Approved Recovery Plan

Recovery Plan for the Southern Corroboree Frog (*Pseudophryne corroboree*)

July 2001

Natural Heritage Trust
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NSW NATIONAL PARKS AND WILDLIFE SERVICE

NSW National Parks and Wildlife Service
43 Bridge Street
(PO Box 1967)
Hurstville NSW 2220
Tel: 02 95856444

www.npws.nsw.gov.au

Information or queries regarding the Southern Corroboree Frog are best directed to the Recovery Team coordinator at:

Threatened Species Unit,
NPWS Southern Directorate,
PO Box 2115
Queanbeyan, NSW 2620
Ph: (02) 6298 9700

Or

The Director,
Regional Wildlife Programs,
Wildlife Australia Branch,
Environment Australia,
PO Box 636,
Canberra ACT 2601

Cover photo: The Southern Corroboree Frog *Pseudophryne corroboree*
Photograph: David Hunter

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Executive Summary

This document constitutes the Approved New South Wales State Recovery Plan for the Southern Corroboree Frog (*Pseudophryne corroboree*), 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 the parties who will carry these out.

The Southern Corroboree Frog is listed as Endangered (Schedule 1, Part 1) on the NSW *Threatened Species Conservation Act 1995*. The species is distinctive and easily recognised because of a striking colour pattern on its upper surface consisting of bright yellow longitudinal stripes alternating with black stripes. Below it is also boldly marked with black, yellow and white blotches. Adults reach a length of between 25-30 mm.

The species has an extremely limited range, being restricted to sub-alpine areas within Kosciuszko National Park in the south of New South Wales. It is only found at high altitudes (between about 1300 and 1760 m), occupying an area of about 400 km^2. The Southern Corroboree Frog utilises two distinct habitat types: a breeding season habitat associated with pools and seepages in sphagnum bogs, wet tussock grasslands and wet heath; and a terrestrial non-breeding habitat in forest, sub-alpine woodland and tall heath adjacent to breeding areas.

It is intended that this recovery plan be implemented over a five-year period. Actions identified in the recovery plan include; (i) monitoring to detect trends in population numbers, (ii) recruitment enhancement through population supplementation, (iii) captive husbandry and breeding trials, (iv) determination of the life-history stage responsible for population decline and age structure of the adult breeding population, (v) screening for pathogens, (vi) habitat protection and (vii) community awareness and involvement.

These will be undertaken by the New South Wales National Parks and Wildlife Service, the Amphibian Research Centre and the University of Canberra using existing resources. An additional $248,750 over the five-year period will be required to implement some currently unfunded actions.

BRIAN GILLIGAN
Director-General

BOB DEBUS MP
Minister for the Environment

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The research into, and management of, the Corroboree Frog has been a combined effort of the NSW National Parks and Wildlife Service (NPWS), The University of Canberra (UCAN) and The Amphibian Research Centre (ARC). A number of people have contributed to survey and research work on the species. The NPWS would like to thank the following individuals:

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Members of the Corroboree Frog Recovery Team who have each in their own way put much thought and effort into the Recovery Program: Stephen Clark (NPWS), Graeme Enders (NPWS), Bob Gay (formerly of NSW State Forests), Graeme Gillespie (Arthur Rylah Institute), Ken Green (NPWS), Steve Horsley (NPWS), David Hunter (UCAN), Ann Jelinek (Env. Aust.), Adrian Johnstone (NPWS), David Lawrence (NPWS), David Leslie (State Forests), Gerry Marantelli (ARC), Will Osborne (UCAN), Marjo Rauhala (Env. ACT), Rod Pietsch (NPWS), Michael Saxon (NPWS), David Shorthouse (Env. ACT), Craig Smith (NPWS) and Andrew Stirling (State Forests). David Hunter is owed particular thanks for undertaking most of the field research and monitoring since 1996.

Environment Australia has provided ongoing funding for the implementation of the Recovery Plan, resulting in considerable improvements in the knowledge and understanding of the ecology of the Corroboree Frog.

