fish stocking programs are understood and managed.	<b>4.4.1. Undertake research to improve understanding of the impact of stocking activities.</b> Research is required to improve the understanding of the impact of stocking other species of native fish, for recreational fishing purposes, into all major dams and weirs within the Brisbane, North Pine, Mary and Burnett Catchments. Conduct a review of fish stocking activities coinciding with the occurrence of Australian lungfish in consultation with key stakeholders and the community. Recreational stakeholder education and involvement is an important component of this action.	DAFF, FFSAQ, fish stocking groups, AAQ, hatchery operators, universities, consultants, Traditional Owners	Burnett, Mary, Brisbane, Nth Pine.	Medium
		<b>4.4.2. Develop and implement protocols (based on findings of 4.4.1) to minimise the risks from future fish stocking.</b> Protocols for fish stocking will be developed on the basis of the review described in 4.4.1 in cooperation with FFSAQ, fish stocking groups and the aquaculture industry. Recreational stakeholder education and involvement is an important component of this action.	DAFF, FFSAQ, fish stocking groups, AAQ, hatchery operators, NRM regional bodies, Traditional Owners.	Burnett, Mary, Brisbane, Nth Pine.	Medium
	4.5. Effective legislative control reduces the incidence of accidental and illegal release of non-endemic and pest species.	<b>4.5.1. Identify additional regulatory controls to reduce the spread of non-endemic and pest species.</b> Review further options for legislative controls to reduce the further spread and/or introduction of non-endemic and pest species. An increase in resources for enforcement will be required to achieve this action.	DAFF, SunWater, other water infrastructure operators.	Burnett, Mary, Brisbane, Nth Pine.	Medium
5. Manage the impacts of fishing and boating	5.1. The impacts of recreational fishing are understood and managed.	<b>5.1.1 Maintain the 'no take' status of Australian lungfish under the Fisheries Act 1994.</b> Australian lungfish are listed under the <i>Fisheries Act 1994</i> as 'no take species' throughout Queensland. The <i>Fisheries Act 1994</i> has provisions to prevent harvest of Australian lungfish and is supported by an established enforcement body, the Queensland Boating and Fisheries Patrol. Maintain this status to minimise the effects of recreational harvest. An important component of this action includes education which links to action 4.2.1.	DAFF	Burnett, Mary, Brisbane, Nth Pine.	High



Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
		<b>5.1.2. Estimate the extent of mortality from recreational angling.</b> The recreational catch of Australian lungfish and the associated injury / mortality rate should be estimated. Tagged Australian lungfish released during recreational fishing competitions could provide a mechanism to assess the post-capture survival rate from data gathered by fisheries independent Australian lungfish monitoring programs. The impact of habitat damage through bait collection in spawning areas should also be quantified.	DAFF, universities, other research providers, fish stocking groups, recreational fishing bodies, Traditional Owners	Burnett, Mary, Brisbane, Nth Pine.	Medium
		<b>5.1.3. Investigate the social and economic implications of additional fisheries management measures.</b> Investigate the possibilities of establishing additional recreational fisheries management measures, such as closing important breeding areas as identified in 3.1.1 to recreational fishing during the breeding season. Any proposed changes should be subject to extensive public consultation. Recreational stakeholder education and involvement is an important component of this action.	DAFF, FFSAQ, fish stocking groups, recreational fishing bodies, Traditional Owners, the community (via public consultation)	Burnett, Mary, Brisbane, Nth Pine.	Low
	5.2. The impacts of recreational water skiing and boating are understood and managed.	<b>5.2.1. Determine the extent of mortality associated with recreational boating.</b> The injury /mortality rate associated with boat strikes is presently unknown. These impacts could be estimated by distributing questionnaires or undertaking boat ramp surveys of recreational boat users within the distribution of Australian lungfish. Implement actions as necessary to abate threat. Recreational stakeholder education and involvement is an important component of this action.	DAFF, universities, other research providers, fish stocking groups, recreational fishing, water skiing and boating bodies, Traditional Owners	Burnett, Mary, Brisbane, Nth Pine.	Medium
6. Address key knowledge gaps to improve Australian	6.1. Key aspects of Australian lungfish biology are understood and incorporated into Australian	<b>6.1.1. Develop methods for ageing.</b> No reliable method exists to accurately age Australian lungfish. Confirmed age information would assist in identifying historical conditions leading to significant recruitment events. Commence a program of testing traditional and novel ageing methods with a view to documenting the age-structure for this species within each population.	DAFF, Universities, consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine.	High

