National Recovery Plan for Booroolong Frog *Litoria booroolongensis*

Australian Government

NSW GOVERNMENT Office of Environment & Heritage

State Government Victoria Department of Sustainability and Environment

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The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved, and may also be constrained by the need to address other conservation priorities. Approved recovery actions may be subject to modifications due to changes in knowledge and changes in conservation status.

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Summary

This document constitutes the national recovery plan for the Booroolong Frog (*Litoria booroolongensis*), and as such considers the conservation requirements of the species across its known range. It identifies actions to be undertaken to ensure the long-term viability of the species in nature, and current stakeholders involved in this recovery program.

The Booroolong Frog is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, Endangered (Schedule 1) under the NSW *Threatened Species Conservation Act 1995*, Threatened under the Victorian *Flora and Fauna Guarantee Act 1988* and is considered Critically Endangered in Victoria (DSE 2007). The species is an obligate river-breeding frog that was historically found along streams on the western fall of the Great Dividing Range in New South Wales between 200 and 1300 metres above sea level. Several populations were also found along eastern flowing streams in the northern half of the species former range. Two populations of the Booroolong Frog have been recently discovered in north-eastern Victoria. This species underwent a dramatic decline during the mid 1980's, and the results of recent surveys suggest that declines have occurred throughout its former known range, particularly on the New England Tablelands. The factors identified as contributing to the historic and continued decline of the Booroolong Frog include disease (Chytridiomycosis) caused by infection with the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*), habitat degradation, altered stream flows, and stream drying associated with recent severe droughts. The introduction of exotic predatory fish is also likely to have impacted on the Booroolong Frog in the wild, and this impact may be continuing.

The Booroolong Frog is the focus of an active recovery program. Conservation research began on this species in 1998, and was soon followed by the implementation of a targeted riparian restoration program in the Murray and Murrumbidgee catchments. More recently, a riparian restoration program for the Booroolong Frog is underway in the Namoi Catchment following an assessment of the species' distribution, abundance and health in this catchment. Further research and management recommended in this recovery plan includes: (i) complete distributional surveys; (ii) determine the taxonomic status of northern and southern populations and genetic sub-structuring within these populations; (iii) reduce the impact of known and perceived threatening processes; (iv) implement a rigorous monitoring program; (v) determine the likely impacts of, and develop a response to climate change; (vi) undertake further research into potentially threatening processes; (vii) increase public awareness and involvement; and (viii) achieve the effective implementation of this recovery plan.

The primary stakeholders who are currently involved in the implementation of this recovery plan are: New South Wales Office of Environment and Heritage; Victorian Department of Sustainability and Environment; Murray, Murrumbidgee, Lachlan, and Namoi Catchment Management Authorities; Taronga Zoo, James Cook University and Amphibian Research Centre. An additional $1,345,000 over the five-year period will be required to implement unfunded actions.

Abbreviations used in this Plan

CMA	Catchment Management Authority
OEH	Office of Environment and Heritage, New South Wales
I&I	Industry and Investment, New South Wales
DSE	Department of Sustainability and Environment, Victoria
TZ	Taronga Zoo
ARC	Amphibian Research Centre
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
FFG Act	*Flora and Fauna Guarantee Act 1988* (Vic)
PV	Parks Victoria
JCU	James Cook University
SAM	South Australian Museum

Species Information

Description

The Booroolong Frog (*Litoria booroolongensis*) is a medium-sized species belonging to the Family Hylidae (Moore 1961). Females may attain 55 mm snout-vent length while males are smaller, attaining 40 mm. The dorsum colour is variable, ranging from grey, olive, or reddish-brown, and may be uniform or consist of indistinct black markings and salmon-coloured flecks. The texture of the dorsum is usually slightly warty, while the ventral surface is pale and finely granular. The throat is typically a pale colour, and many individuals have a thin black stripe passing from the snout, through the eye, over a small distinct tympanum to the shoulder. The backs of the thighs may be dark brown or covered in a yellow and black reticulated pattern. Disks on fingers and toes are medium-sized for a hylid. The fingers are free from webbing, while the toes are strongly webbed. Webbing extends to the base of all discs except the second toe (Moore 1961, Barker *et al*. 1995). Males lack a distinct vocal sac, and their call is relatively quiet, and has been described as 'craww craww craww craww' (Smith and Hunter 2003).

The tadpole of the Booroolong Frog is free swimming (Anstis *et al*. 1998). The body is elongate and flattened, with a rounded snout, and well developed tail musculature. Individuals attain a total length of 50 mm prior to metamorphosis. The eyes are dorso-lateral and the mouth is ventral. Dorsal body colour is uniform rusty-brown with some darker mottling, which continues along the tail muscle. A conspicuous dark brown band is present across the lower back region. The under surface has an almost uniform gold sheen, with some darker patches. The oral disc is large, and a band of oral papillae surround the entire margin. There are two rows of anterior labial teeth, and three posterior rows (Anstis *et al.* 1998).

Conservation Status

The Booroolong Frog is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and Endangered in NSW under the *Threatened Species Conservation Act 1995* (TSC Act). In Victoria this species is listed as Threatened under the *Flora and Fauna Guarantee Act 1988* (FFG Act) and is considered Critically Endangered (DSE 2007).

Distribution

The Booroolong Frog is restricted to New South Wales and north-eastern Victoria, predominantly along western-flowing streams of the Great Dividing Range, from 200 to 1300 metres above sea level (Figure 1) (Heatwole *et al.* 1995, Anstis *et al.* 1998, Hunter and Gillespie 1999, Gillespie and Hunter 2000, NSW Wildlife Atlas, Victorian Wildlife Atlas). There are several records of the species from the eastern slopes of the Great Dividing Range (Australian Museum records, NSW Wildlife Atlas), however, records from eastern flowing streams south of Sydney are not supported by specimens or photos, and require confirmation.

The Booroolong Frog was formerly abundant above 800 metres along streams draining the New England Tablelands (Heatwole *et al.* 1995), however it has not been recorded in this region during the past 25 years, despite targeted surveys for this species (Gillespie 2000). The Booroolong Frog persists along a number of streams in the southern end of the New England Tablelands, with recent surveys locating this species along an estimated 99 km of stream from seven streams in the Namoi catchment (Spark 2009). Two Booroolong Frog populations are known to be persisting along eastern flowing streams - the Isis River in the Hunter River catchment, and the Barnard River in the Manning River catchment (Spark 2009, P. Spark pers. comm.).

Further south, the Booroolong Frog has been recorded from a number of streams in recent years. In the central tablelands region, the species has been recorded along nine streams within the Macquarie River catchment (Central West CMA) (S. Clulow unpub. data), and seven streams in the Abercrombie River catchment (Lachlan CMA). On the south west slopes

of NSW, the Booroolong Frog has been recorded along 15 streams in the Murrumbidgee River catchment and 12 streams in the Murray River catchment (Hunter 2007, Gillespie and Hunter 2000). In Victoria it has been recorded at Burrowye and Guys Forest Creeks in the upper Murray area (Gillespie and Hunter 1999). More recently a second population was discovered in Mt Lawson State Park along Koetong Creek.

Population Information

A recent study identified significant genetic divergence between populations north of the Turon River and populations from the Turon River and south (S. Donnellan pers. comm., Figure 1). Further work is required to resolve the taxonomic status of these populations. As an interim conservation approach, these two broad populations should be managed and prioritized independently of each other.

Genetic sub-structuring within the two broad Booroolong Frog populations has not been investigated at this stage. Given the extensive geographic range and degree of isolation among streams occupied by the Booroolong Frog, it is very likely that multiple 'evolutionary significant units' (see Moritz 1995) exist across the species range. It is also likely that the majority of local populations are effectively independent from each another, regardless of their genetic relatedness, as they have been isolated by large areas of highly modified and unsuitable habitat. Distinguishing these local populations with reasonable confidence is possible for the Namoi, Macquarie (Central West), Lachlan, Murrumbidgee and Murray catchments, as recent thorough surveys for the Booroolong Frog have been undertaken in these areas (Hunter and Smith 2006, Hunter 2007, Spark 2009, S. Clulow unpub. data). These populations are summarised in Appendix 1.

Based on habitat connectivity, 28 local populations are currently known across the range of the Booroolong Frog (Appendix 1). The length of stream occupied for the different populations varies greatly from 0.1km to 40km of stream. Length of stream occupied serves as a useful measure of population resilience for the Booroolong Frog, because it reflects the extent of suitable habitat for this species, and the greater the length of stream occupied the less susceptible the species will be to local perturbations. Because the Booroolong Frog can exhibits large fluctuations in abundance from one year to the next, population abundance is not a useful indicator of population resilience.

Habitat

The Booroolong Frog is generally associated with permanent streams in wet and dry forest, woodland, and cleared grazing land (Anstis *et al.* 1998, Gillespie 1999, Hunter 2007). The species occurs in dissected mountainous country, tablelands, foothills and lowland plains (Anstis *et al.* 1998, Gillespie 1999). Adults tend to occur on or near cobble banks or bedrock structures within stream margins, or near slow-flowing connected or isolated pools that contain suitable rock habitats. By day, frogs shelter under rocks or amongst vegetation near the ground along the edge of the stream. Several individuals may be found sheltering together. During the summer months individuals may bask in the sun on exposed rocks near flowing water. During the breeding season at night, males call from exposed rocks or rock crevices, near shallow pools or runs. Juveniles and adults have also been observed under rocks within the riparian zone during winter (Anstis *et al.* 1998, D. Hunter pers. obs.). The dispersal capabilities and non-breeding habitats used by the Booroolong Frog outside of the riparian zone are not known.

Egg deposition sites are typically in shallow, slow-flowing sections of stream or isolated rock pools along the stream margins (Anstis *et al*. 1998). The egg clutch is a rigid gelatinous clump, adhered to rock in crevices (Anstis *et al*. 1998). Tadpoles have been observed in slow-flowing sections of streams, or in pools (Anstis *et al.* 1998, Gillespie 1999). The tadpoles are benthic and have been found occupying rocks and detritus on the streambed (Anstis *et al*. 1998).

The primary habitat requirements for the Booroolong Frog are extensive rock bank structures along permanent rivers (Gillespie 1999, Hunter and Smith 2006). The Booroolong Frog has also been observed using artificial man made structures, such as weirs (P. Spark pers. comm.). The key feature of these rock structures are rock crevices in relatively shallow, slow

to medium-flowing sections of stream (Hunter 2007). Given the high abundance of Booroolong Frog tadpoles in streams and stream side pools subject to intensive agricultural practises (Hunter 2007), it appears that this species is robust to a range of water quality parameters. Failure to locate the Booroolong Frog along ephemeral streams, and the decline of this species from streams that dried during recent severe droughts, demonstrates the reliance of this species on permanent water (Hunter and Smith 2006, D. Hunter unpub. data). Hence, habitat critical to the survival of the Booroolong Frog is rocky sections of permanent streams occupied by the species. Any action that reduces stream permanency (e.g. pumping water) or results in loss of rock crevices (e.g. smothering by weeds or sedimentation), is likely to threaten the persistence of local populations of this species.

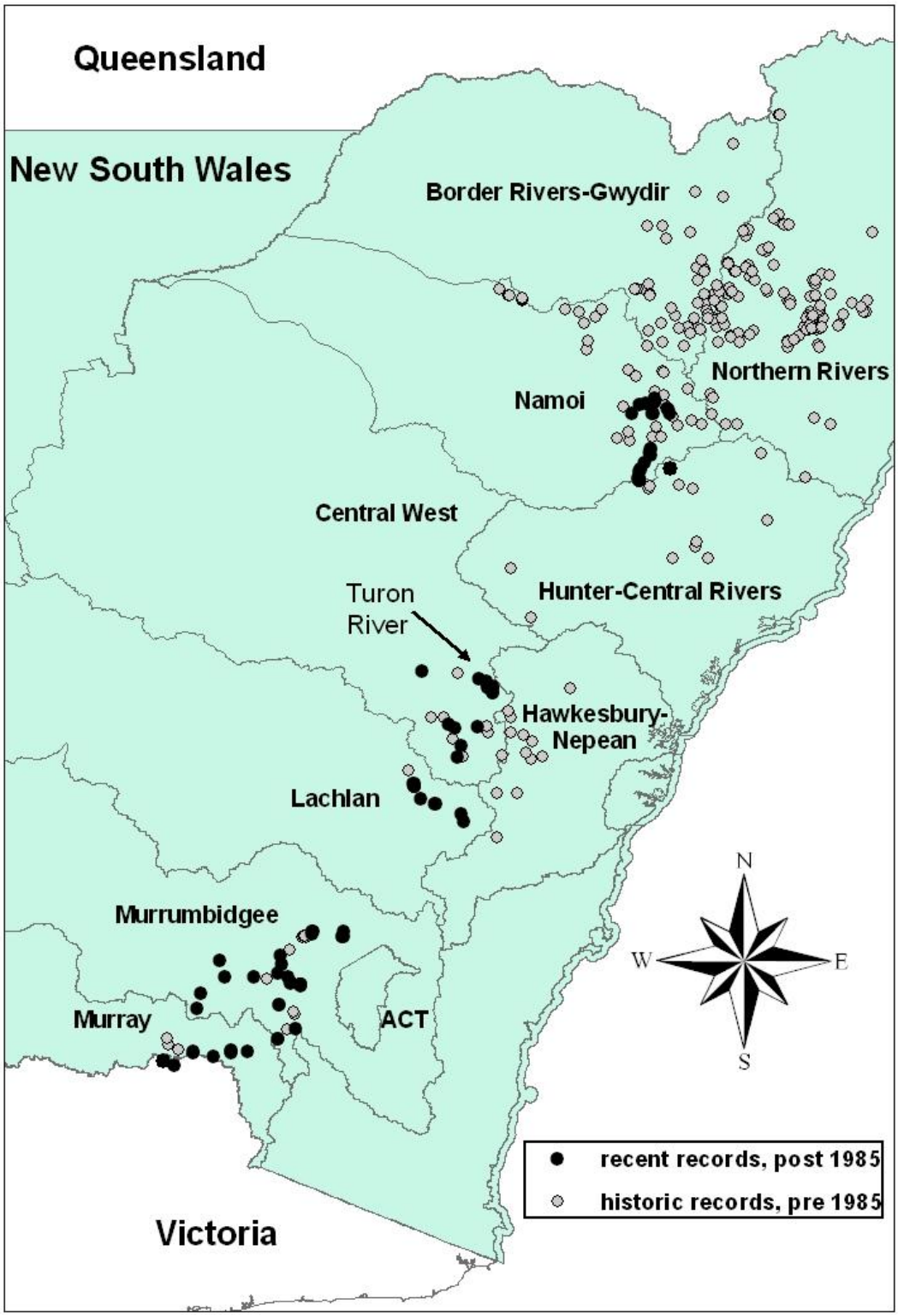

Figure 1. Locality of Booroolong Frog records within different NSW CMA regions. Note – the two localities for this species in Victoria are within the North-East CMA.

Life History

Breeding is known to occur in spring and early summer, from October through to early January. Clutch sizes, based upon egg compliments in museum specimens and field observations, range from 688 to 1784, with a mean of 1331 (Anstis *et al.* 1998; Anstis 2002). Tadpoles take 2-4 months to develop, metamorphosing in late summer to early autumn (Anstis 2002).

Information on the population demography of the Booroolong Frog has been obtained through skeletochronology and a mark-recapture study. Based upon skeletochronological examination of museum specimens, and specimens from the Goobragandra River in southern NSW, males attain sexual maturity within two years and females attain sexual maturity in three years (G. Gillespie unpub. data). A mark-recapture study at two sites (Brungle Creek and Mountain Creek) demonstrated that at lower altitudes, male Booroolong Frogs may take one year to reach sexual maturity while females take two years (Hunter 2001). Maximum age detected using skeletochronology is four years (G. Gillespie pers. comm.), while the maximum age determined through the mark-recapture study was four years (D. Hunter unpub. data).

Information on population size estimates, annual survival, and movements along the stream for adult male and female Booroolong Frogs has been attained from a mark-recapture study at two low altitude sites (Hunter 2001, 2007). The density of frogs varied considerably among years, with a seven fold difference in the abundance of adult males from one year to the next (Hunter 2007). This study found that annual survival for this species is relatively low, with 10% annual survival for adult males and 20% annual survival for adult females (Hunter 2001). Movements along the stream varied with the majority of recaptured individuals moving less than 50 metres within a season, with maximum movements of up to 300 metres being recorded (Hunter 2001).

Decline and Threats

The Booroolong Frog has declined from greater than 50 percent of its former distribution within the past 25 years. This decline has been most noticeable in the northern sections of its range on the New England Tablelands (Figure 1), an area where the Booroolong Frog was observed to be both common and in high abundance prior to the mid-1980's (Heatwole *et al*. 1995, Anstis *et al*. 1998, NSW Wildlife Atlas). Despite the Booroolong Frogs apparent disappearance from much of the New England Tablelands, it is persisting at the southern end of this region in the Namoi and Manning River catchments (Gillespie 2000, Spark 2009).

The Booroolong Frog has also declined and disappeared from streams in the central and southern parts of its former range (Figure 1). These declines appear to be ongoing (Hunter 2007), and the viability of many extant populations may be extremely precarious. The factors causing these historic and continued declines are outlined below.

Disease

There is considerable evidence implicating the disease 'Chytridiomycosis' as the primary cause of many amphibian declines along the eastern ranges of Australia over the past 30 years (Berger *et al*. 1998, Skerratt *et al*. 2007). This disease is caused by infection with the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*), which has been identified as the cause of mass amphibian declines and extinctions on different continents (Berger *et al*. 1998, Lips *et al*. 2006). Current information suggests that this pathogen only recently spread throughout the world, possibly from South Africa (Morehouse *et al*. 2003, Weldon *et al*. 2004). Given the timing and rapid nature of Booroolong Frog declines from the New England Tablelands, which coincided with the disappearance of several other frog species in this region (Mahony 1999, NSW NPWS 2001a), it is very likely that these declines were due to an outbreak of Chytridiomycosis. Moreover, the decline of the Booroolong Frog from this high altitude region, compared with the persistence of populations at lower altitudes, is consistent with the pattern of Chytridiomycosis induced decline observed in other species (Berger *et al*. 1998, Lips 1999). Sick and dead Booroolong Frogs infected with the Amphibian Chytrid

Fungus have been found in the wild on several occasions (D. Hunter pers. obs.), and this species has also been shown to be susceptible to this pathogen in captivity (Scott Cashins unpub. data). Booroolong Frogs that appear healthy in the wild have also tested positive for infection with this pathogen (Spark 2009, D. Hunter unpub. data).

Habitat Degradation

Habitat modification and disturbance has played a major role in the historic decline of the Booroolong Frog. Vegetation clearing, stock grazing, and timber harvesting have occurred adjacent to many streams, or in the headwaters of catchments throughout the species former range (Gillespie 1999, 2000). Weed invasion has also grossly modified riparian habitats along many streams in south-eastern Australia where Booroolong Frogs formerly occurred (Hunter pers. obs.). Manipulation of hydrological regimes has also contributed to the loss of suitable habitat for the Booroolong Frog (Hunter 1999). In particular, the construction of water impoundments, water harvesting which increases susceptibility to stream drying, and increased stream flows during the warmer months have greatly reduced available habitat for this species throughout its range.

Ongoing habitat degradation continues to threaten the viability of many Booroolong Frog populations, particularly in the agricultural landscape (Gillespie 1999, Hunter and Smith 2006, Smith and Hunter 2008). The most significant impact is through smothering and entraining of rock crevices by sediments, and subsequent vegetation, which reduces the quality and extent of breeding habitat for this species (Hunter 2007). Many streams occupied by the Booroolong Frog continue to have high sediment loads entering the aquatic environment. This is due to a range of factors, including erosion due to lack of vegetation cover, inappropriate stock management (particularly overgrazing), use of heavy machinery in the riparian zone, soil ripping to establish crops and plantations, illegal dredging for precious metals, and in-stream sediment disturbance by European Carp (*Cyprinus carpio*). The colonisation of the riparian zone by environmental weeds (e.g. Willows and Blackberries) also significantly reduces the extent of suitable habitat for the Booroolong Frog (Hunter 2007). Willows are particularly effective at disrupting the life-cycle of the Booroolong Frog as their surface roots fill all rock crevices required by this species for oviposition. The impact of sedimentation and weed invasion is further exacerbated by reduced winter flows during drought periods, which are expected to become more frequent under predicted climate change scenarios (see below). The regulation of winter flows from large impoundments and water extraction has also exacerbate sedimentation and weed invasion along streams occupied by the Booroolong Frog.

Stream Drying

Since 2003, severe droughts on the Southern and Central Tablelands of NSW and Victoria have resulted in the drying of many previously permanent streams occupied by the Booroolong Frog. These drying events have been followed by major declines, range contractions and local extinctions of this species (D. Hunter unpub. data). The sensitivity of the Booroolong Frog to stream drying is due to this species' rapid life-cycle (one year for males and two for females in low altitude populations, D. Hunter unpub. data), as it renders populations intolerant of failed recruitment to metamorphosis over two or more consecutive years. This has serious implications for how predicted climate change will impact on the Booroolong Frog, as more severe and prolonged droughts are expected to occur on the Southern and Central Tablelands of NSW (CSIRO 2007).

The establishment of forest plantations in catchments occupied by the Booroolong Frog is also expected to exacerbate the impact of climate change. The amount of surface water flow in streams is likely to significantly decrease, which would increase the likelihood of stream drying during a drought, if greater than 12 percent of a catchment is converted to forest plantations (Keenan *et al*. 2004). This is concerning, as there has been an increase in the establishment of softwood plantations in catchments occupied by the Booroolong Frog over the past five years, with several of these catchments having considerably greater than 12 percent of their area converted to plantations. There is currently no legislation restricting the proportion of a catchment that can be used for forestry plantations, and therefore no protection from this activity on stream water flows.

Prolonged drought since 2003 has also been observed to exacerbate the loss and degradation of breeding habitat for the Booroolong Frog. This has primarily occurred in highly disturbed catchments where drought conditions have allowed large quantities of sediments to smother the rock structures used by the Booroolong Frog for breeding (D. Hunter unpub. data). High winter flows would typically ensure that sediments do not settle and become entrained in the crevices. Once the rock habitat becomes covered in sediments they are more prone to colonisation by plants, which reduces the likelihood that subsequent high flows will be able to re-expose the rock crevices. Since 2003, this process has resulted in the loss of greater than 50% of available breeding habitat along many streams supporting the Booroolong Frog (Smith and Hunter 2008, D. Hunter unpub. data).

Predation by Exotic Predatory Fish

The impact of introduced fish species on amphibian populations is well documented. Introduced trout are believed to be responsible for population declines of amphibian species both overseas (Bradford *et al.* 1993, Vredenburg 2004) and in Australia (Gillespie 2001). Similarly, Mosquito Fish (*Gambusia holbrooki*) have been implicated in the decline of the Green and Golden Bell Frog (*Litoria aurea*) in NSW (Hamer *et al*. 2002). Introduced fish that occur in streams occupied by the Booroolong Frog include: Brown Trout *Salmo trutta*; Rainbow Trout *Oncorhynchus mykiss*; European Carp *Cyprinus carpio*; Goldfish *Carassius auratus*; Redfin Perch *Perca fluviatilis* and Mosquito Fish *Gambusia holbrooki* (McDowall 1996, Hunter and Gillespie 1999, Gillespie 1999). Recent experimental work has demonstrated that introduced Brown and Rainbow Trout, Mosquito Fish, Redfin Perch and European Carp all have the potential to prey on the tadpoles of the Booroolong Frog (Hunter 2007, Hunter *et al*. 2011), and may be impacting on this species at the population level. Several of these species (e.g. Mosquito Fish and Carp) are continuing to expand their range in areas occupied by the Booroolong Frog (D. Hunter pers. obs.).

Herbicide Use

Over the past 20 years there has been an increase in the general use of broad-spectrum herbicides (Tyler 1989). The active ingredient in many formulations, glyphosate, and the surfactants, have been shown to be toxic to frogs and tadpoles (Bidwell and Gorrie 1995). The wide use of these pesticides may have contributed to the decline of the Booroolong Frog in rural landscapes, such as the Northern Tablelands region. Recently, experimental research has implicated the use of ammonium nitrate and calcium phosphate fertilizers with the decline of the Green and Golden Bell Frog from the Northern Tablelands and elsewhere in its range (Hamer *et al*. 2004). These herbicides and fertilizers are likely to accumulate in varying concentrations in river systems occupied by the Booroolong Frog following heavy rain periods. Moreover, the herbicide 'atrazine', which is capable of causing endocrine disruption in some frog species (Hayes *et al*. 2002), is commonly used to control weeds in forest plantations and agricultural areas adjacent to Booroolong Frog populations. Research is required to determine whether the use of herbicides is currently impacting on this species.

Recovery Information

Existing Conservation Measures

A number of recovery actions have been completed, or are currently being implemented for the conservation of the Booroolong Frog. These include:

- Thorough systematic surveys undertaken throughout much of the Booroolong Frog's range (Gillespie 1999, 2000, Hunter and Smith 2006, Spark 2009, S. Clulow unpub. data).
- Research undertaken into the ecology, habitat requirements and causal factors of decline (Hunter 2007, Spark 2009).
- Population genetic study initiated (Steve Donnellan pers. com.).

- Riparian protection and restoration along streams supporting the Booroolong Frog in the Murray, Murrumbidgee, and Namoi catchments.
- Establishment of a monitoring program to identify population trends in relation to stream drying (climate change) and riparian restoration (stream bank protection and weed management).
- Development of captive breeding techniques (Taronga Zoo and Amphibian Research Centre).
- Experimental reintroductions undertaken into drought affected populations (D. Hunter unpub. data).
- Research initiated into acquired immunity to Chytridiomycosis, implications of this disease to reintroduction programs, and development of most efficient reintroduction techniques (James Cook University, Taronga Zoo).
- Community outreach program targeting local communities and property owners where extant populations of the Booroolong Frog occur (Taronga Zoo, various CMAs).
- A Victorian Action Statement has been prepared for the species (Clemann 2003).

Recovery Objectives

The overall objective of recovery is to minimise the probability of extinction of the Booroolong Frog in the wild, and to increase the probability of populations becoming self-sustaining and viable in the longer term.

Within the duration of this Recovery Plan, the specific objectives are to:

1. Determine the species distribution in areas that have not been the focus of targeted surveys.
2. Determine the taxonomic status of northern and southern Booroolong Frog populations, and identify further genetic sub-division within these populations.
3. Reduce the impact of known or perceived threats contributing to the ongoing decline of the Booroolong Frog.
4. Determine population trends across the species range, and in areas subject to different management regimes.
5. Identify the potential impacts of climate change, and determine management responses to reduce these impacts.
6. Identify other potentially threatening processes.
7. Increase community awareness and involvement in the Booroolong Frog recovery program.
8. Achieve the effective implementation of the recovery plan.

Program Implementation and Evaluation

This Recovery Plan guides recovery actions for the Booroolong Frog and will be implemented and managed by the Office of Environment and Heritage for NSW and the Department of Sustainability and Environment for Victoria, with support from other agencies, regional natural resource management authorities, husbandry institutions, universities, and community groups as appropriate. In particular, the Catchment Management Authorities are considered well positioned to undertake the majority of on-ground protection and restoration works as the majority of populations occur on privately owned land. Technical, scientific, and education components of the recovery program will be referred to specialist groups as required. Liaison will be maintained between state agencies on issues concerning implementation of the recovery plan. The recovery plan will be reviewed and revised, if necessary, within five years of the date of its adoption as a national plan under the EPBC Act.

Recovery Objectives and Actions

Objective 1. Determine the species distribution in areas that have not been the focus of targeted surveys.

Recovery Criterion:
All streams supporting extant populations of the Booroolong Frog identified, and the extent of occupancy along those streams determined within five years.

Action 1.1 Complete systematic surveys for the Booroolong Frog across its entire range.

A detailed understanding of the current distribution of the Booroolong Frog provides a basis for successfully achieving other high priority recovery actions. This information is particularly important for undertaking the population genetic study, monitoring program, and undertaking targeted riparian restoration. Knowing the current distribution is also critical for prioritising recovery actions such as captive breeding, reintroduction, and assisted colonisation. Thorough surveys for the Booroolong Frog have been undertaken throughout much of this species range; however, there is much scope to increase our understanding of this species distribution. This is particularly important in the northern section of the species former range, and eastern flowing streams throughout the species former range where targeted surveys have been limited. It is particularly important to thoroughly determine the distribution of the Booroolong Frog in the Upper Hunter Catchment, Hawkesbury Nepean Catchment, and on the New England Tablelands. The objective of surveys for the Booroolong Frog should be to identify the location and area of occupancy of all remaining populations.

Responsibility: NSW Office of Environment and Heritage (OEH), Victorian Department of Sustainability and Environment (DSE)

Objective 2. Determine the taxonomic status of northern and southern Booroolong Frog populations, and identify further genetic sub-division within these broad populations.

Recovery Criterion:
The taxonomic status of northern and southern Booroolong Frog population groups is determined, and other levels of genetic sub-division identified.

Action 2.1 Determine the taxonomic status of northern and southern Booroolong Frog populations using molecular genetic techniques.

Initial work suggests that there is a significant genetic break between northern and southern Booroolong Frog populations (S. Donnellan pers. comm.). Clarifying this result and its possible taxonomic implications is critical for the management of these two broad populations, as prioritising resource allocation is strongly influenced by species level taxonomy. This recovery action includes the work required to publish the results.

Responsibility: OEH, South Australian Museum (SAM)

Action 2.2 Identify genetic sub-division within northern and southern populations of the Booroolong Frog.

Identifying significant genetic sub-division within the Booroolong Frog will provide a basis for defining management units (Moritz 1995), and will greatly enhance our capacity to conserve existing genetic diversity within this species. Given the likelihood that many streams occupied by the Booroolong Frog will be at risk of local extinction due to stream drying, this knowledge will be particularly valuable for prioritising which local populations to target for pro-active recovery efforts.

Responsibility: OEH, SAM

Objective 3. Reduce the impact of known or perceived threats contributing to the ongoing decline of the Booroolong Frog.

Recovery Criterion:
The majority of streams occupied by the Booroolong Frog in the agricultural landscape are the focus of riparian protection and restoration.

Action 3.1 Continue and expand riparian protection and restoration where the Booroolong Frog occurs in the agricultural landscape.

Riparian protection and restoration in the agricultural landscape constitutes one of the most important recovery actions for the conservation of the Booroolong Frog. To date, extensive riparian restoration has been undertaken to enhance habitat for the Booroolong Frog in the Murray and Murrumbidgee catchments, and similar works have commenced in the Namoi catchment. These works involve; eradicating willows from core habitat, restricting stock access to the riparian zone, and promoting regeneration of native riparian vegetation. These works require considerable involvement from property owners and local communities, and help protect and enhance river systems for broader biodiversity and environmental health. Conservation management agreements for high priority sites will be negotiated, developed and implemented. General prescriptions for undertaking riparian restoration in areas occupied by the Booroolong Frog are presented in Appendix 2.

An important consideration when undertaking control/removal of willows from sections of stream is that stream banks may become unstable and more prone to erosion. This is particularly the case in areas where willows form the dominant riparian vegetation. Hence, it is most desirable to stage the removal of willows, such that relatively short sections of stream are treated and replaced with native vegetation in any given year.

Responsibility: OEH, DSE, CMAs

Action 3.2 Regulate the establishment of softwood plantations immediately adjacent to, or upstream of Booroolong Frog populations.

The establishment of forest plantations within catchments supporting the Booroolong Frog has the potential to cause significant impacts on this species via the following mechanisms:

- Increasing propensity for stream drying during drought as a result of increasing the proportion of high density forestry plantations within a catchment.
- Increasing risk of significant weed colonisation within the riparian zone as a result of reduced stock grazing and inadequate weed management.
- Increasing sedimentation into streams as a result of extensive soil ripping and increased use of heavy machinery.
- Physiological disruption to individual frogs as a result of the broad application of chemical herbicides.

It is critical that all plantations within catchments supporting the Booroolong Frog adhere to the requirements of the *Plantation and Reafforestation Act 1999* with regards to ensuring weeds are appropriately managed within the riparian zone and elsewhere on the property (particularly Willow and Blackberry). Furthermore, it is recommended that a minimum 30 metre riparian buffer is established around all streams and tributaries adjacent to or upstream of Booroolong Frog populations. It is also recommended that native vegetation should be maintained or re-established within these buffers. It may also be necessary to consider engineering options for controlling erosion and sedimentation. It would also be desirable to ensure that new forest plantations have minimal impact on surface water flows along sections of stream occupied by the Booroolong Frog, however this is currently not considered in the assessment of environmental impacts.

Responsibility: NSW Department of Industry and Investment (I&I)

Action 3.3 Enforce legislation protecting streams and water flow.

To reduce the likelihood of stream drying during drought, it is important to ensure that restrictions on pumping water for irrigation are maintained in accordance with the *Water Management Act 2000* (WM Act). Furthermore, any works or manipulations of riparian habitat that require a 'controlled activities permit' under the WM Act, should consider potential impacts on the Booroolong Frog. It is also important that illegal dredging for precious metals is prevented in streams supporting populations of the Booroolong Frog. Any activities that may increase stream erosion or sedimentation, damage or remove rock habitats, or result in the increased proliferation of weeds adjacent to or upstream of a Booroolong Frog population may have a significant impact on this species. These activities may only be undertaken if all relevant regulatory and legislative requirements are met.

Responsibility: OEH, I&I

Action 3.4 Reduce the transmission of potentially harmful pathogens both within and among populations of the Booroolong Frog.

Management or research being undertaken within close proximity of Booroolong Frog populations should adhere to strict quarantine protocols, such as those outlined in the 'Hygiene protocols for the control of disease in frogs' (NSW NPWS 2001b). In particular, any projects involving the handling of frogs should incorporate protocols to minimise the potential spread of harmful pathogens among individual frogs. The movement of frogs or fish from one stream to another should be thoroughly reviewed for the possibility of translocating harmful pathogens. This includes the translocation of different strains of the Amphibian Chytrid Fungus, as the virulence of this pathogen can vary greatly across different areas (Berger *et al*. 2005). This approach to managing the threat of Chytridiomycosis outbreaks is consistent with recommendations in the National Threat Abatement Plan for this disease (DEH 2006).

Responsibility: OEH

Action 3.5 Prevent impacts from introduced predatory fish.

Preventing the impact of introduced fish should involve restricting stocking programs and preventing habitat alterations that may enhance the spread or density of introduced fish species. In the case of stocking fingerling trout, it is recommended that this action should not occur within streams where Booroolong Frog populations are restricted or appear vulnerable. Moreover, attempts to establish populations of non-indigenous fish species (native or exotic) should not occur in streams supporting Booroolong Frog populations without assessment of potential impacts.

Responsibility: OEH

Objective 4. Determine population trends across the species range, and in areas subject to different management regimes.

Recovery Criterion:
An assessment of the conservation status, impact of stream drying, and influence of riparian restoration works has been undertaken within five years.

Action 4.1 Implement an effective monitoring program to assess ongoing conservation status, impact of stream drying, and population response to riparian restoration works.

A Booroolong Frog monitoring program is currently being undertaken to provide information on a range of issues associated with the conservation of this species. This includes assessing

the impact of recent stream drying events, and the capacity for this species to recover following significant population declines. The monitoring program is also being used to assess habitat and population response to riparian conservation works in the Murray and Murrumbidgee catchments. It is critical that conservation programs targeting the Booroolong Frog are implemented in an adaptive manner such that monitoring is used to assess outcomes and inform future works. The current monitoring program in the southern half of the species range is briefly outlined in Appendix 2. This program will be expanded to include sites in the northern half of the species range.

Responsibility: OEH, DSE, Parks Victoria (PV), CMAs

Objective 5. Identify the potential impacts of climate change, and determine management responses to reduce these impacts.

Recovery Criterion:
The likely impacts on the Booroolong Frog from climate change are assessed, and techniques and strategies to minimise impacts are developed.

Action 5.1 Model the influence of predicted climate change on streams supporting populations of the Booroolong Frog.

The susceptibility of the Booroolong Frog to stream drying has major implications for the potential impact of climate change on this species. Climate change is predicted to cause more severe and prolonged droughts on the Southern and Central Tablelands of NSW (CSIRO 2007). Modelling the likely extent of future stream drying will provide valuable information for prioritising conservation efforts, and assist in developing a response strategy to deal with declines and local extinctions. It is also important to assess the potential for the northern tablelands region to be a climate change 'refuge' for the Booroolong Frog, as this region is predicted to sustain current levels or greater rainfall (CSIRO 2007). Applying the results of this modelling will rely on having delineated significant management units for the Booroolong Frog (see Action 2.2).

Responsibility: OEH

Action 5.2 Develop efficient reintroduction techniques for establishing wild populations of the Booroolong Frog.

In the event that stream drying causes local extinction of Booroolong Frog populations, it may be possible to re-establish populations from captive bred stock when sufficient flows resume. This management response has been trialled along two streams (Maragle Creek and Burrowye Creek), with captive bred individuals reintroduced to Maragle Creek surviving through to sexual maturity (McFadden et al. 2010). An impediment to implementing this strategy over multiple sites is the significant resources required to breed large numbers of individuals for reintroduction. Hence, determining efficient reintroduction techniques would increase the capacity to use captive breeding and reintroduction as a management tool. Two experiments are currently being undertaken by researchers and staff at James Cook University and Taronga Zoo. The first is assessing the capacity to increase the resistance of Booroolong Frogs to Chytridiomycosis through exposure and subsequent treatment, and then testing whether this increases post-release survivorship. The second is examining the most successful and cost effective life-stage for release by comparing the release of tadpoles, juvenile frogs and adult frogs.

Responsibility: OEH, DSE, Taronga Zoo (TZ), Amphibian Research Centre (ARC), James Cook University (JCU)

Action 5.3 Assess the capacity to use assisted colonisation to conserve wild populations of the Booroolong Frog.

Assisted colonisation has been suggested as a possible technique for conserving threatened populations under a rapid climate change scenario (Hoegh-Guldberg *et al*. 2008). Given the likelihood that many streams currently supporting Booroolong Frog populations will become unsuitable for this species if severe droughts persist or increase in frequency, it may be desirable to shift some populations to streams that appear to have maintained more suitable habitat. Undertaking assisted colonisation for the Booroolong Frog should involve assessing the availability of more permanent streams with suitable habitat, determining possible risks to other fauna in the host environment, and undertaking trial releases to assess whether the technique may actually work. Assisted colonisation could be undertaken using captive bred stock, or stock harvested from relatively abundant and healthy populations.

Responsibility: OEH, TZ

Objective 6. Identify other potentially threatening processes.

Recovery Criterion:
The extent to which potentially threatening processes are impacting on the Booroolong Frog is understood.

Action 6.1 Determine the impact of herbicide use on the Booroolong Frog.

Booroolong Frogs are likely to be directly or indirectly exposed to herbicides on both government and privately managed land. To ensure the safe application of these chemicals, it is necessary to identify which chemicals are likely to have deleterious effects on this species. Both field and laboratory studies are required to achieve this, and should involve identifying the concentrations that frogs may be exposed to in the wild, and whether these concentrations cause physiological disruption. In the absence of specific data for the Booroolong Frog, the precautionary approach should be taken whereby any chemical shown to have deleterious effects on frogs should be prevented from use in the vicinity of Booroolong Frog populations.

Responsibility: OEH

Action 6.2 Determine the current influence of Chytridiomycosis on Booroolong Frog populations.

It is important to understand how Chytridiomycosis may be contributing to the current regulation of Booroolong Frog populations, and hence potentially limiting the recovery of this species. This should be undertaken via a mark-recapture study that assesses the field survival probabilities for individuals infected with the Amphibian Chytrid Fungus versus those that are not infected (cf. Murray *et al*. 2009). This information can then be used to model the overall impact of this pathogen on the Booroolong Frog, and determine the extent to which efforts should be undertaken to mitigate these impacts.

Responsibility: OEH, JCU

Action 6.3 Determine the current impact of predation by introduced fish on the Booroolong Frog.

While introduced fish have been shown to prey on Booroolong Frog tadpoles in experimental ponds (Hunter 2007, Hunter *et al*. 2011), identifying whether population-level impacts are occurring requires research into predation in the wild. Ideally, this question would be assessed by eradicating introduced fish species from sections of stream, and monitoring the subsequent Booroolong Frog population response (cf. Vredenburg 2004). Eradicating fish from sections of river requires large resources and is logistically very difficult to achieve, and so may not be feasible within the duration of this plan. An alternative approach would be to conduct a field experiment within stream enclosures where tadpole survivorship is assessed under different fish densities.

Responsibility: OEH

Action 6.4 Determine the likely influence of reduced water quality to Booroolong Frog population persistence.

While the Booroolong Frog appears robust to a range water quality parameters (such as temperature, dissolved oxygen, turbidity, nitrogen levels), there is currently no empirical data on how water quality affects their life cycle, disease transmission or habitat quality. Altered or reduced water quality may decrease the population level resilience of this species to other threatening processes. Determining the range of water quality parameters currently experienced by the Booroolong Frog, and examining how these influence individual fitness and population persistence, would enhance the capacity to understand possible interactions among threatening processes and their role in the ongoing decline of this species. This recovery action should incorporate both field and laboratory studies.

Responsibility: OEH

Objective 7. Increase community awareness and involvement in the Booroolong Frog recovery program.

Recovery Criterion:
The community is engaged in conservation efforts for the Booroolong Frog.

Action 7.1 Increase public awareness about the conservation of the Booroolong Frog.

In recent years there has been considerable effort to increase public awareness about the Booroolong Frog recovery program. This has been undertaken through: production and dissemination of an information brochure, presentations to Landcare and other interest groups; media releases about specific achievements, interpretive signs where management actions are visually conspicuous to the public, and an education program run by Taronga Zoo in the Tumbarumba region. These activities will continue as they encourage land owners/managers to consider this species in their general management and operations, and also encourage landowners to become involved in incentive programs aimed at enhancing habitat for this species.

Responsibility: OEH, DSE, CMAs, TZ, ARC.

Action 7.2 Provide specific education and training about the Booroolong Frog to relevant members of the public and management authorities.

Training programs will be developed and undertaken to provide management staff of various agencies (e.g. OEH, DSE) with the necessary knowledge and expertise for identification, monitoring and survey, and appropriate stream protection and rehabilitation procedures. A campaign aimed at providing education and information to property owners where the Booroolong Frog occurs will be undertaken. This will involve producing and disseminating information pamphlets, and undertaking education seminars for property owners outlining how they can help this species. An annual newsletter should be produced and circulated among interest groups and participants in recovery actions for the purpose of disseminating the latest news and information relating to the Booroolong Frog.

Responsibility: OEH, DSE

Objective 8. Achieve the effective implementation of the recovery plan.

Recovery Criterion:
A recovery team is established which comprises relevant expertise and stakeholders to effectively implement the recovery actions outlined in this Recovery Plan.

Action 8.1 Establish a recovery team for the Booroolong Frog to oversee the implementation of this recovery plan.

A recovery team should be established to oversee the implementation, assessment and direction of actions outlined in this recovery plan. The recovery team should contain people who are involved in the broader conservation management of the Booroolong Frog, or who oversee other works or programs that may influence the overall conservation of this species. The recovery team should also contain relevant scientific expertise that are either directly involved in undertaking recovery actions, or who can provide scientific expertise in areas relevant to recovery actions.

Responsibility: OEH

Management Practices

Protecting and enhancing habitat is critical to the conservation of the Booroolong Frog. Populations of this species appear robust to other potentially threatening processes (ie. fish

predation, Chytridiomycosis, herbicide use) while ever extensive suitable habitat remains available. Hence, the following management practices should be followed to conserve the Booroolong Frog:

- Maintain natural flow regimes in unregulated rivers supporting the Booroolong Frog.
- Reinstate natural flow regimes in regulated rivers supporting the Booroolong Frog through the use of environmental flows.
- Restrict stock access to the riparian zone within and upstream of Booroolong Frog populations.
- If stock are used to manage weeds in the riparian zone, undertake pulse or time constrained grazing using sheep or goats, rather than cattle.
- Control and eradicate exotic trees and shrubs, and other environmental weeds, which have the potential to dominate the riparian zone (e.g. Willows, Blackberry).
- Rehabilitate active erosion gullies upstream of Booroolong Frog populations.
- Improve general grazing management to reduce the risk of sheet erosion and creation of erosion gullies.
- Ensure illegal dredging for precious metals is not occurring.
- Limit the proportion of a catchment converted to forestry plantations to ensure persistence of surface water flows is not significantly reduced.
- Recommend that forest plantations maintain a minimum 30 metre buffer zone around all streams and tributaries within catchments supporting the Booroolong Frog.
- Maintain and encourage the re-establishment of native riparian vegetation within catchments supporting the Booroolong Frog.
- Do not stock introduced predatory fish in streams occupied by restricted or vulnerable Booroolong Frog populations.

Affected Interests

The key affected interests include government NRM agencies in NSW (OEH) and Victoria (DSE, PV), as well as select CMA and local councils and private land holders that manage areas supporting Booroolong Frog populations. Landcare groups, and professional societies (e.g. Australian Society of Herpetologists), as well as select conservation management networks will also take some interest in the survival and management of the Booroolong Frog and its habitat.

The recovery program will provide an important public education role as threatened vertebrates have the potential to act as ‘flagship’ species for highlighting biodiversity conservation issues in the environment. This has certainly been the case for the Booroolong Frog, as this species has been the focus of an extensive riparian restoration program that will benefit boarder biodiversity conservation, particularly in riparian zones.

Biodiversity Benefits

Implementing this recovery plan will provide benefits to many other species and vegetation communities occurring within the range of the Booroolong Frog. This will be achieved through the protection, rehabilitation and management of riparian habitats. In particular, many extant Booroolong Frog populations occur on private property where there is considerable scope for further habitat protection. This has already been undertaken along greater than 70 km of stream in the Murray, Murrumbidgee, and Namoi catchments. The broader public awareness generated through using the Booroolong Frog as a ‘flagship’ species, will also promote involvement in similar projects in other parts of the landscape. The distribution and habitat used by the Booroolong Frog also overlaps with a range of other threatened species (eg. Southern Pygmy Pearch, Macquarie Perch, Tiger Quoll), and as such, they will also benefit from conservation and management of habitat for the Booroolong Frog. Moreover, protection and rehabilitation of habitat for the Booroolong Frog will also directly benefit EPBC listed endangered ecological communities where this species occurs, such as; the ‘New England

Peppermint Grassy Woodland', and the 'White Box-Yellow Box-Blakely's Red Gum Grassy Woodland'.

In addition to habitat protection, the research and management outlined in this Recovery Plan will greatly benefit other threatened frog species. Valuable distribution and population information will be gathered on other sympatric threatened frog species through surveys and monitoring for the Booroolong Frog. Investigation of the underlying causes of the Booroolong Frog decline and how to ameliorate these are likely to aid our understanding and management of other declining amphibian species, particularly other riverine species occurring along the eastern ranges of Australia.

Role and Interests of Indigenous People

This recovery plan acknowledges that indigenous cultural heritage values may be relevant to some Booroolong Frog sites, and that it is important to work in partnership with traditional owners and indigenous communities to ensure that indigenous cultural heritage values are supported and protected. Indigenous communities on whose traditional lands the Booroolong Frog occurs will be advised, through the relevant regional Indigenous facilitator, of the preparation of this Recovery Plan and will be invited to provide comments and be involved in the implementation of the Plan. Given the importance of river corridors to Indigenous culture, the Booroolong Frog recovery program should be consistent with the management and conservation of culturally significant sites.

Social and Economic Impacts

The conservation of the Booroolong Frog outlined in this recovery plan is likely to have a range of economic impacts and costs to the broader community, primarily through protection and rehabilitation of stream habitats on privately owned and managed lands. However, this should be perceived as off-setting the longer term costs of catchment management and environmental rehabilitation. Due to extensive environmental damage to a large proportion of the Murray-Darling catchment, and the resulting economic and social costs, the broader community in Australia is becoming increasingly aware of the need to maintain healthy and intact river ecosystems. Actions outlined in this Recovery Plan will involve determining adequate procedures for conserving and enhancing Booroolong Frog populations on private properties, and develop a system for informing and negotiating with land owners and managers on how to best incorporate these procedures with existing farming and other land practices.

The conservation of the Booroolong Frog may also incur a social and economic cost to other organisations, companies and private individuals. Timber harvesting, water management, recreational use (e.g. recreational vehicles, fossicking), and mining represent possible conflicting uses in some catchments. These will be evaluated as actions proposed in this Recovery Plan are implemented. The results will be incorporated into forest management plans, catchment management plans, National Park management plans, and town planning.

This recovery plan estimates that the total costs of implementing the recommended actions will be $1,195,000 however this does not include the significant funds required to implement targeted riparian protection and restoration. The implementation of recovery actions within this plan will be dependant on available resources.

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Priority, Feasibility and Estimated Costs of Recovery Actions

Action	*Description*	*Priority*	*Feasibility*	*Responsibility*	*Cost estimate ($'000)*					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total
1	**Determine species distribution**									
1.1	Complete systematic surveys	1	100%	OEH, DSE	50	50	50			150
2	**Determine the taxonomic status and identify genetic sub-division**									
2.1	Determine the taxonomic status of northern and southern populations	1	100%	OEH, SAM	30	15				45
2.2	Identify genetic sub-division across the species range	1	100%	OEH, SAM	30	30				60
3	**Reduce the impact of known or perceived threats**									
3.1	Continue and expand riparian protection and restoration	1	100%	OEH, DSE, CMAs	Dependant on available resources and suitable properties					
3.2	Regulate the establishment of softwood plantations	1	100%	I&I						
3.3	Enforce legislation protecting streams and water flow	1	80%	OEH, I&I						
3.4	Reduce the transmission of potentially harmful pathogens	1	100%	OEH						
3.5	Prevent impacts from introduced predatory fish	2	90%	OEH						
4	**Determine population trends across range and in areas of different management regimes**									
4.1	Implement an effective monitoring program	1	100%	OEH, DSE, CMAs	30	30	30	30	30	150
5	**Impacts and response to climate change**									
5.1	Model the influence of predicted climate change	1	90%	OEH	40	15				55
5.2	Develop efficient reintroduction techniques	1	100%	OEH, DSE, TZ, ARC, JCU	40	40	40	40		160
5.3	Assess the capacity to use assisted colonisation	2	100%	OEH, TZ	40	40	20	20		120
6	**Identify other potentially threatening processes**									
6.1	Determine impact of herbicides	3	90%	OEH	50	25	25			100
6.2	Determine the current impact of Chytridiomycosis	3	90%	OEH, JCU	45	45	45			135
6.3	Determine the current impact of introduced fish	3	50%	OEH	50	30	30			110
6.4	Determine the influence of reduced water quality	3	90%	OEH	50	50	50			
7	**Increase community awareness and involvement**									
7.1	Increase public awareness	1	80%	DECC, DSE, CMAs, TZ, ARC	15	15	10	10	10	60
7.2	Provide specific education and training	2		OEH, DSE	5	5	5	5	5	25
8	**Achieve the effective implementation of the recovery program**									
8.1	Establish a recovery team	2	100%	OEH	5	5	5	5	5	25

TOTALS	**480**	**395**	**310**	**110**	**50**	**1345**

Appendix 1. Summary of Booroolong Frog Populations and Threatening Processes.

Information obtained from Hunter (2007), Spark (2009), D. Hunter, D. Coote, S. Clulow, P. Spark, G. Johnson (unpub. data).

Population	Streams Occupied	Estimated Length of Stream Occupied (km)	Estimated Proportion within Conservation Reserve	Significant Immediate Threats		Targeted Conservation Works in Progress
				Drying	Weeds/ Sedimentation	
MURRAY CATCHMENT						
Jingelic Ck	Jingelic Ck	7.5	0	X	X	X
	Coppabella Ck	13	0	X	X	X
	Lankeys Ck	9.5	0	X	X	X
Horse Ck	Horse Ck	0.1	0	X	X	
Manus Ck	Manus Ck	19.5	80		X	X
	Sappling Yards Ck	5.5	90	X	X	
McCabe Ck	McCabe Ck	0.1	0	X	X	X
Maragle Ck	Maragle Ck	15	0	X	X	X
	Maragle Back Ck	4	0	X	X	
Tooma R	Tooma R	6.5	100			
Burrowye Ck (Victorian Population)	Burrowye Ck	20	0	X	X	X
Koetong Ck (Victorian Population)	Koetong Ck	unknown	unknown	X	X	
MURRUMBIDGEE CATCHMENT						
Goobragandra R	Goobragandra R	40	50			X
	Sandy Waterfall Ck	5	0			
	Stony Ck	0.5	0	X		
	Peak R	10	80			
Mountain Ck	Mountain Ck	4.5	0	X	X	
Macpherson Swamp Ck	Macpherson Swamp Ck	4	50	X	X	
Brungle Ck	Brungle Ck	15.5	0		X	X
Bombowlee Ck	Bombowlee Ck	8	0	X	X	
Gilmore Ck	Gilmore Ck	23	0	X	X	X
Adelong Ck	Adelong Ck	18	0		X	X
Yaven Yaven Ck	Yaven Yaven Ck	30	20	X	X	
Umbango Ck	Umbango Ck	12	0	X	X	
	Carabost Ck	15	0	X	X	
Jounama Ck	Jounama Ck	7	100			
Yarrangobilly R	Yarrangobilly R	10.5	100			
LACHCLAN CATCHMENT						
Abercrombie R	Abercrombie R	> 20	20	X	X	X
	Gove Ck	4.3	40	X		
	Copperhannia Ck	unknown	0	X		
	Retreat R	18	90	X		X
	Silent Ck	10	80	X		
	Cooksvale Ck	unknown	0	X	X	
	Tuena Ck	> 5	80	X		

Appendix 1 continued.

Population	Streams Occupied	Estimated Length of Stream Occupied (km)	Estimated Proportion within Conservation Reserve	Significant Immediate Threats		Targeted Conservation Works in Progress
				Drying	Weeds/ Sedimentation	
CENTRAL WEST CATCHMENT						
Sewells Ck	Campbell R	2.5	0		X	
	Chain of Ponds Ck	3	0	X	X	
	Native Dog Ck	3.5	0	X	X	
	Captain Kings Ck	7	0	X	X	
	Wisemans Ck	2	0	X	X	
	Sewells Ck	20	0	X	X	
Upper Fish River	Fish R	1.5	0	X	X	
	Duckmaloi R	> 1	0	X	X	
Lower Fish River	Fish R	2	0	X	X	
Turon River	Coolamigal Ck	3.5	100	X	X	
	Turon R	40	30	X	X	
	Round Swamp Ck	> 2	0	X	X	
NAMOI CATCHMENT						
Cockburn R.	Cockburn R	31	10		X	
	Mulla Mulla Ck	10	0			
	Swamp Oak Ck	21	0			
	Oakey Ck or Jamiesons Ck	4	0		X	
Peel R.	Swamp Ck or Burrow Ck	0.1	0			
	Peel R	18	0			X
	Wombramurra Ck	7	15			X
HUNTER CATCHMENT						
Isis River	Isis River	> 1	0		X	
MANNING CATCHMENT						
Barnard R.	Barnard R.	> 1	100			X

Appendix 2. General Approach to Riparian Restoration and Protection for the Booroolong Frog

The following information outlines the objectives and general approach to undertaking riparian restoration for the Booroolong Frog. The overall objective is to protect and enhance the availability of breeding habitat for this species. This can be achieved by fencing the riparian zone so that stock access can be controlled, reducing the abundance or eradicating environmental weeds, and promoting the regeneration of native riparian vegetation. The initial priority should be to protect sections of stream occupied by the Booroolong Frog, and then focus on upstream sections. The most desirable longer-term outcome would be to protect and enhance all sections of stream within catchments supporting this species, as local impacts of sedimentation and weed invasion are typically the result of processes operating higher in the catchment.

Objectives:

1) Reduce stream bank erosion caused by lack of vegetation and constant stock access, within and up-stream of Booroolong Frog populations.
2) Re-expose potential breeding habitat through reducing the abundance or eradicating environmental weeds adjacent to rocky sections of stream.
3) Reduce the capacity for further environmental weeds infestation by reducing the abundance of these weeds from the catchment.
4) Promote the establishment of native riparian vegetation that will stabilise banks and filter sediments from surrounding areas.

Control/Eradication of Environmental Weeds:

Weed control in areas occupied by the Booroolong Frog will typically involve the use of chemical herbicides for stem injection or cutting and painting for larger trees, and foliar spraying for smaller plants. It is important that only herbicides that are registered for use near waterways are used. Roundup Bio-active™ has been used successfully for Willow and Blackberry control and this product is unlikely to significantly impact on the Booroolong Frog (see Mann and Bidwell 1999).

An important consideration when undertaking control/removal of willows from sections of stream is that stream banks may become unstable and more prone to erosion. This is particularly the case in areas where willows form the dominant riparian vegetation. Hence, it is most desirable to stage the removal of willows, such that relatively short sections of stream are treated and replaced with native vegetation in any given year.

Removing Willows and use of Heavy Machinery:

In many situations, willows are important for maintaining riverbank stability, and it is important that the control of willows does not undermine this service.

For reasons of aesthetics and protection of infrastructure, it may be necessary to remove the tops of large Willows. The root ball of the Willow should not be disturbed, but rather the Willow should be cut off at the trunk. Excavators should not be driven within the stream (unless at ford crossings for access purposes), or driven within two metres of rocky habitats along the stream margins. If the tops are being removed before the Willow has been completely killed, it is important to catch and remove all branch fall.

Follow-up Weed Management:

There is often a proliferation of weeds following the removal of stock. Furthermore, initial attempts to kill large Willows may fail, and new Willows may become established from branches that were not collected and removed during the poisoning processes. It is likely that chemical herbicides will be required for foliar spraying small Willow and Blackberry during follow-up weed control. If pulse or time controlled grazing within the riparian zone is used to assist with weed management, it is preferable to use sheep rather than cattle, as sheep will not enter the aquatic environment and cause less erosion by virtue of their smaller size. Promoting an increased cover of native riparian vegetation will also reduce the future weed load. Failure to undertake follow-up weed management is likely to undermine the objectives of this program.

Appendix 3. Booroolong Frog Monitoring Program

The following information outlines the objectives and approach currently used to monitor the Booroolong Frog in the Murray, Murrumbidgee and Lachlan catchments.

Monitoring Objectives:

1. *Determine whether the Booroolong Frog is continuing to decline across its range.*

The most efficient means of achieving this objective is through presence/absence monitoring across sites that represent this species current distribution.

2. *Determine the ability for Booroolong Frog populations to recover from stream drying.*

Achieving this objective will involve monitoring the breeding habitat occupancy (presence/absence) of the Booroolong Frog along sections of stream where it has contracted in range since the onset of severe droughts in 2003. This monitoring program is currently being undertaken along several streams for which pre-drought distribution data exists, and sections of stream where no range contraction occurred as controls.

3. *Determine the Booroolong Frog population and habitat response to riparian protection and restoration.*

The current monitoring program assessing riparian restoration works involves determining temporal changes in breeding habitat occupancy, and changes in the distribution and structure of rocky habitats. This is being undertaken along sections of stream that have been the focus of restoration works, plus sections where no works have been undertaken in the agricultural landscape and more protected streams in National Parks.

Methods:

Frog Monitoring

Presence/absence surveys are use to determine the occupancy of the Booroolong Frog at the scale of 500 metre sections of stream (Objective 1), and breeding habitat (Objectives 2 and 3). Night surveys are undertaken during the breeding season (mid October to late December) by spotlighting within the riparian zone for eye-shine. Occupied breeding habitat is defined as an area of rocky habitat occupied by one or more mature male Booroolong Frogs during the breeding season. The location, sex, and total number of frogs observed during each census are recorded. A small proportion of the sites for each objective are surveyed on three occasions within each season to ensure detectability remains high.

Breeding Habitat monitoring

The habitat monitoring involves determining the distribution, type, and length of rock habitats along the stream banks. The rock type is divided into two broad categories: Cobble banks - a section of stream bank greater than one metre in length with a continuous cover of loose rock. Bedrock banks - defined as a section of stream bank greater than one metre in length with a continuous cover of solid rock that is embedded in the ground. The number of crevices within each rock habitat is also recorded. A crevice is defined as a space under or between rocks where a 2.5 cm wide, 1 cm high and 3 cm long piece of metal could be freely inserted, but which was no higher than 3 cm. This area was considered a representation of the area that could be used by the Booroolong Frog for egg deposition. Regardless of crevice length, continuous crevices in bedrock or under individual rocks are only counted as one crevice.

Survey Frequency

A proportion of the sites are surveyed each year, with each site being surveyed once every three to five years.

Interpreting Results

Due to the high detectability of the Booroolong Frog during the breeding season (Hunter 2007), relatively small shifts in this species occupancy can be confidently identified. For Objective one, examining the raw data is sufficient to determine trends in this species occupancy across its range. For Objectives 2 and 3, a repeated-measures design should be used to analyse the frog and habitat data.