1 Introduction

There is considerable international concern about declines and extinctions of many populations of amphibians at high altitudes (eg. McDonald 1990; Carey 1993; Fellers and Drost 1993). The Australian Alps has not been immune from such declines, where at least five species of frog are reported to be in serious decline (Gillespie *et al.* 1995; Hollis 1995; Hunter *et al.* 1997). These include several endemic species such as the Baw Baw Frog (*Philoria frosti*) (Hollis 1997) and the Southern Corroboree Frog (*Pseudophryne corroboree*). This Recovery Plan summarises our current knowledge of the Southern Corroboree Frog (*P. corroboree*), documents the research and management actions undertaken to date, and identifies the actions required and parties responsible to ensure the ongoing viability of the species in the wild.

The attainment of this Recovery Plan's objectives is subject to budgetary and other constraints affecting the parties involved. It may also be necessary to amend this Recovery Plan in the event of new information or following recommended changes to the Recovery Program by the Recovery Team. The information in this Recovery Plan is accurate to January 2001.

2 Legislative Context

2.1 Legal Status

The Southern Corroboree Frog is now considered to be Critically Endangered using the criteria applied by IUCN (Tyler 1997) and has been officially listed as Endangered under both the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC Act) *1999* and the NSW Government *Threatened Species Conservation Act* (TSC Act) *1995*.

2.2 Recovery Plan Preparation

The TSC Act provides a legislative framework to protect and encourage the recovery of threatened species, endangered populations and endangered ecological communities in NSW. Under this legislation the Director-General of National Parks and Wildlife (NPW) has a responsibility to prepare Recovery Plans for all species, populations and ecological communities listed as endangered or vulnerable on the TSC Act schedules. Similarly, the EPBC Act requires the Commonwealth Minister for the Environment to ensure the preparation of a Recovery Plan for nationally listed species and communities or adopt plans prepared by others including those developed by State agencies. Both Acts include specific requirements for the matters to be addressed by Recovery Plans and the administrative process for preparing Recovery Plans.

This Recovery Plan has been prepared to satisfy both the requirements of the TSC Act and the EPBC Act and therefore will be the only Recovery Plan for the species. It is the intention of the Director-General of NPW to forward the final version of this draft Recovery Plan to the Commonwealth Minister of the Environment for adoption, once it has been approved by the NSW Minister for the Environment.

2.3 Recovery Plan Implementation

The TSC Act requires that a public authority must take any appropriate measures available to implement actions included in a Recovery Plan for which they have agreed to be responsible. Public authorities and councils identified as responsible for the implementation of Recovery Plan actions are required by the TSC Act to report on measures taken to implementation those actions. In addition, the Act specifies that public authorities must not make decisions that are inconsistent with the provisions of the Plan

The NSW NPWS is the only public authority responsible for the implementation of this Recovery Plan.

2.4 Relationship to Other Legislation

The lands on which the Southern Corroboree Frog occurs include those that are owned or managed by the NPWS. Relevant legislation includes:

- *National Parks and Wildlife Act 1974*
- *Environmental Planning and Assessment Act 1979*
- *Rural Fires Act 1997*
- The Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*

The interaction of these Acts with the TSC legislation is varied. The most significant implications are described below and in Section 2.5.

The *Rural Fires Act 1997* requires that all parties involved in fire suppression and prevention must have regard to the principles of Ecologically Sustainable Development (ESD) when exercising their functions and when preparing Operational Plans and Bush Fire Risk Management Plans. Consideration of the principles of ESD must include the conservation of biological diversity and ecological integrity. Within this, consideration must be given to the impact on threatened species and their habitats.

2.5 Environmental Assessment

The New South Wales *Environmental Planning and Assessment Act 1979* (EP&A Act) requires that consent and determining authorities, and the Director-General of National Parks and Wildlife, as a concurrence authority, consider relevant Recovery Plans when exercising a decision-making function under Parts 4 and 5 of the EP&A Act. Decision-makers must consider known and potential habitat, biological and ecological factors and the regional significance of individual populations.

The only public authority that has a decision making function in relation to the Southern Corroboree Frog is the NSW NPWS. Activities as defined under the EP&A Act require the approval of the Director-General. Any other action not requiring approval under the EP&A Act, and which is likely to have a significant impact on the Southern Corroboree Frog, requires a Section 91 licence from the NPWS under the provisions of the TSC Act. Such a licence can be issued with or without conditions, or can be refused.

The EPBC Act regulates actions that may result in a significant impact on nationally listed threatened species and ecological communities. It is an offence to undertake any such actions in areas under State or Territory jurisdiction, as well as on Commonwealth-owned areas, without obtaining prior approval from the Commonwealth Environment Minister. As the Southern Corroboree Frog is listed nationally under the EPBC Act, any person proposing to undertake actions likely to have a significant impact on this species should refer the action to the Commonwealth Minister for the Environment for consideration. The Minister will then decide whether the action requires EPBC Act approval.

Administrative guidelines are available, from Environment Australia, to assist proponents in determining whether their action is likely to have a significant impact. In cases where the action does not require EPBC Act approval, but will result in the death or injury of a Southern Corroboree Frog and that individual is in, or on a Commonwealth area, a permit issued by the Commonwealth Minister under the EPBC Act will be required.

The Environment Minister can also delegate the role of assessment and approval to other Commonwealth Ministers under a Ministerial Declaration, and to the States and Territories under bilateral agreements. At the time of writing of this plan the development of a bilateral agreement between NSW and the Commonwealth was not complete. When in place such an agreement will avoid the need for duplication of environmental assessment.

2.6 Critical Habitat

The TSC Act makes provision for the identification and declaration of Critical Habitat. Under the TSC Act, Critical Habitat may be identified for any endangered species, population or ecological community occurring on NSW lands. Once declared, it becomes an offence to damage Critical Habitat (unless the action is exempted under the provisions of the TSC Act) and a Species Impact Statement is mandatory for all developments and activities proposed within declared Critical Habitat.

Under the EPBC Act, Critical Habitat may be registered for any nationally listed threatened species or ecological community. When adopting a Recovery Plan the Federal Minister for the Environment must consider whether to list habitat identified in the Recovery Plan as being critical to the survival of the species or ecological community. It is an offence under the EPBC Act for a person to knowingly take an action that will significantly damage Critical Habitat (unless the EPBC Act specifically exempts the action). This offence only applies to Commonwealth areas. However an action which is likely to have a significant impact on a listed species is still subject to referral and approval under the EPBC Act.

To date, Critical Habitat has not been declared for the Southern Corroboree Frog. The declaration of critical habitat is not considered to be a priority for the species, as other mechanisms provide for its protection. Given that it only found on land managed by the NPWS, the type of developments or activities which are likely to occur are limited by the provisions of the *National Parks and Wildlife Act 1974* (the NPW Act).

This Recovery Plan identifies those habitat features and the location of sites currently known to be critical to the survival of the Southern Corroboree Frog, as required by the EPBC Act.

3 Species Information

3.1 Description and Taxonomy

The Corroboree Frog (*Pseudophryne corroboree*) (Anura: Myobatrachidae) was described by Moore (1953) from a single specimen collected at Round

Mountain (Colefax 1956). The collection site is now within Kosciuszko National Park. Until recently, only one species of Corroboree Frog was recognised (Cogger 1992). However, Wells and Wellington (1985) provided a brief argument for recognising the Northern Form as a separate species, which they named *P. pengilleyi* after Dr R. Pengilley who undertook substantial research on the species in the 1960's. More recently, Osborne *et al.* (1996) provided a detailed geographic analysis of variation in the morphology and calls of *P. corroboree* and recommended that *P. pengilleyi* be recognised. This recommendation has been generally accepted by other authorities (eg. Tyler 1997). *Pseudophryne pengilleyi* is also now recognised as a distinct species in the TSC Act (on Schedule 2, Vulnerable).

All reference to *P. corroboree* in this Recovery Plan refers to the Southern Corroboree Frog. *Pseudophryne pengilleyi* refers to the Northern Corroboree Frog, a species with a more extensive distribution in the Fiery Range and Brindabella Range (Osborne 1989) (Figure 1).

The Southern Corroboree Frog is distinctive and easily recognised because of its striking dorsal colour pattern consisting of bright yellow longitudinal stripes alternating with black stripes (Cogger 1992). The ventral surface is boldly marked with black and yellow and white blotches. A large flat femoral gland is present on each hind limb, and the inner metatarsal tubercle is low and round. