National Recovery Plan for the Southern Corroboree Frog *Pseudophryne corroboree* and Northern Corroboree Frog *Pseudophryne pengilleyi*

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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 Southern Corroboree Frog (*Pseudophryne corroboree*) and Northern Corroboree Frog (*Pseudophryne pengilleyi*), and as such considers the conservation requirements of these species across their known range. It identifies actions to be undertaken to ensure the long-term viability of both species in nature, and current stakeholders involved in their recovery. This is the first national recovery plan for the Northern Corroboree Frog and the second for the Southern Corroboree Frog.

The Southern Corroboree Frog is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and Endangered under the NSW *Threatened Species Conservation Act 1995*. The Northern Corroboree Frog is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, Vulnerable under the NSW *Threatened Species Conservation Act 1995*, and Endangered under the ACT *Nature Conservation Act 1980*. These species are distinctive, and are among Australia's most iconic frogs because of their striking colour patterns consisting of bright yellow or green longitudinal stripes alternating with black stripes. The range of the Southern Corroboree Frog is restricted to the Snowy Mountains Regions of Kosciuszko National Park in New South Wales, while the Northern Corroboree Frog occurs in New South Wales and the Australian Capital Territory within Kosciuszko National Park, Bondo State Forest, Micalong State Forest, Wee Jasper State Forest, Namadgi National Park, Brindabella National Park and Bimberi Nature Reserve. Since the mid 1980's, both corroboree frog species have been in decline, with the Southern Corroboree Frog and Brindabella Range populations of the Northern Corroboree Frog likely to become extinct in the wild within the next ten years if recovery efforts are unsuccessful. The primary cause of this decline is a disease known as chytridiomycosis, which is caused by infection with the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*). Chytridiomycosis is the primary cause of decline for many Australian frog species, and has been listed as a key threatening process at both a state and national level. Other factors that have historically or continue to impact on corroboree frogs include; climate change, weed invasion, loss and degradation of habitat associated with forestry activities, historic cattle grazing, and feral pigs and horses.

A recovery program for corroboree frogs has been in operation since 1996, which has greatly enhanced our understanding of the causes of decline and capacity to prevent their extinction. This recovery plan outlines the direction of the recovery program for the next five years. Actions identified in the recovery plan include: (i) monitoring and surveys, (ii) refinement of captive breeding protocols and establishment of a viable captive colony, (iii) development of effective reintroduction techniques, (iii) development of methods to mitigate chytridiomycosis and climate change, (iv) protection of habitat from weeds, feral animals and forestry operations and (v) community awareness raising.

The primary stakeholders involved in the implementation of these actions include: New South Wales Office of Environment and Heritage; Australian Capital Territory Parks, Conservation and Lands (which includes Tidbinbilla Nature Reserve); Forests NSW; Murray Catchment Management Authority; Amphibian Research Centre; Taronga Conservation Society Australia; Zoos Victoria; Australian National University, University of Wollongong and James Cook University. An additional $1130,000 over the five-year period will be required to implement some currently unfunded actions.

Abbreviations:

ARC	Amphibian Research Centre
CMA	Catchment Management Authority
OEH	New South Wales Office of Environment and Heritage
FNSW	Forests New South Wales
IUCN	International Union for Conservation of Nature
ANU	Australian National University
JCU	James Cook University
UW	University of Wollongong

NCF	Northern Corroboree Frog
PCL	Australian Capital Territory, Parks, Conservation and Lands
SCF	Southern Corroboree Frog
TNR	Tidbinbilla Nature Reserve
TZ	Taronga Zoo
ZV	Zoos Victoria

Species Information

Description

The Southern Corroboree Frog (hereafter referred to as SCF) and Northern Corroboree Frog (hereafter referred to as NCF) are distinctive and easily recognised because of their striking dorsal colour patterns consisting of bright yellow or green longitudinal stripes alternating with black stripes (Moore 1953). The SCF always has bright yellow stripes, while the stripes of the NCF vary from yellow to lime green. The ventral surface of both species is boldly marked with black, yellow or lime green, and white blotches. Adult corroboree frogs reach a length of between 25 and 30 mm. There are several differences between the SCF and NCF, including considerable genetic divergence (Roberts and Maxson 1989; Osborne and Norman 1991, Morgan *et al*. 2008), differences in colour-pattern and morphology (Pengilley 1966, Osborne *et al.* 1996), and skin biochemistry (Daly *et al.* 1990). The ranges of these two species do not overlap (Figure 1). Tadpoles of the corroboree frogs are dark in colour, have a relatively long paddle shaped tail, and grow to 30 mm in total length (Anstis 2002).

Conservation Status

The SCF is listed as Endangered under both the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC Act) *1999*, and the NSW *Threatened Species Conservation Act* (TSC Act) *1995*. This species has been listed as Critically Endangered by the International Union for Conservation of Nature (IUCN).

The NCF is listed as Vulnerable under both the EPBC Act and Critically Endangered under the TSC Act. In the Australian Capital Territory (ACT) the species is listed as Endangered under the *Nature Conservation Act 1980*. This species has been listed as Endangered by the IUCN.

Distribution

The two corroboree frog species have a limited geographic distribution (Figure 1). The historic range of the SCF is entirely within Kosciuszko National Park, from Smiggin Holes in the south, and northwards to the Maragle Range. This constitutes a linear range of 51km, with the overall area being approximately 500 km^2 (Osborne 1989). The broadest part of the range (24 km) occurs near Mount Jagungal. The SCF occupies a relatively narrow altitudinal strip between about 1300 and 1760 m above sea level. The occupied range of the SCF has greatly contracted over the past 25 years, and the species now occurs in a small number of remnant populations along the north-western edge of its former range (Figure 1).

The NCF occurs throughout the Fiery Range and Bogong Mountains in Kosciuszko National Park, Bondo State Forest, Micalong State Forest, and Wee Jasper State Forest in NSW, and along the Brindabella Ranges in Namadgi National Park in the ACT, and Bimberi Nature Reserve and Brindabella National Park in NSW. The species occupies an altitudinal range between 750m and 1800m, and a total area of approximately 950 km^2 (Osborne 1989). Populations in the Fiery Range and Bogong Mountains appear to be contiguous, however within the Brindabella Ranges, the NCF occurs as two sub-populations (Osborne 1989). The southern Brindabella sub-population is found only in the subalpine zone (above about 1400m) from near the summit of Mount Bimberi northwards to Ginini Flats (ACT). The northern sub-population occurs at lower altitudes along the Brindabella Range from Bushrangers Creek (ACT) northwards to near California Flats in NSW. The NCF is separated from populations of the SCF (Figure 1) by the comparatively dry and wind-swept Kiandra and Coolamine Plains.

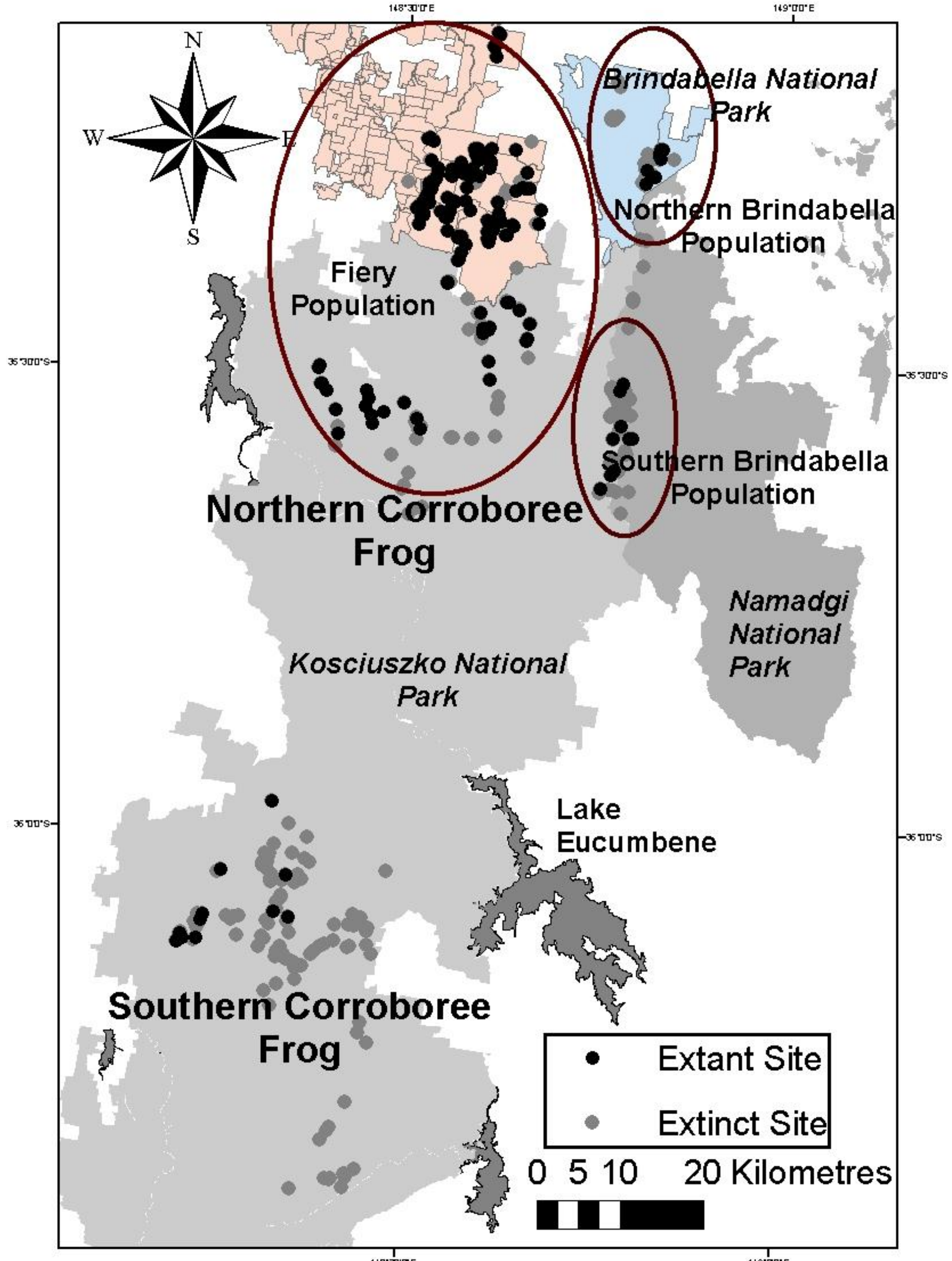

Figure 1. Distribution of extant and extinct sites for the Southern and Northern Corroboree Frogs to 2010. Areas circled represent the significant management units (populations) within the Northern Corroboree Frog Range.

Population Information

Given the small range occupied by both SCF and NCF, all extant populations of these species are considered important to their survival. The SCF currently occupies only a small number of sites within or immediately adjacent to the Jagungal Wilderness Area of Kosciuszko National Park (Figure 1). The monitoring results for 2012 suggested that there were only nine males remaining across five sites, with the largest site containing only four males (Hunter unpub. data). A recent study found no evidence of genetic sub-division within the SCF (Morgan *et al*. 2008), and therefore remaining populations are considered one management unit.

The NCF broadly occupies three distinct geographic areas (Osborne 1989) (Figure 1), which correspond with significant levels of genetic subdivision (Morgan *et al*. 2008). As such, these areas are considered three separate populations or management units (hereafter referred to as Southern Brindabella, Northern Brindabella, and Fiery populations). The two Brindabella NCF populations are in critically low abundance. The Fiery NCF population currently persists in greater abundance, and over a larger range, however significant declines and range contractions have also occurred in this population (R. Pietsch, B. Scheele, W. Osborne, D. Hunter unpub. data).

Habitat

Habitat critical to the survival of both corroboree frog species includes both the breeding habitat, and adjacent areas where these frogs may forage. Corroboree frogs use a variety of habitat types for breeding which includes pools and seepages in sphagnum bogs, wet tussock grasslands, fens and wet heath (Osborne 1990). They also forage and shelter in montane forest, sub-alpine woodland and tall heath adjacent to the breeding areas. During the summer, the adult frogs breed in shallow pools and seepages within the breeding area. The corroboree frogs have a strong tendency to breed in ephemeral water bodies that are dry during the breeding season (Osborne 1990, Hunter *et al*. 2009a). Breeding sites are usually of gently sloping topography, and typically occur on granitic and volcanic substrates (Osborne 1990, Lowery 2006). The vegetation present at breeding sites varies considerably, ranging from sphagnum bog and wet-heath at higher altitudes, to wet sod-tussock grasslands and seepage lines in montane forest. Outside the breeding season, corroboree frogs have been found sheltering in dense litter and under logs and rocks in adjacent woodland and tall moist heath (Pengilley 1966). Osborne (1988 and unpublished) found that following breeding, adult NCF are capable of moving over 300 metres into the surrounding woodland.

Life-history and Ecology

The corroboree frogs have a typical biphasic amphibian life-cycle with an aquatic tadpole stage and terrestrial post-metamorphic juvenile and adult frog stage. Adult males move into breeding areas in early to late summer, and call from late December through to mid March. The males call from small chambers (nests) in moss or other soft vegetation at the edges of the breeding pools (Osborne 1990). The males have three call types; an advertisement call, threat call, and courtship call (Pengilley 1971a). The advertisement call and courtship call are used to attract females to the nest site, whereas the threat call serves as a warning to other males (Pengilley 1971a). Advertisement call intensity varies depending on the weather, with more calling occurring during warmer overcast conditions, and during late afternoon (Pengilley 1971a, Osborne 1989).

Females lay their eggs in the terrestrial nests occupied by the breeding males. Males remain in their nest site through the breeding season and may accumulate multiple clutches in their nest. Clutch size for these species is relatively low for amphibian species; 16 to 38 eggs per female (Pengilley 1973). The eggs are amongst the largest in the genus (Tyler 1989), measuring about 3.5 mm in diameter, with the transparent capsules swelling to about 9 mm in diameter when hydrated. The eggs are laid in a terrestrial nest within or adjacent to a suitable pool, where the embryos develop to an advanced stage prior to entering diapause. Typically, the pools are dry during the breeding season when the eggs are laid. The embryos remain in diapause until flooding of the nest site in autumn or winter stimulates them to hatch. After hatching, the tadpoles move out of the nest site and into the adjacent pool where they live for the remainder of the larval period as a free swimming and feeding tadpole. The tadpoles show little growth during winter, when temperatures at the breeding sites are very low and snow often covers the ground (Hunter and Osborne 2000). At the end of winter, when snow has melted from the breeding sites, the tadpoles continue growing slowly until metamorphosis in early summer (Hunter *et al*. 1999).

Information on survivorship from egg laying to metamorphosis has been obtained for SCF clutches across several sites between 1997 and 1999. This study determined average survivorship from egg to metamorphosis to be 20 percent in the absence of early pool drying (Hunter 2000). Early pool drying (i.e. drying of the pools before tadpoles reach metamorphosis) during drought years typically caused complete failure of recruitment to metamorphosis for that year (Hunter 2000). The typically low survivorship of nest sites is consistent with the results of tadpole surveys that found that one third of small remnant breeding populations attain no recruitment to metamorphosis each year (Hunter 2001).

Very little is known about the life history of either corroboree frog species after they leave the pools as juveniles. Pengilley (1966, 1992) suggested that they remain in moist vegetation near the breeding pools for several months, where they feed on a wide variety of small invertebrates. As they grow larger, the juveniles leave the breeding area and move into the adjacent non-breeding habitat where it is thought they remain until they are adults. The diet of sub-adults and adults consists mainly of small ants and, to a lesser extent, other invertebrates (Pengilley 1971b).

Age to sexual maturity from metamorphosis for the SCF was determined using skeletochronology (age determination based on growth rings in bone). Age to first reproduction was found to be four years from metamorphosis for the majority of individual males, with a small proportion of individuals attaining sexual maturity in three years (Hunter 2000). The oldest individuals identified using this technique were nine years old (Hunter 2000). It is likely that the majority of females take four or five years to attain sexual maturity. Based on the proportion of individuals in different age classes from one year to the next, annual survivorship for adult males was determined to be between 50 and 60 percent (Hunter 2000). There is currently no information on survivorship from metamorphosis to sexual maturity for either corroboree frog species.

Decline and Threats

The corroboree frogs have been the focus of a population monitoring program since 1986 (Osborne *et al*. 1999, Hunter *et al*. 2009b, Murray Evans unpub. data). The aim of this program was to identify broad population trends across the range of both species (Osborne 1991). This monitoring program demonstrated that the corroboree frogs have been declining across their range, with the greatest declines occurring in the SCF, and the two Brindabella NCF populations. Due to the extensive declines, the monitoring program was redesigned to include all known extant sites of the SCF, and the majority of extant sites for the Brindabella NCF populations.

There is little doubt as to the severity of the continued decline of the corroboree frogs. Without effective recovery actions, these declines are likely to continue until the SCF and two Brindabella NCF populations become extinct in the wild, possibly within the next ten years. The recovery team is undertaking a proactive and intensive program to achieve the recovery of these species. The key factors contributing to the recent and continued decline in these species are outlined below.

Disease

There is considerable and increasing evidence implicating the disease ‘chytridiomycosis’ as the primary cause of decline in the corroboree frogs (Hunter *et al*. 2010, see also Skerratt *et al*. 2007). This disease is caused by infection with the Amphibian Chytrid Fungus, *Batrachochytrium dendrobatidis*, which has spread throughout the world over the past three decades and caused mass amphibian declines and extinctions (Berger *et al*. 1998, Skerratt *et al*. 2007). The capacity for chytridiomycosis to cause ongoing decline in corroboree frogs appears to be facilitated by the Common Eastern Froglet (*Crinia signifera*) acting as a non susceptible, reservoir host for *B. dendrobatidis* in the shared environment (Hunter 2007). Mitigating the impact of *B. dendrobatidis* will require facilitating the development of population resistance to disease caused by this pathogen. Population resistance may arise through a range of processes, including: reduced virulence in the pathogen, increased resistance in individual hosts, a shift in ecological interactions, or any combination of these. This appears to have occurred in populations of other threatened frog species that were initially susceptible to this pathogen (cf. Retallick *et al*. 2004). Mitigating the impact of chytridiomycosis on corroboree frogs within their known range is likely to require an increase in individual resistance, because the presence of the Common Eastern Froglet limits shifts in ecological interactions or selection for decreased virulence.

Anthropogenic Climate Change

Climate change is expected to have a significant impact on corroboree frogs (Osborne and Davis 1997). Based on current climate models for the Australian Alps, winter and spring precipitation and snowfall are likely to continue to decrease (Hennessey *et al*. 2003), reducing the water table during late spring and early summer, and resulting in earlier pool drying. Given the strong tendency for corroboree frogs to breed in highly ephemeral pools (Osborne 1990, Hunter *et al*. 2009a), the most immediate and direct impact of climate change will result from increased rates of pool drying prior to metamorphosis. While pre-decline corroboree frog populations would have been robust to failed recruitment during El Niño events (Hunter 2000), an increase in the frequency of droughts will only further compromise the capacity for these species to recover from their current low population size. Moreover, the impact of *B. dendrobatidis*, through decreasing adult survival (cf. Scherer *et al*. 2005), will increase population susceptibility to failed recruitment. This is because failed recruitment in some years is compensated by the adults being able to live longer and breed over consecutive years. Climate change will also impact on corroboree frogs by altering the vegetation structure of breeding pools and the hydrological functioning of wetlands, which is likely to be exacerbated by increased fire frequency. This process appears to have already occurred across many sites occupied by the NCF, as many sites previously occupied by the NCF no longer appear to contain suitable pools (B. Scheele 2010).

Feral Animals

While corroboree frogs are unlikely to be threatened by feral predators, due to their poisonous skin properties (Daly et al. 1990), a number of feral herbivores are damaging breeding and non-breeding habitat for these species. In recent years, Feral Pigs (*Sus scrofa*) and Feral Horses (*Equus caballus*) have been observed damaging corroboree frog breeding habitat by trampling and grazing (R. Pietsch, D. Hunter, W. Osborne pers. obs.). Feral Pigs currently occur throughout the range of both corroboree frog species, while Feral Horses currently occur along the western edge of the SCF distribution, and the Fiery Range population of the NCF (although within this region they are absent from much of the Bogong Peaks Wilderness area). There is also concern that Sambar Deer (*Cervus unicolor*) and Fallow Deer (*Dama dama*) abundance will increase to a level where environmental impacts will be significant in areas occupied by the corroboree frogs. The Feral Horse population in the Fiery Range and adjacent areas is particularly concerning, and it is obvious that they are causing considerable damage to many NCF breeding sites (W. Osborne, R. Pietsch, D. Hunter, B. Scheele pers. obs.). Feral Horses have the capacity to cause incision of wetlands and alter drainage patterns and vegetation structure (Costin *et al*. 1959, McDougall 1989, Whinam and Chilcott 2002). It is critical to the conservation of the NCF that horse abundance is maintained at levels where environmental impacts are negligible. As an interim protection measure in this region, it would be valuable to erect exclusion fences to protect key monitoring sites that are currently being heavily impacted from horses. Horse exclusion fencing would need to allow native herbivore access, particularly wombats. Exclusion fences would also provide an opportunity to quantify the magnitude of horse impacts on NCF breeding habitat.

Weeds

Because corroboree frogs typically breed in pools that are exposed to solar radiation (Osborne 1990, Hunter *et al*. 2009a), shading by weeds such as Blackberry (*Rubus fructicosus* aggregate) is likely to impact these species. The spread of Blackberry (*Rubus fructicosus* aggregate) is a significant threat to NCF breeding sites. Blackberries are particularly abundant in Bondo, Micalong and Wee Jasper State Forests, and parts of northern Kosciuszko National

Park, where many breeding sites have been invaded by this weed, and appear no-longer suitable for the NCF (W. Osborne, R. Pietsch, D. Hunter, B. Scheele pers. obs.). Moreover, forestry activities are likely to exacerbate the spread of Blackberries in this region. While there are no weeds currently impacting on the SCF, Orange Hawkweed (*Hieracium aurantiacum*) has the potential to significantly impact on this species if control efforts are unsuccessful in Kosciuszko National Park.

Habitat Degradation

Historic cattle grazing has caused significant soil erosion in the Snowy Mountains region of Kosciuszko National Park (Costin 1954, Wimbush and Costin 1979, McDougall 1989). Costin (1954) noted that trampling by livestock caused incision in peatlands leading to erosion and deeper drainage channels. These deeper channels lowered the water table and caused the drying of peatbogs, which would have resulted in a reduction in the extent of breeding habitat for corroboree frogs. While cattle grazing no longer occurs in areas occupied by the corroboree frogs, the reduction in suitable breeding habitat caused by historic grazing has compromised the recovery of these species.

Loss and degradation of breeding habitat for the NCF would have also occurred when large areas of native forest were cleared for the establishment of softwood plantations. A significant proportion of the Fiery NCF population (approximately 25%) currently occurs within areas subject to forestry activities. The impact of timber extraction on the survival of NCF populations is unknown and requires specific research to determine its significance.

Recovery Information

Existing Conservation Measures

An active recovery program for corroboree frogs began in 1996, and since then, a number of recovery actions have been achieved, or are currently being implemented (see Appendix 1 for a review of recovery actions and discussion of their effectiveness from the previous National Recovery Plan for the Southern Corroboree Frog, 2001). This recovery program has been successful at providing the critical information required to further the recovery prospects of these species. Below is a brief summary of previously completed and ongoing actions:

- *Thorough systematic surveys undertaken for the SCF and Brindabella Range NCF populations.*

Thorough surveys for the SCF and Brindabella Range NCF populations have been undertaken. Due to the ongoing and severe decline in these populations, these surveys have provided critical baseline information for implementing the majority of other recovery actions (see below).

- *Annual monitoring program implemented for both species.*

The annual monitoring program has been implemented over the past 15 years for both SCF and NCF. Information gained from this program has demonstrated the ongoing decline in both species (Hunter *et al*. 2009b). Due to the precariously low population size of the SCF and Brindabella Range NCF populations, monitoring has been expanded to include all known extant sites for these species/populations. Furthermore, the annual monitoring program has been used as a basis to assess reintroduction trials (Hunter 2007).

- *Research undertaken into the ecology, habitat requirements and factors causing decline* (Osborne 1990, Hunter *et al*. 1999, Hunter 2000, Hunter 2007, Hunter *et al*. 2010, Scheele 2010).

This recovery action has provided critical information relating to the demography (Hunter 2000), habitat requirements (Lowery 2006, Hunter *et al*. 2009b, Scheele 2010), and causal factors of corroboree frog declines (Hunter *et al*. 2010, Scheele 2010). Information attained on the demography of corroboree frogs (age to sexual maturity and annual survivorship) has greatly enhanced interpretation of monitoring results and capacity to implement actions relating to captive husbandry and reintroduction. The research into the habitat requirements and causal factors of decline has demonstrated the role of the amphibian chytrid fungus and severe droughts in the decline of the corroboree frogs, and has allowed the pursuit of management actions aimed at mitigating these threatening processes.

- *Population genetic study completed.*

This action successfully identified evolutionary significant units within the NCF that will be a priority for conservation efforts, particularly captive breeding and reintroduction (Morgan *et al*. 2008).

- *Development of a genetic sexing technique for assisting the captive breeding program (Quinn 2009).*

Because corroboree frogs that have only recently attained sexual maturity cannot be reliably sexed using external morphology, an alternative sexing technique was required to assist in the implementation of captive breeding trials. This was achieved through the development of genetic sex markers.

- *Trial reintroductions and translocations of eggs, tadpoles and adult frogs currently being undertaken (Hunter et al. 1999, Hunter 2007, Hunter et al. 2009b).*

Trial reintroductions of captive bred and reared eggs and adult frogs have been undertaken for the SCF. The results of these studies suggest that both egg and frog releases can be used to re-establish wild populations of this species. The potential for egg releases into artificial pools to be a more efficient release strategy is currently being assessed.

- *Development of effective captive breeding protocols, including the application of assisted reproductive technologies, currently being undertaken (Hunter et al. 2009b, Byrne and Silla 2009).*

Captive breeding of both SCF and NCF has been achieved at all the major husbandry institutions involved in this program (Amphibian Research Centre, Taronga Zoo, Tidbinbilla Nature Reserve, Melbourne Zoo, Healesville Sanctuary). Initial trials using assisted reproductive technologies show potential for this technique to successfully produce viable corroboree frog progeny, however further work is required to increase the survivorship of fertilized ova.

- *Establishment of captive breeding colonies of both SCF and NCF.*

Large numbers of both the SCF and northern and southern Brindabella populations of the NCF have been secured in captivity across the five husbandry institutions involved in this recovery program (Amphibian Research Centre, Taronga Zoo, Tidbinbilla Nature Reserve, Melbourne Zoo, Healesville Sanctuary). Based on the recent success in breeding these species in captivity, these colonies will be self sustaining, and have begun producing stock for reintroduction back to the wild.

- *Application of population modeling to examine strategies for captive breeding and reintroduction (McCarthy 2008, Hunter et al. 2009b).*

This modeling has provided information on the level of captive breeding success and colony size required to adequately assist field reintroductions.

- *Control of Feral Pigs and Horses from sensitive areas.*

Over the past fifteen years, Feral Pigs and Horses have been effectively controlled throughout the distribution of the SCF and southern Brindabella Range population of the NCF. This work has prevented significant impacts on habitat critical to the persistence of corroboree frogs.

- *Protection of key sites from wildfire.*

Key sites that are currently the focus of reintroduction programs will be considered a high priority asset for protection in the event of wildfire (NSW DECC 2008)

- *Prescriptions to protect breeding habitat in areas subject to forestry operations.* (Appendix 2)

This action has resulted in the regulation of forestry activities in the vicinity of NCF breeding habitat

- *Implementation of a community outreach and fund raising program.*

This component of the corroboree frog recovery program has been successful at attracting considerable media interest and exposure, and has resulted in significant resources being acquired through sponsorship and fund raising.

Recovery Objectives

The overall objective of recovery is to prevent the extinction of corroboree frogs in the wild, and to increase the viability of populations so they are self-sustaining in the longer term. This cannot be achieved in the five year program outlined in this plan; however, critical steps towards achieving this overall objective can be undertaken. More specifically, this recovery plan outlines a strategy of consolidating current knowledge and recovery efforts for the corroboree frogs, and developing effective management actions that will increase the distribution and abundance of corroboree frogs in the wild. Furthermore, implementing the actions outlined in this plan will establish the foundations for a program that can adopt new knowledge and techniques for mitigating the impact of the Amphibian Chytrid Fungus, which has devastated the global amphibian fauna, and is currently the focus of much research throughout the world.

The objectives for the five year program outlined in this plan are as follows:

1. Determine the distribution, abundance, and populations trends for the SCF and NCF.
2. Establish and maintain viable captive breeding colonies.
3. Develop, implement, and assess reintroduction techniques.
4. Reduce the impacts of known threatening processes.
5. Minimise impacts from forestry activities on NCF.
6. Integrate the conservation requirements of corroboree frogs into the general management of National Parks, Nature Reserves, and State Forests.
7. Increase community participation in corroboree frog recovery.
8. Ensure the recovery program is well coordinated, consultative and adequately resourced.

Program Implementation and Evaluation

This recovery plan provides guidance and coordination for recovery actions for both the SCF and NCF. Conservation and recovery of corroboree frogs is the responsibility of the Australian, NSW and ACT governments under their respective legislation. However, other organisations also contribute to recovery actions, including husbandry institutions, universities, regional natural resource management authorities and community groups. This recovery plan will be maintained and managed by OEH. The recovery plan is intended to run for a maximum of five years from the date of its adoption under the EPBC Act, and will be reviewed, and possibly revised, within five years of the date of its adoption by OEH, PCL and the recovery team, in consultation with DSEWPaC. The implementation of specific recovery actions is the responsibility of the relevant governments and will be dependent on available resources. Technical, scientific and education components of the recovery plan will be referred to specialist groups as required. It is also acknowledged that the corroboree frog recovery program is dynamic, with a high likelihood that the priority of actions will change and new actions will be established as new information arises within the projected five year duration of this plan.

Recovery Objectives and Actions

Objective 1. Determine the distribution, abundance, and populations trends for the SCF and NCF.

Recovery Criterion:

Population trajectory for SCF and NCF, and temporal trends in breeding habitat structure are determined on an ongoing basis, and thorough understanding of NCF distribution and abundance in the Fiery Range has been attained by 2015.

Action 1.1 Continue annual corroboree frog monitoring.

The primary objective of the corroboree frog monitoring program is to assess ongoing trends in abundance and occupancy, locate nests for egg harvesting, and assess the outcomes of experimental reintroductions (see actions 3.1 and 3.2). Monitoring for the SCF and Brindabella NCF populations are undertaken at the majority of extant sites, while only a small sub-set of sites are monitored for the Fiery NCF population. A recent assessment of NCF monitoring in State Forests (part of Fiery population) recommended that additional sites be incorporated to optimise the statistical power of this program (Lemckert *et al*. 2011). A similar assessment should be undertaken for NCF monitoring in Kosciuszko National Park. Annual monitoring across the range of both SCF and NCF should be expanded to include an assessment of pool and bog characteristics that may be impacted from climate change, forestry operations, fire, and feral animals.

Frog monitoring and surveys target the breeding male population, and use a technique referred to as shout-response. This technique involves shouting loudly in the vicinity of breeding habitat, to which the males respond with their threat call. This technique has been shown to be highly efficient at detecting both corroboree frog species (Hunter 2000, Scheele 2010).

Responsibility: OEH, PCL, FNSW

Action 1.2 Complete distributional survey for the NCF in the Fiery Range.

Thorough surveys have been undertaken for the SCF, and Brindabella NCF populations. In the Fiery Range, systematic surveys have been undertaken in Wee Jasper, Bondo, and Micalong State Forests, however surveys have been limited in Kosciuszko National Park. Given the extensive declines observed throughout the range of both species, it is critical that this action is completed in the Fiery Range to provide an accurate basis for further assessment of population trends, conservation status, and impact of threatening processes.

Responsibility: OEH

Objective 2: Establish and Maintain viable captive breeding colonies.

Recovery Criterion:

Two separate viable captive breeding colonies have been established for the SCF, and each of the two Brindabella NCF management units, by 2015.

Action 2.1 Ensure the viability of captive colonies.

Since wild populations of the SCF and Brindabella NCF will continue to decline to extinction without the support of captive breeding and reintroduction, maintaining existing captive colonies is one of the highest priority recovery actions for this recovery program. It is necessary to demonstrate that the proportion of females breeding each year, and viability of eggs produced, are sufficiently high to meet the requirements of the overall recovery program (maintaining the captive assurance colony and supplying progeny for reintroductions and other experiments).

Responsibility: OEH, PCL, TNR, TZ, ARC, ZV

Action 2.2 Develop protocols for using assisted reproductive technologies to produce viable corroboree frog offspring.

Developing efficient and reliable methods for producing viable corroboree frog progeny in captivity is important for maximising the overall capacity of the recovery program. One technique that has been critical in the success of other amphibian captive breeding programs is the use of assisted reproductive technologies (i.e. hormone induced ovulation and release of sperm and subsequent fertilisation, see Kouba *et al*. 2009). The application of such techniques may reduce the need for large breeding enclosures, allow the maintenance of rigorous quarantine procedures, increase the rate at which individuals successfully produce viable progeny, and enhance the management of genetic diversity. Initial trials testing the application of these techniques to SCF have been encouraging, as eggs and sperm have been successfully obtained, and fertilisation has been achieved (Byrne and Silla 2009, 2010). Further work is required to refine these techniques for corroboree frogs.

Responsibility: OEH, UW, TZ, ARC, ZV

Action 2.3 Use demographic modelling to assist the development of captive husbandry and reintroduction priorities.

Demographic modeling can assist in the development of a strategic focus for the captive husbandry program through examining the interaction between the captive and field populations. Initial modeling has been undertaken (McCarthy 2008, Hunter *et al*. 2009b), and has provided valuable insight into the requirements of the captive breeding program for producing sufficient progeny for reintroduction back to the wild. This modeling process should be further refined as new information is attained. In particular, further modeling should be undertaken once the current reintroductions and breeding trials have been completed (within the next three years).

Responsibility: OEH, PCL

Objective 3. Develop, implement, and assess reintroduction techniques.

Recovery Criterion:
Effective reintroduction techniques have been developed and implemented, and SCF and Brindabella populations of the NCF are persisting at four locations in the wild.

Action 3.1 Assess the effectiveness of releasing SCF eggs into artificial pools.

Reintroducing corroboree frog eggs, as opposed to tadpoles or frogs, has the following advantages; eggs are less likely to carry pathogens, it is logistically easy to transport eggs from captivity to the wild, and eggs have minimal rearing costs. While a previous study suggested that reintroducing early life-history stages is not effective at increasing the breeding adult population (Hunter 2007), this result may have been strongly influenced by mortality associated with disease and early pool drying. The current program of reintroducing eggs into artificial pools should greatly reduce the impact of both these factors, as the pools typically remain free of Amphibian Chytrid Fungus infection, and will maintain water in drought years until the tadpoles have reached metamorphosis (Hunter *et al*. 2009b). Assessing the use of artificial pools began in 2007 (Hunter *et al*. 2009b), and will continue until the capacity for this technique to establish breeding populations has been adequately assessed (at least until 2015).

Responsibility: OEH, TZ, ARC, ZV

Action 3.2 Assess the effectiveness of releasing captive reared adult SCF that have attained greater immunity to chytridiomycosis.

This action will assess the capacity to increase post-release survivorship of frogs by increasing their immunity to chytridiomycosis prior to release. A trial reintroduction of four and five-year-old SCF suggested that this technique could be used to establish populations in the wild (Hunter *et al*. 2009a). However, this would be costly to implement on a large scale due to the apparent low post-release survivorship and resources required to produce adult frogs. For this technique to be more viable, greater post-release survivorship is required. Depending on the extent to which post-release survivorship is influenced by chytridiomycosis, greater survivorship could be achieved if the frogs were afforded greater resistance to this pathogen. Attempts to increase immunity to chytridiomycosis will be undertaken through an exposure/treatment/re-exposure experiment in the laboratory, followed by a reintroduction experiment comparing post-release survivorship of frogs with enhanced immunity to control/naive frogs. This project will be initiated in 2012.

Responsibility: OEH, ARC, JCU, TZ

Action 3.3 Implement NCF reintroduction program in the ACT.

A captive insurance colony has been established for the southern Brindabella NCF populations as security against extinction of this management unit. Progeny from this program will provide an opportunity to bolster extant populations in Namadgi National Park, which are currently at critically low levels. The problems faced by small populations (termed the “small population paradigm”, Caughley and Gunn 1996) mean that even if the impact of the Amphibian Chytrid Fungus was removed these critically low populations could still become extinct (the so-called ‘extinction vortex’) without assistance to increase population size. This action will assess the capacity to augment and maintain wild breeding populations at two or more sites in Namadgi National Park though reintroduction or restocking with captive-bred individuals and (where possible) with wild-bred eggs that have been ‘head-started’ in captivity. This action will focus on releasing individuals when they are six to twelve months post-metamorphosis, an age that is likely to have relatively high survivorship in the wild yet minimises the period spent in captivity (and consequent possible modification of natural behaviour in a captive environment). This action will also form part of the strategy to improve population-level resistance to chytridiomycosis as outlined in Action 4.2.

Responsibility: PCL, TNR

Action 3.4 Assess the effectiveness of releasing captive bred NCF eggs directly into natural pools.

A captive breeding program for the Northern Brindabella NCF population is currently being undertaken as security against extinction of this significant management unit (see ‘Population Information’, page 12). Progeny from this program are being used to bolster recruitment at extant sites, which are currently at critically low levels. An assessment of the likely impact of chytridiomycosis on progeny released into natural pools will be undertaken, and if necessary, alternative release techniques developed (such as releasing into chytrid free pools).

Responsibility: OEH, ANU, TZ

Action 3.5 Assess the capacity to establish chytrid free SCF populations.

Creating chytrid free wild populations of the SCF will provide valuable insight into the impact/implications of this pathogen to recovery efforts, and could be used as 'nursery' sites from which to harvest stock for reintroduction elsewhere. Given the resource and logistical constraints on the number of SCF that can be produced in captivity, the capacity to harvest SCF from chytrid free areas may greatly enhance reintroduction efforts for this species. Since chytrid free areas currently exist in the Australian alps (Hunter et al. 2009c), it should be feasible to create such sites in areas with limited or no vectors for this pathogen.

Responsibility: OEH, TZ, ARC, ZV

Objective 4. Reduce the impacts of known threatening processes.

Recovery Criterion:
Processes impacting on corroboree frogs, or predicted to impact in the future, are understood and potential mitigation measures initiated by 2013.

Action 4.1 Determine the factors associated with more robust NCF populations.

Understanding why some NCF populations appear more robust to the factors causing decline will provide valuable insight into how management can assist the recovery of corroboree frogs elsewhere. A research program is currently being undertaken to determine whether NCF abundance correlates with rates of chytrid infection and Common Eastern Froglet abundance. Moreover, completion of the distributional survey will allow an assessment of habitat variables associated with more resilient sites, and provide a baseline from which to establish a non-invasive monitoring program to more accurately determine the current population trajectory of these sites (see actions 1.1 and 1.2). The monitoring program will also be designed to determine whether sites maintaining greater NCF abundance are less susceptible to pool drying prior to metamorphosis.

Responsibility: OEH, ANU

Action 4.2 Undertake research to determine how corroboree frogs may attain population level resistance to chytridiomycosis through a stronger immune response to infection.

The recovery of corroboree frogs within their natural range will require facilitating increased resistance to chytridiomycosis at the population level. One possible way to achieve this, which is recommended in the National Threat Abatement Plan for chytridiomycosis (DEH 2006), is to implement a captive breeding and reintroduction program in a manner that promotes ongoing selection for increased immunity to this disease. Since a genetic basis for resistance to chytrdiomycosis has been demonstrated in other frog species (e.g. Savage and Zamudio In press), this may be possible for corroboree frogs. A more targeted approach would be to selectively breed for resistant individuals in captivity. Implementing such a program would require an understanding how the frog immune system responds to infection with the Amphibian Chytrid Fungus, and the genetic basis for this, as this would allow for the breeding program to target specific traits. Research investigating the immune response of corroboree frogs to this pathogen is currently being undertaken at James Cook University and Taronga Zoo.

Responsibility: OEH, PCL, TZ, ARC, JCU

Action 4.3 Determine likely areas where SCF could be released outside their current range to reduce the impact of the amphibian chytrid fungus, and facilitate the establishment of self-sustaining populations.

While the most desirable option for recovering corroboree frogs is facilitating population level resistance within the species current range, this may not be possible within a satisfactory timeframe (within the next 50 years). However, it may be possible to establish self-sustaining corroboree frog populations outside the species known range, in areas where the species has an advantage over the amphibian chytrid fungus. Scoping the possibility of successfully establishing corroboree frog populations in others areas should commence as a preliminary step to considering this option.

Responsibility: OEH, PCL, TZ, ARC

Action 4.4 Through pool manipulation and monitoring, gain an understanding of the current and future threats to corroboree frogs from climate change, and investigate the capacity to use pool manipulation as a possible management response.

Climate change is likely to impact on corroboree frogs via a number of processes, including: increased egg mortality associated with reduced autumn rainfall, early pool drying causing mortality of tadpoles prior to metamorphosis in spring/early summer, and structural changes to breeding pools associated with reduced soil moisture and increased fire frequency. Developing a management response to these impacts will require a detailed understanding of temporal and spatial variation in pool hydrology, timing and success of egg hatching, tadpole development rates, and breeding pool vegetation structure. This information is required to forecast future impacts, and develop a management response to climate change. Since climate related changes to breeding pools have already been observed in many sites supporting NCF (Scheele 2010), methods for enhancing the structural suitability of breeding pools should be trialled immediately. Pool manipulation should be guided by the results of corroboree frog breeding habitat assessments (W. Osborne 1990, Hunter et. al. 2009a, Scheele 2010), and involve a rigorous monitoring program to determine outcomes and guide future work. Monitoring the structure and dynamics of corroboree frog breeding habitat should be incorporated into the annual monitoring program.

Responsibility: OEH, PCL

Action 4.5 Implement control measures to reduce the abundance of feral animals that cause damage to corroboree frog habitat.

It is important for the conservation of corroboree frogs that the abundance of feral pigs and horses is maintained at levels where impacts to breeding habitat are negligible. This has been successfully achieved for pigs throughout much of the distribution of corroboree frogs, and for horses in areas occupied by the SCF, and southern Brindabella NCF population in the ACT. It is critical that this work is continued, in particular, ensuring that horses are prevented from colonising the broader Jagungal Wilderness Area where remnant SCF populations occur. There is an immediate need for increased feral animal control in Northern Kosciuszko National Park where horses are causing substantial environmental damage in and around NCF breeding habitat (D. Hunter, B. Scheele, R. Pietsch, W. Osborne pers. obs). This has been identified as a priority action in the Horse Management Plan for Kosciuszko National Park (NSW OEH 2008).

Responsibility: OEH, PCL

Action 4.6 Undertake a strategic Blackberry control program.

Because corroboree frogs typically breed in pools that are exposed to solar radiation, shading by weed species such as Blackberry (*Rubus fructicosus* aggregate) is likely to impact these species. Given the heavy infestation of Blackberries in areas occupied by the Fiery NCF population, controlling this weed will provide considerable benefits. Control of blackberry in the vicinity of corroboree frog breeding habitat using glyphosate is undertaken during a time when there are no eggs or tadpoles in the breeding habitat, and has been undertaken over the past 15 years without obvious impacts on the frogs (David Hunter personal observations). An initial project mapping the extent of infestations, and associated NCF populations and breeding habitat, will provide a basis for developing a strategic control program, and evaluating the benefits of these works. This survey and mapping will be undertaken in conjunction with the broad scale survey (Action 1.2), and so is anticipated to be completed in 2014.

Responsibility: OEH, FNSW

Action 4.7 Investigate possible impacts from herbicide application.

While the timing of herbicide (glyphosate) application to control blackberries occurs outside the perceived sensitive period when eggs/tadpoles/breeding adults are in breeding habitat, there remains the possibility that frogs in non-breeding habitat may be exposed. Determining the likely impacts may be best determined in the laboratory under controlled conditions, coupled with a field assessment of likely concentrations that may reach frogs. In addition to this, thorough monitoring of breeding populations where weed management is being undertaken may also indicate whether herbicide application is impacting on this species at the population level.

Responsibility: OEH

Objective 5. Minimise impacts from forestry activities on NCF.

Recovery Criterion:
The potential impacts of forestry activities are understood, and current prescriptions reviewed and, if necessary, modified to ensure impacts are minimal within five years.

Action 5.1 Monitor the effectiveness of all relevant forestry prescriptions on frog habitat and populations, and implement measures to mitigate adverse impacts.

Forestry activities in the vicinity of NCF breeding habitat have the potential to impact on this species. In particular, road construction and maintenance, logging operations, hazard reduction burning, and subsequent Blackberry proliferation may all have negative impacts that require rigorous assessment. This assessment should be undertaken in conjunction with a thorough, systematic survey of the Fiery Range NCF population, and assessment of potential climate change impacts (see action 4.3).

Responsibility: OEH, FNSW

Action 5.2 Determine the longer-term viability of NCF populations in areas converted to softwood plantations.

The persistence of the NCF in areas converted to softwood plantation is intriguing, as this has resulted in gross modification of non-breeding habitat. The high density planting of pines would also be expected to reduce the amount of water within breeding habitat, and promote the proliferation of Blackberries. Given the large proportion of the Fiery NCF population occurring within softwood plantations, the longer-term viability of these populations should be the focus of targeted research. This should initially involve a detailed survey and assessment of the factors associated with the current persistence of NCF in softwood plantations, which should then be used to establish a monitoring program assessing the on-going viability of these sites.

Responsibility: OEH, FNSW

Objective 6. Integrate the conservation requirements of corroboree frogs into the general management of National Parks, Nature Reserves and State Forests.

Recovery Criterion:
As an ongoing procedure, all operations and works occurring in the vicinity of known or potential corroboree frog breeding habitat are assessed for their potential impacts and if required, modified accordingly.

Action 6.1 Continue to assess all management activities undertaken in National Parks, Nature Reserves and State Forests (i.e. weed control, fire and road management, timber harvesting) for their potential impacts on corroboree frogs, and modify if required.

Relevant park and forest managers will be informed of all aspects of the corroboree frog recovery program, and will consult members of the recovery team when operations are undertaken in the vicinity of breeding populations or potential breeding habitat. This recovery action has been successfully achieved over the past eight years through constant engagement and involvement of staff in the monitoring program and other recovery actions. Furthermore, the conservation requirements of corroboree frogs will continue to be incorporated into relevant management plans. It is particularly important to undertake a review of hazard reduction burning across the range of the NCF to ensure that there is variation in fire frequency across sites occupied by this species. This is particularly important given the extensive wildfires that have occurred throughout much of the NCF distribution since 2003.The ACT Regional Fire Management Plan contains locations and prescriptions for protection of NCF sites during hazard reduction burns.

Responsibility: OEH, PCL, FNSW

Action 6.2 Protect key corroboree frog sites from wildfire.

Due to their extremely low population size, the SCF and Brindabella NCF populations would be extremely susceptible to increased mortality associated with wildfire. Wildfire may also impact on corroboree frogs through altering the structure of breeding habitat. Hence, it is important that resources are allocated during large wildfire campaigns to protect key sites that are critical to the persistence of these species. It is particularly important that wildfire is prevented from impacting on sites that are the focus of a reintroduction program, as this may confound the interpretation of results and damage important infrastructure such as artificial pools (plastic tubs) and associated piping. There are a number of different fire suppression techniques that may be used in the event of wildfire, including – aerial attack and back-burning. The protection of key corroboree frog sites from wildfire has been identified as a priority action in the Kosciuszko National Park ‘Fire Management Strategy’ (NSW DECC 2008) and the ACT Fire Suppression Plan.

Responsibility: OEH, PCL

Objective 7: Increase community participation in corroboree frog recovery.

Recovery Criterion:
Public involvement and awareness of this recovery program increased on an ongoing basis, through actively pursuing all relevant avenues of media, public presentations, fund raising events, and displays.

Action 7.1 Increase public involvement, exposure and awareness about the corroboree frog recovery program.

Promoting public awareness about the conservation of corroboree frogs is an integral component of the recovery program, particularly for generating sponsorship, funding, and support from government agencies. A number of strategies have been pursued over the past few years to achieve greater education and awareness for this program, which includes: school and public presentations, media releases, fund raising events, shopfront displays, sponsorships, and displays at various husbandry institutions. The establishment of a corroboree frog charitable trust fund in 2009, and associated television commercial and website, by the Murray CMA will be a valuable resource for achieving the aims of this recovery action.

Responsibility: Murray CMA, OEH, PCL, TNR, TZ, ARC, ZV

Objective 8: Ensure the recovery program is well coordinated, consultative and adequately resourced.

Recovery Criterion:
The corroboree frog recovery program is being successfully coordinated and adequate funding has been obtained to facilitate the implementation of priority recovery actions outlined in this document.

Action 8.1 Coordinate recovery program and obtain funding to implement recovery actions.

A corroboree frog recovery program has been in operation since 1996. OEH undertakes the coordination of this program with the primary objectives being; 1) develop and facilitate the aims of the recovery team, 2) act as a general interface between the recovery program and other government agencies, institutions and the broader community, and 3) source funding for implementing recovery actions. The recovery team includes individuals who are directly involved in the management or research of these species, and individuals who can provide expert advice on important aspects of this recovery program. The primary aim of the recovery team is to oversee the implementation of recovery actions, evaluate their effectiveness, and guide future direction as the program progresses. One of the greatest challenges for the management of the corroboree frog recovery program is obtaining the necessary funds to implement recovery actions. OEH staff coordinating this program require adequate provision of time to pursue all possible avenues of government and non-government funding for this program.

Responsibility: OEH

Management Practices

Ensuring management practices are conducive to the conservation of corroboree frogs is critical to their survival. This is particularly important because reducing the impact of factors within our control (weeds, prescribed burning, feral animals) will reduce the likelihood of cumulative impacts from threatening processes that are widespread and more difficult to manage (e.g. disease and climate change). While there remains much to learn about the population response of corroboree frogs to management practices, a precautionary approach to protecting their habitat is warranted until further information comes to light. Current management recommendations include:

- The abundance of feral pigs, horses, and deer should be controlled to levels where impacts to corroboree frog breeding habitat are negligible.
- In the event of wildfire, sufficient resources are allocated to protect key corroboree frog sites, particularly sites that are the focus of reintroduction and habitat protection/manipulation.
- Road crossings occupied by corroboree frogs should not be maintained or upgraded in a manner that will alter the hydrology or increase sedimentation into corroboree frog breeding habitat.
- General fire trail maintenance should avoid activities that may disrupt or increase sedimentation into breeding habitat.
- Adherence to ACT Regional Fire Management Plan prescriptions for protection of NCF sites during hazard reduction burns.
- Adherence to Kosciuszko Fire Management Plan prescriptions for protection of SCF and NCF sites during both wildfire and hazard reduction burns.
- Adherence to the NSW NPWS chytrid protocols.
- Weeds, particularly Blackberries, are eradicated from all known and potential corroboree frog breeding habitat.
- Forestry prescriptions are adhered to (see Appendix 2 and 3).

Affected Interests

The key affected interests include government natural resource management agencies in NSW (OEH, FNSW) and the Australian Capital Territory (PCL), as well as the Murray and Murrumbidgee CMAs. Several husbandry institutions (ARC, TNR, TZ, ZV) have made considerable investment into the corroboree frog recovery program with the understanding that this program will be adequately implemented. 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 corroboree frogs and their 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 corroboree frog, as these species are arguably Australia’s most iconic frog species and have been the focus of an active recovery program that has received considerable media attention.

Biodiversity Benefits

It appears likely that six frog species have become extinct in Australia over the past three decades, the most significant loss from a vertebrate taxon group in Australia in modern times. Since chytridiomycosis is the primary cause of frog declines in Australia, developing management techniques to ameliorate the impact of this disease on the corroboree frogs will be directly applicable to the recovery of many other frog species, both in Australia and abroad. In addition, the habitat management and protection undertaken for the corroboree frog will benefit other significant flora and fauna species occurring in the same environments, such as the sedge *Carex raleighii* and the Broad Toothed Rat (*Mastacomys fuscus*), and will also assist in the protection of the nationally threatened ecological community ‘Alpine Sphagnum Bogs and Associated Fens’. The actions outlined in this recovery plan are not anticipated to cause any negative impacts on non-target native species.

Role and Interests of Indigenous People

This recovery plan acknowledges that indigenous cultural heritage values may be relevant to the corroboree frog, and sites where these species occur, 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. A consultation processes has been initiated with indigenous communities on whose traditional lands the corroboree frog occurs. This has initially involved contact with the relevant regional Indigenous facilitators on the preparation of this recovery plan, and an invitation to provide comments and be involved in the implementation of recovery actions.

Social and Economic Impacts

Since the majority of remaining populations occur within national parks or nature reserves, there are minimal costs associated with land reservation, protection, or foregone opportunities associated with alternative land uses. Furthermore, habitat requirements can be readily incorporated with other park management objectives and it is unlikely that significant conflict would arise. The exception to this is the state forest region of NSW, where implementation of forestry prescriptions for the NCF may reduce the amount of timber available for harvesting.

The corroboree frogs are a distinctive and striking species that have captured public attention. Their decline sends a message about the overall deterioration in the quality of our environment. If we can successfully bring these species back from the brink of extinction, there could be significant social benefits in terms of how we perceive our environment and its general health. The considerable economic benefits of saving corroboree frogs, whilst being very difficult to quantify, need to be taken into account in any assessment of the relative costs of recovery planning for these species.

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Priority, Feasibility and Estimated Costs of Recovery Actions

The total costs of implementing the recommended actions are estimated at $3,350,000 over the five year period covered by the plan. Over the past decade, significant investment into the corroboree frog recovery program has been made by the Australian, NSW and ACT governments and husbandry institutions such as ARC, TZ, and ZV. In particular, these husbandry institutions bring considerable resources to this program that may otherwise not be available to a threatened species recovery program.

At this stage, funding for many important recovery actions (denoted with an asterisk*) are unsecured, and assistance will be sought from the NSW, ACT and Commonwealth government agencies to provide funding for critical recovery actions.

Action	*Description*	*Priority*	*Feasibility*	*Responsibility*	*Cost estimate ($'000), Unfunded actions(*)*					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total
1	**Determine distribution, abundance and population trends**									
1.1	Continue annual corroboree frog monitoring	1	100%	OEH, FNSW, PCL	35	35	35	35	35	175
1.2	Complete distributional survey for the NCF in the Fiery Range	1	100%	OEH	30*	30*	30*	30*		120
2	**Establish and maintain viable captive breeding colonies**									
2.1	Develop effective captive husbandry techniques	1	90%	OEH, PCL, ARC, TNR, TZ, ZV	250	250	250	250	250	1250
2.2	Develop protocols for using assisted reproductive technologies	1	90%	OEH, ARC, TZ, MU, ZV	50*	50*	30*			130
2.3	Model captive husbandry and reintroduction program	2	100%	OEH, PCL				35*		35
3	**Develop, implement, and assess reintroduction techniques**									
3.1	Assess the effectiveness of releasing SCF eggs into artificial pools	1	100%	OEH, TZ, ARC, ZV	40	40	10	10	10	110
3.2	Assess effectiveness of releasing adult SCF with greater immunity to chytridiomycosis	1	60%	JCU, TZ, ARC, OEH	30*	30*	30*	10*	10*	110
3.3	Implement NCF reintroduction program in ACT	1	100%	PCL, TNR	30	30	30	10	10	110
3.4	Assess effectiveness of releasing NCF eggs directly into natural pools	1	100%	OEH, PCL, TZ	30	30	30	30	30	150
3.5	Assess capacity to establish chytrid free SCF populations	1	100%	OEH, TZ	20	15	15	15	15	80
4	**Mitigate known threatening processes**									
4.1	Determine factors associated with more robust NCF populations	1	70%	OEH, ANU, TZ	30*	30*	30*			90
4.2	Assist population level resistance to chytridiomycosis	1	70%	JCU, TZ, ARC, OEH, PCL	50*	50*	50*	20*	20*	190
4.3	Determine likely areas where the SCF could be released outside their current range	2	100%	OEH	20	20	20			60
4.4	Determine climate change impacts and investigate management responses	1	70%	DECC, PCL	45*	45*	30*	30*	30*	180
4.5	Reduce the abundance of feral animals	1	100%	OEH, PCL	30	30	30	30	30	150
4.6	Undertake strategic Blackberry control	1	100%	OEH, FNSW	40	40	40	40	40	200

4.7	Investigate possible impacts from herbicides	3	50%	OEH	50*	50*	50*			150
5	**Minimise impacts from forestry activities on NCF**									
5.1	Monitor potential impacts on NCF from hardwood logging operations	2	80%	OEH, FNSW	25*	15*	15*	15*		70
5.2	Determine viability of NCF populations in softwood plantations	2	80%	OEH, FNSW	20*	20*	15*			55
6	**Corroboree Frogs and general management activities**									
6.1	Management in National Parks, Nature Reserves, and State Forests	1	100%	OEH, PCL, FNSW	10	10	10	10	10	50
6.2	Ensure protection of sites during wildfire events	1	90%	OEH, PCL	5	5	5	5	5	25
7	**Media/education/community awareness**									
7.1	Increase public involvement, exposure and awareness	1	100%	OEH, PCL, ARC, TNR, TZ, ZV, Murray CMA	20	20	20	20	20	100
8	**Recovery program coordination and funding**									
8.1	Coordinate recovery program and obtain funding	2	80%	OEH	10	10	10	10	10	50
				TOTALS	**870**	**855**	**785**	**605**	**525**	**3640**

Appendix 1. Evaluation of recovery actions from the National Recovery Plan for the Southern Corroboree Frog, 2001.

As part of the performance evaluation, each recovery action was assessed and scored between 0-3 using the following criteria:

0 No progress / cannot be assessed

1 Insufficient action to meet criteria

2 Action underway – most elements of actions met or it is anticipated they will be

3 Criteria met – further action may or may not be required

Specific Objective 1	**Identify the cause of the continuing population decline and obtain ecological information that can be used in experimental management.**
Action 1.1	Prepare and implement a rigorous but minimal disturbance annual program for monitoring representative remaining populations and extinction sites.
Recovery Criterion 1.1	Implementation of an effective program to monitor representative populations, including known extinction sites, for twenty years.
Comments	An annual monitoring program incorporating 40 discrete sites/populations was established in 1999. This program has demonstrated the ongoing decline of the SCF (Hunter *et al*. 2009b). Due to the precariously low population size of the SCF this monitoring program has been expanded to include all known extant sites for this species. Furthermore, the annual monitoring program has been used as a basis to assess reintroduction trials (Hunter 2007).
Status	3
Action 1.2	Identify the life-history stage contributing most to demographic failure and leading to decline.
Recovery Criterion 1.2	Research completed which determined which life-history stage is contributing most to the current demographic failure and decline.
Comments	This research was undertaken through a combination of field monitoring of egg and tadpole survivorship in natural pools, and determining the age structure and annual survival of adult frogs through the aging of bone material (skeletochronology) (Hunter 2000). The results suggested that demographic failure in corroboree frog populations is most strongly associated with increased mortality during the terrestrial frog stages, which is consistent with the hypothesis that the decline of this species is due to disease associated with the Amphibian Chytrid Fungus.
Status	3
Action 1.3	Develop techniques and obtain preliminary information on the age structure of the adult breeding population.
Recovery Criterion 1.3	Information on the age structure of the adult breeding population obtained.

Comments	The age structure of the SCF breeding adult population was determined through aging of bone material (skeletochronology) (Hunter 2000). Age to sexual maturity for adult male SCF was determined to be four years, with a small proportion of males attaining sexual maturity in three. The youngest sexually mature females were four years old. The oldest individuals identified were ten years, and annual survival of the adult male population was determined to range between 40 and 60 percent.
Status	3
Action 1.4	Determine sensitivity of the Southern Corroboree Frog to UV-B radiation.
Recovery Criterion 1.4	Field experiments determining the sensitivity of eggs, embryos and tadpoles of the Southern Corroboree Frog to ambient ultraviolet radiation completed.
Comments	Field monitoring of eggs and tadpoles, and a field experiment manipulating UV-B exposure of tadpoles, suggested that UV-B radiation is not significantly contributing to early life-history mortality in SCF and is not contributing to the ongoing decline of this species (Hunter 2000, Hunter 2001).
Status	3
Specific Objective 2	**Prevent the continuing decline in population numbers by experimentally increasing population size at selected sites.**
Action 2.1	Increase the size of the breeding adult population through artificially decreasing egg and tadpole mortality.
Recovery Criterion 2.1	Further decline in population numbers at sites with extant populations has been prevented through active management of eggs and tadpoles in the field.
Comments	This was initially attempted through a program of increasing survivorship to metamorphosis (Hunter *et al*. 1999). This program failed to prevent ongoing decline in manipulated populations (Hunter 2007). Two reintroduction techniques are currently being trialled to prevent ongoing decline of the SCF; reintroduction of eggs into artificial pools, and reintroduction of adult frogs (Hunter *et al*. 2009b).
Status	2
Specific Objective 3	**In the longer term (by 2015), to increase the total metapopulation to a level predicted to be adequate for long term viability (both in terms of number of individuals and number of populations).**
Action 3.1	Develop a captive breeding program.
Recovery Criterion 3.1	An increase in population numbers at sites targeted for recruitment enhancement through the captive husbandry program is achieved.
Comments	Successful captive breeding is being achieved at all the husbandry institutions involved in the SCF recovery program (ARC, TZ, ZV). Reintroduction to the wild of progeny from this program commenced in 2010. It is anticipated that this program will increase the size of target populations.
Status	2

Action 3.2	Screening of captive reared individuals for pathogens prior to release.
Recovery Criterion 3.2	A screening program designed and implemented for the presence of pathogens in field and captive reared Southern Corroboree Frogs returned to field populations.
Comments	Prior to release, each tadpole cohort was screened for the presence of the amphibian chytrid fungus, and other potential frog pathogens.
Status	3
Action 3.3	Breeding pool manipulation
Recovery Criterion 3.3	Successful completion of experimental population translocation to known extinction sites in conjunction with habitat enhancement (eg. pool construction) and maintenance of suitable hydrological conditions.
Comments	Due to a perceived lack of suitable breeding pools in some sites, the initial intention of this action was to create new pools through digging into bog habitat. Further assessment determined that suitable pools for breeding were not lacking, and therefore digging new pools was not required. However, it was deemed appropriate to create artificial pools to reduce infection with the amphibian chytrid fungus and prevent early pool drying. This is currently being undertaken at four sites (Hunter *et al*. 2009b).
Status	3
Specific Objective 4	**Ameliorate threatening processes which have contributed to the decline of the species, including ensuring that human activities will not add increased risk to remaining populations.**
Action 4.1	Implement management of the habitat of the Southern Corroboree Frog and include habitat management prescriptions in relevant plans and operational procedures, with particular emphasis on management of roads, fire and feral pigs.
Recovery Criterion 4.1	Habitat management prescriptions are implemented, including high priority management protocols to prevent disturbance to remaining occupied breeding sites and adjacent non-breeding habitat; through management actions, protection of sites from fire, vehicle disturbance and the activities of pest animals, particularly pigs.
Comments	SCF habitat has been adequately protected during fire and road operations. An intensive pig eradication has been undertaken over the past 15 years throughout the range of the SCF, and has successfully maintained pigs at low abundance.
Status	3
Specific Objective 5	**Increase community awareness and involve the community in aspects of the recovery program.**
Action 5.1	Provide information to the public about the species and training in appropriate management to relevant authorities.
Recovery Criterion 5.1	Community information brochures, interpretation signs, and informative articles prepared and representatives of relevant authorities trained to assist with appropriate research and management activities.

Comments	The SCF recovery program has been the focus of a very active community outreach program, which has included; targeted media events (television, radio and newspaper), community outreach and associated website (http://www.corroboreefrog.com.au/corroboree-frog), SCF merchandise being sold at visitor centers (National Parks and Snowy Hydro), live displays at two major zoos (Melbourne and Taronga Zoo), and engagement with potential philanthropic donors. All the major zoos involved in this program have live SCF displays and associated signage.
Status	3
Specific Objective 6	**Achieve the effective implementation of the Recovery Program.**
Action 6.1	Ensure the continued operation of the Recovery Team and the carrying out of the Actions identified in the Recovery Plan.
Recovery Criterion 6.1	The Recovery Team continues to operate and recovery actions continue to the implemented.
Comments	The SCF has been the focus of a recovery program since 1996. The ongoing implementation and achievements attained by this program has been the result of a dedicated recovery team consisting of a range of stakeholders including; national park managers and rangers, threatened species managers, academic scientists, zoo keepers and managers, and CMA staff.
Status	3

Appendix 2. Forestry prescriptions for Northern Corroboree Frog

Forestry operations

a) This condition only applies in Bondo and Micalong State Forests.

b) A 30m radius exclusion zone must be established around all Northern Corroboree Frog records.

c) A 30m exclusion zone must be established around all bogs, soaks and seepages. The exclusion zone must be measured from the outer edge of the bog, soak or seepage. Where the bog, soak or seepage is fringed by tea-tree the exclusion zone must be measured from the outer edge of the tea-tree.

d) Where bogs, soaks, seepages and drainage lines have been surveyed according to protocols outlined below, the 30m exclusion zone (Condition c) above) is not required where no Northern Corroboree Frogs were detected.

e) All bogs, soaks, seepages and Northern Corroboree Frog records that are protected by this prescription must be clearly recorded on a compartment map and archived by SFNSW. A copy of this map must be provided to OEH at the completion of the operation.

Survey

a) Surveys are conducted using the shout-response technique which consists of loud shout directed toward the ground followed by a listening period of 30 seconds to count or estimate the number of males responding. Northern Corroboree Frogs will generally respond within a 3-5 metre radius of a shout. Therefore, the area to be surveyed must be traversed with a series of shouts 3-5 metres apart.

b) Areas surveyed and the approximate traverse route (or GPS tracklog if available) must be mapped in the prelogging survey report.

c) Surveys must be conducted during the day under fine conditions.

d) Survey season: February (note: on the day of survey, calling must be confirmed at a known site prior to surveying new areas).

Appendix 3. General forestry prescriptions within the distribution of the Northern Corroboree Frog.

General Operations

- All specified forestry activities are prohibited in exclusion zones.
- Trees must not be felled into exclusion zones. If a tree falls into an exclusion zone, then no part of that tree can be removed from the exclusion zone.
- Subject to the statutory requirements under the *Rural Fires Act* 1997, hazard reduction work must not be conducted in exclusion zones and buffer zones

Stream Exclusions

- Exclusion zones of at least ten metres wide must be implemented on both sides of all first order streams.
- Exclusion zones of at least 20 metres wide must be implemented on both sides of all second order streams.
- Exclusion zones of at least 30 metres wide must be implemented on both sides of all third order streams.
- Exclusion zones of at least 50 metres wide must be implemented on both sides of all fourth and higher order streams.
- Trees must not be felled into Stream Exclusion Zones. If a tree falls into an area of Stream Exclusion Zone, then no part of that tree can be removed from that area

Ridge & Headwater Exclusions

- For each 500 hectares of forest within the Tumut Sub-region as identified in the IFOA, SFNSW must implement:
- A minimum of two exclusion zones at least 40 metres wide which connect second order streams, OR
- A minimum of one exclusion zone at least 80 metres wide which connects third order streams
- Exclusion zones implemented under condition 5.5 a) i. and a) ii. above must, wherever possible, establish links between streams of different third order catchments.
- Where the Ridge and Headwater Habitat exclusion zones do not link different third order streams, a minimum length of 250 metres must be established for each exclusion zone in condition 5.5 a) i. (e.g. total length 500 metres), or a 500 metres minimum length established for the exclusion zone in condition 5.5 a) ii.
- Exclusion zones implemented under part a) above should connect the relevant second or third order stream via the associated lower order stream(s).
- Ridge and Headwater Habitat must not, to the greatest extent practicable, cross existing roads.

Wetland Exclusions

- Specified forestry activities are prohibited in all wetlands, irrespective of the size of the wetland and their surrounding exclusion zones.
- Exclusion zones of at least ten metres wide must be implemented around all wetlands less than 0.5 hectare (approx. 70 metres x 70 metres) surface area.
- Exclusion zones of at least 20 metres wide must be implemented around all wetlands between 0.5 hectare (approx. 70 metres x 70 metres) and 2.0 hectares (approx. 150 metres x 150 metres) surface area.
- Exclusion zones of at least 40 metres wide must be implemented around all SEPP 14 wetlands irrespective of size, and other wetlands greater than 2.0 hectares surface area.

- The area of wetlands and their surrounding exclusion zones must be measured from the edge of the current saturated zone or from the outer edge of where the vegetation type indicates a wetter micro-environment than the surrounding country, whichever is larger.
- Grazing and associated burning should be excluded from wetlands

Heath & Scrub Exclusions

- Specified forestry activities are prohibited from all areas of heath and scrub greater than 0.2 hectares (approx. 45 metres x 45 metres) surface area.
- Exclusion zones of at least 10 metres wide must be implemented around all heath and scrub of more than 0.2 hectares surface area.

Ground Habitat Protection

- SFNSW must, to the greatest extent practicable, protect ground habitat from specified forestry activities. Ground habitat includes, but is not limited to, understorey vegetation, ground cover vegetation, thick leaf litter and fallen timber.