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
lungfish management	lungfish management strategies.	<b>6.1.2. Implement long-term monitoring programs.</b> With the exception of a 10 year monitoring program in the Burnett Catchment, no ongoing programs are in place to document and monitor the structure of Australian lungfish populations. Implement ongoing monitoring programs to document Australian lungfish population dynamics and breeding behaviour in the Mary, Brisbane and North Pine Catchments, including Enoggera Reservoir.	DAFF, Universities, consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine, Coomera, Logan/Albert, Condamine.	High
		<b>6.1.3. Model population responses to alternate management arrangements.</b> Recruitment processes in Australian lungfish are poorly understood. Commence studies to estimate the minimum area of breeding habitat required to maintain positive recruitment levels. These studies should also examine the effects of overcrowding on Australian lungfish breeding success.	DAFF, Universities, consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine.	Low
		<b>6.1.4. Determine the impacts of poor water quality on recruitment.</b> Little is known about the effects of poor water quality on development of Australian lungfish eggs. Commence laboratory studies to test the tolerance of Australian lungfish eggs and juveniles to factors such as elevated salinity, reduced oxygen concentration and pH.	DAFF, Universities, consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine.	Medium
		<b>6.1.5. Determine habitat requirements, survival and dispersal patterns of juveniles.</b> Knowledge of all aspects of juvenile Australian lungfish ecology has long been identified as a major shortfall in understanding the recruitment process. In particular the effects of fluctuating water levels on habitat use, mortality and movements of juvenile Australian lungfish will require long-term targeted research.	DAFF, Universities, consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine.	Medium
		<b>6.1.6. Determine level of genetic variability within catchment populations to review appropriateness of current spatial management units.</b> There is a need to identify the degree of genetic structuring among natural populations. This will assist in determining whether management strategies are appropriately applied at the catchment scale or reach scale containing genetically-distinct populations.	DAFF, Universities, Private consultants, Interstate Fisheries agencies, other research providers.	Burnett, Mary, Brisbane, Nth Pine.	High

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
	6.2. Opportunities for Australian lungfish recruitment within impounded waters are improved.	<b>6.2.1. Commence development and testing of methods to maximise potential for Australian lungfish spawning in or near impoundments.</b> There is good evidence that impoundments provide sub-optimal habitat for Australian lungfish spawning and recruitment. Methods for improving spawning potential within and near impoundments should be initiated. Improvements in this area should not be viewed as a potential solution for habitat loss within existing high quality Australian lungfish sites as there are other negative impacts on the ecosystem that cannot be adequately mitigated.	Universities, DAFF, SunWater, other water infrastructure operators, Coordinator General, consultants, other research providers, NRM Regional Bodies, MRCCC, Traditional Owners	Burnett, Brisbane, Nth Pine.	Medium
	6.3. Key aspects of macrophytes are understood and incorporated into management strategies.	<b>6.3.1. Investigate ecology of aquatic macrophytes required for successful recruitment.</b> Initiate research to improve current understanding of the ecology of macrophytes, in particular environmental factors contributing to the establishment of suitable spawning habitat.	DAFF, SunWater, other water infrastructure operators, Universities, consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC.	Burnett, Mary, Brisbane, Nth Pine.	Medium
		<b>6.3.2. Investigate causes of aquatic weed proliferation.</b> The proliferation of aquatic weeds is known to have a large impact on individuals and habitat. Investigate environmental conditions that facilitate proliferation.	DAFF, SunWater, other water infrastructure operators, Universities, Private consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC.	Burnett, Mary, Brisbane, Nth Pine.	Low

Objectives	Performance Criteria	Actions	Potential contributors	Relevant population(s)	Priority
7. Facilitate high levels of community participation in the implementation of management strategies	7.1. Increased levels of community understanding of conservation and involvement in implementing the Australian lungfish management strategies.	<p><b>7.1.1. Encourage and promote community groups and local councils to participate in programs promoting Australian lungfish conservation and management.</b></p> <p>Many community groups, NGO's and NRM Regional Bodies are already taking a proactive role in promoting conservation and management. Review the current scope of these activities to facilitate a coordinated approach and identify further opportunities in this area.</p> <p>Local communities will be encouraged to participate in Australian lungfish conservation efforts including habitat restoration, monitoring and education programs. Issues to be specifically promoted would include but not be limited to:</p> <ul style="list-style-type: none"> <li>- safe handling and release of lungfish caught by recreational anglers</li> <li>- the importance of aquatic macrophytes in shallow water for breeding</li> <li>- safe bait collection practices</li> <li>- risks of boating to Australian lungfish</li> <li>- best practices for stock watering to avoid damage to riverine habitat</li> <li>- best practices for landholders for safe use and disposal of chemicals</li> <li>- control of noxious aquatic weeds</li> <li>- measures to mitigate dryland salinity</li> <li>- the importance of in-stream and riparian vegetation</li> <li>- water quality monitoring and improvement</li> <li>- riparian vegetation restoration</li> </ul>	NRM regional bodies, MRCCC, Traditional owners, local councils, conservation groups, other NGO's, DAFF, other local authorities.	Burnett, Mary, Brisbane, Nth Pine.	High
		<p><b>7.1.2. Develop protocols for ongoing liaison with the Burnett-Mary Traditional Owner Working Group and other indigenous groups to establish proactive ongoing roles for Traditional Owners in Australian lungfish conservation and management.</b></p> <p>Traditional Owners have indicated strong interest in future management and preservation of Australian lungfish through the Burnett-Mary Traditional Owner Working Group (TOWG). Implementation of this plan will require ongoing consultation with the TOWG and other indigenous communities and people to facilitate their participation in Australian lungfish management on country.</p>			Medium

### 13. Evaluating performance of the plan

This plan should be reviewed no later than five years from when it was endorsed and made publically available. The review will determine the performance of the plan and assess:

- whether the plan continues unchanged, is varied to remove completed actions, or varied to include new conservation priorities, or
- whether a recovery plan is no longer necessary for the species as conservation advice will suffice, or the species is recommended for removal from the threatened species list.

The review will be coordinated by Australian Government Department of the Environment in association with relevant Australian and state government agencies and key stakeholder groups such as non-governmental organisations, local community groups and scientific research organisations.

Key stakeholders who may be involved in the review of the performance of the National Recovery Plan for the Australian lungfish (*Neoceratodus forsteri*) include organisations likely to be affected by the actions proposed in this plan.

#### **Australian Government**

Department of the Environment and Energy

#### **Non-government organisations**

Sunwater

Recreational fishers and boat owners

Mary River Catchment Coordinating Committee

Other catchment committees within the range of the Australian lungfish

#### **Queensland government**

Department of Agriculture and Fisheries

Department of Natural Resources and Mines

Department of Energy and Water Supply

Department of Environment and Heritage Protection

Department of National Parks, Sports and Racing (Qld)

Relevant regional Councils and Catchment management groups

#### **Traditional Owners**

### 14. Australian Lungfish Recovery Team

Recovery teams provide advice and assistance in coordinating actions described in recovery plans. They may include representatives from organisations with a direct interest in the recovery of the species, including those involved in funding and those participating in actions that support the recovery of the species. Members are committed to the conservation of the species and the achievement of recovery objectives and implementation of recovery strategies.

The Australian lungfish recovery team has the responsibility of providing advice and coordinating the implementation of the recovery actions outlined in this recovery plan. The membership of this recovery team may include individuals with relevant expertise from Queensland State and local governments, Catchment management groups, environmental groups and Traditional Owners.



## 15. Implementation costs

The estimated cost of implementing actions in the recovery plan is \$18.67 million over ten years (Table 3). Costs associated with addressing high priority actions over the life of the plan are \$10.8 million. It should be noted that some of these actions are already in various stages of development or completion.

**Table 3 Proposed costs associated with implementation of recovery actions for the Australian lungfish**

Note: Any actions without costs allocated to them are un-costed as it was considered that existing positions and/or resources could be utilized to progress them.

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL	Priority
Administrative costs: Convene annual meeting of recovery team to evaluate performance	\$10,000	\$10,000	\$10,000	\$10,000	\$30,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$120,000	High
1.1.1. Ensure that new waterway barrier works comply with fish passage requirements contained in the <i>Fisheries Act 1994</i> .												High
1.2.1. Document artificial barriers to Australian lungfish movement and develop potential mitigation measures.	\$110,000	\$210,000									\$320,000	High
1.3.1. Develop and implement measures to minimise stranding events.	\$200,000	\$150,000	\$200,000								\$550,000	High
1.3.2. Determine and minimise injury/mortality rates associated with stranding events and movements over weir and dam walls.		\$115,000	\$115,000								\$230,000	High
1.4.1. Produce detailed fishway management plans.	\$120,000										\$120,000	Med

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL	Priority
1.4.2. Ensure compliance with fishway management plans.	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000	\$200,000	High
2.1.1. Ensure that water resource planning processes recognise appropriate management plans and fishway operation.	\$10,000	\$10,000	\$10,000								\$30,000	High
2.1.2. Repair existing fishways on Burnett River.	\$500,000	\$1,000,000	\$1,000,000	\$1,000,000							\$3,500,000	High
3.1.1. Identify priority breeding sites for protection, restoration and management.	\$115,000	\$115,000	\$115,000								\$345,000	High
3.1.2. Identify and implement strategies to conserve key habitat.	\$50,000	\$50,000	\$50,000	\$50,000							\$50,000	High
3.2.1. Minimise impacts of stock in shallow river margins.	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000	\$800,000	High
3.3.1. Maintain water quality in water storages and during releases.												Medium
4.1.1. Expand existing aquatic weed removal programs.	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$3,300,000	Medium
4.2.1. Develop education programs to stop the further spread of pest animals and plants within the distribution of Australian lungfish.	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000				\$210,000	High
4.3.1. Control or screen water releases to prevent the translocation of non-endemic and pest species between and within catchments.		\$300,000	\$300,000	\$300,000	\$300,000						\$1,200,000	Medium

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL	Priority
4.4.1. Undertake research to improve understanding of the impact of stocking activities.			\$220,000	\$120,000	\$120,000						\$460,000	Medium
4.4.2. Develop protocols (based on findings of 4.4.1) to minimise the risks of future fish stocking on Australian lungfish populations.					\$15,000	\$15,000					\$30,000	Medium
4.5.1. Identify additional regulatory controls to reduce the spread of non-endemic and pest species.												Medium
5.1.1 Maintain the 'no take' status of Australian lungfish under the <i>Fisheries Act 1994</i> .												High
5.1.2. Investigate the social and economic implications of additional fisheries management measures.		\$70,000	\$70,000	\$70,000							\$210,000	Low
5.1.3. Estimate the extent of Australian lungfish mortality from recreational angling.			\$130,000	\$120,000	\$90,000						\$340,000	Medium
5.2.1. Determine the extent of mortality associated with recreational boating.			\$300,000	\$300,000	\$150,000						\$750,000	Medium
6.1.1. Develop methods for ageing.		\$100,000	\$100,000	\$100,000							\$700,000	High
6.1.2. Implement long-term monitoring programs.	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$3,300,000	High
6.1.3. Model population responses to alternate management arrangements.						\$200,000	\$100,000				\$300,000	Low

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL	Priority
6.1.4. Determine the impacts of poor water quality on recruitment.						\$120,000	\$120,000				\$240,000	Medium
6.1.5. Determine habitat requirements, survival and dispersal patterns of juveniles.				\$50,000	\$50,000	\$50,000					\$150,000	Medium
6.1.6. Determine level of genetic variability within catchment populations to review appropriateness of current spatial management units.	\$100,000	\$50,000									\$150,000	High
6.2.1. Commence development and testing of methods to maximise potential for spawning in or near impoundments.		\$150,000	\$150,000	\$50,000							\$350,000	High
6.3.1. Investigate ecology of aquatic macrophytes required for successful recruitment.							\$80,000	\$80,000	\$80,000		\$240,000	Medium
6.3.2. Investigate causes of aquatic weed proliferation.					\$15,000	\$30,000					\$45,000	Low
7.1.1. Encourage and promote community groups and local councils to participate in programs promoting conservation and management.	\$26,000	\$38,000	\$38,000	\$38,000	\$38,000	\$38,000	\$38,000	\$26,000	\$26,000	\$26,000	\$332,000	High

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL	Priority
7.1.2. Develop protocols for ongoing liaison with the Burnett-Mary Traditional Owner Working Group and other indigenous groups to establish proactive ongoing roles for Traditional Owners in Australian lungfish conservation and management.	\$12,000	\$12,000									\$24,000	Medium
7.1.3 Educate landholders on measures to mitigate dryland salinity.		\$28,000	\$28,000	\$15,000							\$71,000	Medium
	\$2m	\$3.3m	\$3.73m	\$3.21m	\$1.6m	\$1.25m	\$1.14m	\$876k	\$876k	\$786k	\$18.67m	

## 16. Current management practices

As the Australian lungfish is protected under the EPBC Act, it is an offence to kill, injure, take, trade, keep, or move any individual without a permit in Commonwealth areas and Commonwealth waters. In addition, all listed threatened species are considered matters of national environmental significance (MNES), and any action that may have an impact on MNES must be referred to the Minister of the Environment for approval. The Department of the Environment and Energy, as the Australian Government Department responsible for administering the EPBC Act, maintains a suite of interactive tools that allow users to search, find and generate reports on information and data describing MNES, including the giant freshwater crayfish.

The Australian lungfish is also protected across its range in Queensland. Under the Queensland *Fisheries Act 1994*, the Australian lungfish is a no take species. The Australian lungfish is also a critical priority species for the State under the Back on Track Phase I species prioritisation framework (DERM, 2010).

The Australian lungfish is also included in Appendix II of the Convention on International Trade in Endangered Species (CITES). Appendix II contains species that are not necessarily threatened with extinction, but may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with the survival of the species in the wild. International trade in specimens of Appendix II species may be authorized by the granting of an export permit.

## 17. Social and Economic Issues and Impacts

Implementation of recommended actions could create adverse social and economic impacts, and care must be taken to ensure these are minimised whilst not compromising the effectiveness of Australian lungfish recovery efforts. Potential impacts are discussed below.

1. Water extraction occurs within each of the catchments throughout the distribution of Australian lungfish, and any actions that alter or reduce the amount of water available for allocation or extraction may have economic impacts for water users.
2. The recreational fishery is substantial within each catchment known to contain Australian lungfish. The State-wide Recreational Fishing Survey (2010) revealed that 26% of residents within the Wide Bay/Burnett Regions and 260,000 residents within the Brisbane region fish recreationally. Whilst Australian lungfish are not targeted by either recreational or commercial fishers, there is a low but unquantified level of incidental take. Implementation of seasonal or spatial closures limiting recreational fisher access may intermittently impact industries supported by recreational fishermen.
3. Impoundments stocked with recreationally important species could offer significant social and economic benefits to regional communities. Any action to limit stocking activities within the distribution of the Australian lungfish would influence fishermen and hatchery operators. It is noted that any amendment to fisheries legislation will require public consultation.
4. Recreational boat use is popular within the Mary, Burnett, Brisbane, and Coomera River catchments. Restricting boating activity to reduce incidence of boat strike would require extensive public consultation to minimize impacts on other interests.
5. A small number of Australian lungfish are sold legally to the aquarium trade, and it is not anticipated that actions described within this plan would impact on this industry.



6. Legislative provisions in the Queensland *Fisheries Act 1994* already require that fish passage be provided on all new barriers to fish movement in Queensland, but the implementation of the recovery plan may increase the impact of the existing legislation. Further, the presence of Australian lungfish in waterways may actually provide sufficient grounds to prevent construction of further dams or weirs which could financially impact upon contractors and end users of the water storage.
7. Implementation of actions to facilitate recovery of Australian lungfish populations such as riparian rehabilitation, livestock exclusion and provision of environmental flows may present short term economic implications, however these should be considered in the context of long-term benefits delivered to Australian lungfish populations.

## 18. Affected Interests

All catchments inhabited by Australian lungfish contain significant human population centres which use land in a manner that can influence the nearby aquatic environments. Consequently there is potential for implementation of actions described within the current plan to affect a variety of stakeholders.

Water resource planning in Queensland is administered by the Department of Natural Resources and Mines (DNRM) under the *Water Act 2000*. Plans for sustainable management of water supply are detailed in Water Resource Plans (WRP) published as subordinate legislation under the *Water Act 2000*. Rules for the use and management of water are encompassed in Resource Operating Plans (ROP). Services such as water infrastructure management and bulk water supply are provided largely by Sun Water, a Queensland government owned corporation. Within the Brisbane River catchment, major water storages are managed by Seqwater. Water storages in the Brisbane, North Pine, and Mary and Burnett catchments have been heavily stocked with native fish since the mid 1980's under a scheme administered by DAFF. Recreational fishing is now recognized as a major recreational activity in all three catchments within the distribution of Australian lungfish. DAFF prohibits harvest of Australian lungfish under the provisions of the *Fisheries Act 1994*.

Strong benefits may be achieved through authentic engagement with community groups to garner support for recovery initiatives for the Australian lungfish. Traditional owners have expressed strong interest in the ongoing conservation of the Australian lungfish, citing the benefits to general river health as positive outcomes that will be associated with the implementation of this plan. The Burnett/Mary Regional Group (BMRG) has facilitated the development of a Traditional Owner Working Group (TOWG), who has indicated an interest in ongoing proactive participation. Eve Mumewa Doreen Fesl, Elder of the Gubbi Gubbi people has stated publicly that Australian lungfish have sacred (totemic) value. The Gubbi Gubbi did not kill or eat Australian lungfish, but sought to ensure that it was protected from harm. Where possible, involvement of Traditional Owners (both from the Burnett/Mary region, and other catchment areas within the distribution of Australian lungfish) should be actively engaged in Australian lungfish management. Any management proposal with potential to affect indigenous interests (e.g. restrictions on fishing activities, declaration of protected areas) will require specific consultation via these sub-committees and other interested indigenous groups. There are also a number of other sectors of the community (including recreational fishers, boating enthusiasts, and primary producers) who offer potential to be strong advocates for recovery initiatives for this species if engaged effectively. A list of affected interests can be found in table 4.

## 19. Benefits for other species/ecological communities

The threats impacting on the Australian lungfish also impact on a number of other native species, and consequently the implementation of actions discussed within this recovery plan would offer benefit to a variety of species which live with Australian lungfish. In the Mary River catchment, Australian lungfish coexist with three other EPBC-listed aquatic species. The Mary River cod (*Maccullochella mariensis*) and the Mary River turtle (*Elusor macrurus*) are both listed as Endangered under the EPBC Act. The Mary River turtle is also listed as Endangered under the Queensland *Nature Conservation Act 1992* and ranked a critical priority under the DEHP policy initiative, *Back on Track*. Mary River cod are a protected species under the *Fisheries Act 1994* and ranked a high priority under *Back on Track*. The White Throated Snapping Turtle (*Elseya albagula*), which exists in both the Mary and Burnett River catchments, was listed as Critically Endangered under the EPBC Act in November 2014. Although the White Throated Snapping Turtle is currently listed as Least Concern in Queensland (*Nature Conservation Act 1992*) it is ranked as a high priority under *Back on Track*. Efforts to benefit Australian lungfish will also benefit these species.

The implementation of broad-scale interventions to recover the Australian lungfish, coupled with the collection of baseline data to monitor success of recovery measures will benefit other threatened aquatic species and communities occurring in association with Australian lungfish, particularly those species with similar habitat requirements and life history characteristics.

Table 4 Affected Interests

Organisation	Acronym	Type
<b>National</b>		
Department of the Environment		Australian Government
<b>Queensland</b>		
Department of Agriculture and Fisheries	DAF	State Government
Department of Natural Resources and Mines	DNRM	State Government
Department of Energy and Water Supply	DEWS	State Government
Department of Environment and Heritage Protection	DEHP	State Government
Queensland Treasury	QT	State Government
Department of State Development	SD	State Government
Department of Premier and Cabinet	QP&C	State Government
Department of National Parks, Sport and Racing	NPSR	State Government
Sun Water	SW	Bulk water supplier / infrastructure manager
South East Queensland Water	Seqwater	Bulk water supplier / infrastructure manager
Bundaberg Regional Council, North Burnett Regional Council, South Burnett Regional Council, Sunshine Coast Regional Council, Gympie Regional Council, Fraser Coast Regional Council, Cherbourg Aboriginal Shire Council		Wide Bay/Burnett Local Government
Brisbane City Council, Redland City Council, Ipswich City Council, Gold Coast City Council, Moreton Bay Regional Council, Somerset Regional Council		South east Local Government
Burnett Mary Regional Group, Condamine Alliance and SEQ Catchments		NRM Regional Bodies
Mary River Catchment Coordinating Committee	MRCCC	Regional Authority

Traditional Owners		
Conservation groups e.g. Queensland Conservation, Wide Bay Burnett Conservation Council		Community group
Freshwater Fish and Stocking Association of Queensland	FFSAQ	Fishing/Stocking group
Sunfish Queensland		Queensland Recreational Fishing Peak Body
Marine Queensland		Marine Queensland
Burnett Catchment Care Association		Community group
Private landholders		Members of the public
Aquaculture Association Queensland	AAQ	Industry peak body
Australia New Guinea Fishes Association		Community group
Canegrowers		Industry peak body
Waterskiers		Members of the public
Recreational fishers		Members of the public
Recreational boat owners		Members of the public
Aquarium trade/Australian lungfish breeders		Industry group

## References

- Arthington, A.H. (2009). Australian Lungfish, *Neoceratodus forsteri*, threatened by a new dam. *Environmental Biology of Fish* 84:211–221. DOI 10.1007/s10641-008-9414-y.
- Australian Government (2009). NRM MERI Framework. Australian Government Natural Resource Management Monitoring, Evaluation, Reporting and Improvement Framework. Australian Government.
- Bancroft, T.L. (1928). On the life history of *Ceratodus*. Proceedings of the Linnean Society of New South Wales, 53:315 – 317.
- Baumgartner, L.J., Reynoldson, N.K. and Gilligan, D.M. (2006). Mortality of larval Murray cod (*Maccullochella peelii peelii*) and golden perch (*Macquaria ambigua*) associated with passage through two types of low-head weirs. *Marine and Freshwater Research* 57:187–191.
- Berghuis, A. (2001). Migratory fish communities at the Mary River Barrage prior to upgrading of the fishway. Department of Primary Industries unpublished report for the Department of Natural Resources and Mines.
- Berghuis, A.P. & Broadfoot, C.D 2004. Downstream passage of fish at Ned Churchward Weir fishlock, Queensland Fisheries Service, Bundaberg, Report to the Dept. of State Development.: 18.
- Berghuis, A. (2012). Personal observation. Department of Agriculture, Forestry and Fisheries.
- Biology Online (2008). Macrophyte definition. <http://www.biologyonline.org/dictionary/Macrophyte> cleaving (accessed 6/9/12).
- Brooks, S. (1995). Short-Term study of the breeding requirements of lungfish (*Neoceratodus forsteri*) in the Burnett River with specific reference to the possible effects of the proposed Walla Weir. Unpublished report for the Queensland Department of Primary Industries.
- Brooks, S.G. and Kind, P.K. (2002). Ecology and demography of the Queensland lungfish (*Neoceratodus forsteri*) in the Burnett River, Queensland with reference to the impacts of Walla Weir and future water infrastructure development. Final Report, prepared for the Queensland Department of Natural Resources and Mines.
- +Caldwell, W.H. (1885). The eggs and larvae of *Ceratodus*. Proceedings of the Linnenan Society of N.S.W. 18:138.
- Clayton, P.D., Fielder, D.P., Howell, S. and Hill, C.J. (2006). Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett River Catchment. Published by the Environmental Protection Agency, Brisbane.
- Dean, B. (1906). Notes on the living specimens of the Australian lungfish, *Ceratodus forsteri*, in the Zoological Society's collection. Proceedings of the Zoological Society of London. 1906:168 – 178.

- Department of Employment, Economic Development and Innovation – Fisheries Queensland (DEEDI) (2012). Paradise Dam Downstream Fishway Monitoring Program Final V1.1. for Burnett Water Pty Ltd.
- Johnson D.P. (1997). State of the Rivers. Mary River and Major Tributaries. An Ecological and Physical Assessment of the Condition of Streams in the Mary River Catchment. ISBN 07242 7783 8
- Department of Environment Resource Management (DERM) (2010). Burnett Mary Natural Resource Management Region Back on Track » Actions for Biodiversity Taking action to achieve species conservation in the Burnett Mary Natural Resource Management Region, Department of Environment and Resource Management, Brisbane.
- DeRose, R., Prosser, I., Wilkinson, L., Hughes, A. and Young, W. (2002). Regional Patterns of Erosion and Sediment and Nutrient Transport in the Mary River Catchment, Queensland, Technical Report 37/02, CSIRO Land & Water, Canberra.
- De Vis, C.W. (1885). *Ceratodus* Post-Pleistocene. Proceedings of the Royal Society of Queensland 1:40 – 43.
- Duivenvoorden, L.J. (2008). Effects of water level fluctuations on *Vallisneria nana* in the Burnett River in southeast Queensland, Australia. *River Research and Applications* DOI 10.1002/rra.1157.
- EPA (2001). Mary River- water quality condition and trends. Queensland Waterways 6: December 2001.
- Frankel, O.H. and Soule, M.E. (1981). Conservation and Evolution. Cambridge University Press, Cambridge.
- Frentiu, F.D., Ovenden, J.R. and Street, R. (2001). Australian lungfish (*Neoceratodus forsteri*: Dipnoi) have low genetic variation at allozyme and mitochondrial DNA loci: a conservation alert. *Conservation Genetics*. 2:63 – 67.
- Grigg, G.C. (1965a). Studies on the Queensland lungfish, *Neoceratodus forsteri* (Krefft). III. Aerial respiration in relation to habits. Australian Journal of Zoology. 13:413 – 421.
- Grigg, G.C. (1965b). Spawning behavior in the Queensland lungfish, *Neoceratodus forsteri*. Australian Natural History. 15:75.
- Hamlyn, A. (no date). Department of Agriculture, Fisheries and Forestry, Queensland, unpublished data.
- Hobday, A.J., Matear, R. (eds, 2005). *Review of the Climate Impacts on Australian Fisheries and Aquaculture: Implications for the Effects of Change*, Report to the Australian Greenhouse Office, Canberra, Australia. December 2005.
- Hollaway, M. and Hamlyn, A. (2001). Freshwater Fishing in Queensland. A guide to stocked waters. Second Edition.
- Hydrobiology (2007). Traveston Crossing Dam Aquatic Ecological Survey. Prepared by Hydrobiology Pty Ltd for Queensland Water Infrastructure Pty Ltd.
- Illidge, T. (1893). On *Ceratodus forsteri*. Proceedings of the Royal Society of Queensland. 10:40 – 44.

- Johnson, D.P. (1997). An Ecological and Physical Assessment of the condition of Streams in the Mary River Catchment. Department of Natural Resources – Resource Sciences Centre. State of the Rivers – Mary River and Major Tributaries.
- Johnson, J.R. (2001). Review of the draft lungfish report (Ecology and demographics of lungfish (*Neoceratodus forsteri*) and general fish communities in the Burnett River, Queensland with reference to the impacts of Walla Weir and future water infrastructure development, by St. Report for Burnett Water, 4 July 2001. Queensland: Queensland Museum.
- Joss, J. and Joss, G. (1995). Breeding Australian lungfish in captivity. Fish Symposium 95, Austin, Texas, (USA).
- Kelly, S. (1997). Mary River Catchment Strategy. Mary River Catchment Coordinating Committee. 58pp.
- Kemp, A. (1981). Rearing of embryos of the Australian lungfish *Neoceratodus forsteri* under laboratory conditions. *Copeia*. 4:776–784.
- Kemp, A. (1982). The embryological development of the Australian lungfish, *Neoceratodus forsteri*, (Krefft). *Memoirs of the Queensland Museum*. 20:553 – 597.
- Kemp, A. (1984). Spawning of the Australian lungfish, *Neoceratodus forsteri* (Krefft) in the Brisbane River and in Enoggera Reservoir, Queensland. *Memoirs of the Queensland Museum*, 21:391 – 399.
- Kemp, A. (1986). The Biology of the Australian lungfish, *Neoceratodus forsteri*. *Journal of Morphology*, supplement 1:181 – 198.
- Kemp, A. (1990). A relic from the past – The Australian lungfish. *Wildlife Australia*, 10, 11pp.
- Kemp, A. (1993). An unusual oviposition site for *Neoceratodus forsteri* (Krefft 1870) (Osteichthyes: Dipnoi) *Copeia*, 1993:240 – 242.
- Kemp, A. (1994). Pathology in eggs, embryos and hatchlings of the Australian lungfish, *Neoceratodus forsteri* (Osteichthyes: Dipnoi). *Copeia*. 4:935 – 943.
- Kemp, A. (1995). Threatened fishes of the world: *Neoceratodus forsteri* (Krefft, 1870). (*Neoceratodontidae*).” *Environmental Biology of Fishes* (43):310.
- Kemp, A. (2008). The Natural History of the Australian lungfish (unpublished manuscript). <http://www.annekempslungfish.com/naturalhistory.pdf> (accessed 8/7/2012).
- Kemp, A. (2011). Comparison of embryological development in the threatened Australian lungfish *Neoceratodus forsteri* from two sites in a Queensland river system. *Endangered Species Research*, 87 – 101.
- Kind, P.K. (2002). Movement patterns and habitat use in the Queensland lungfish *Neoceratodus forsteri* (Krefft 1870). Ph.D. Thesis. University of Queensland, Brisbane, Australia Master, LL, SR Flack, and BA Stein, editors. 1998.
- Kind, P., Ramage, A. and Brooks, S. (2008). Survival Strategy for the Australian lungfish *Neoceratodus forsteri*. Department of Primary Industries and Fisheries.



- Krefft, G. (1870). Description of a giant amphibian allied to the genus *lepidosiren* from the Wide Bay district, Queensland. *Proceedings of the Zoological Society of London*. 1870: 221 – 224.
- Lissone, I. (2003). Conservation genetics and the Australian lungfish *Neoceratodus forsteri* (Krefft, 1870); a spatiotemporal study of population structure. MSc thesis, The University of the Sunshine Coast, Sippy Downs.
- Longman, H. (1928). Discovery of juvenile lung-fishes with notes on *Epiceratodus*. *Memoirs of the Queensland Museum*. 9:161 – 173.
- Mary River threatened species recovery team (2011). Minutes of Recovery Team meeting, Gympie Bridge Club, Queensland, May 2011.
- O'Connor, D. (1897). "Report on Preservation of *Ceratodus*." *Proc. Roy. Soc. Qld.* (xii): 101 – 102.
- Pusey, B.J., Kennard, M.J. and Arthington, A.H. (2004). *Freshwater Fishes of North-Eastern Australia*. CSIRO, Collingwood, Victoria.
- QDPI (1990). *Mary River Overview*. Queensland Department of Primary Industries, Brisbane.
- Semon, R. (1899). *In the Australian Bush*. London, Macmillan and Company.
- Simpson, R. (1994). An investigation into the habitat preferences and population status of the endangered Mary River cod (*Maccullochella peelii mariensis*) in the Mary River system, south-eastern Queensland. Department of Primary Industries – information series. Report QI94011.
- Spencer, W.B. (1892). A trip to Queensland in search of the *Ceratodus*. *Victorian Naturalist*. 9:16 – 32.
- Stockwell, B. (1999). *Mary River and Tributaries Rehabilitation Plan*. Department of Natural Resources. 93pp.
- Stockwell, B., Fennessy, R., Berghuis, A, Johnston, B., and Hutchison, M. (2008). Burnett Mary regional biopass strategy – Reconnecting the Dreamtime's Rainbow Serpent. Burnett Mary Regional Group and Queensland Department of Primary Industries and Fisheries.
- Stuart, I. G. and Berghuis, A.P. (2002). Upstream passage of fish through a vertical-slot fishway in an Australian subtropical river. *Fisheries Management. and Ecology*. 9:111 – 122.
- Tait, J. (2009). lungfish Passage through Fishways and the Impacts of Restricted Passage at Paradise Dam for Australian lungfish (*Neoceratodus forsteri*) in the Burnett River. Report prepared for the Federal Court of Australia at Brisbane in proceedings *Wide Bay Burnett Conservation Council Inc v Burnett Water Pty Ltd* (No. QUD 319/08). 156pp.
- Thompson, J.M. (1975). A place for fishes. *Proceedings of the Royal Society of Queensland*. 89:121 – 128.
- Tucker, A.D., Priest, T., Guarino, E. and Couper, P. (1999). Turtle biodiversity in regard to regional conservation planning: additional recommendations for mitigation in Cumulative Effects of

Dams and Weirs on Freshwater Turtles: Fitzroy, Kolan, Burnett and Mary Catchments. Report for Queensland Parks & Wildlife Service, Bundaberg. Page(s) 105 – 130.

Watson, D., Maskall, D. and Wedlock, B. (2003). Implementing the Mary River and Tributaries Rehabilitation Plan: monitoring and evaluation report, Mary River Catchment Coordinating Committee, viewed 21 November 2006.

Watt, M., Evans, C.S. and Joss, J.M.P. (1999). Use of electroreception by the Australian lungfish. *Animal Behavior*. 58:1039 – 1045.

Whitley, G.P. (1927). The Queensland lungfish. *Australian Museum Magazine*. 3:50 – 52.

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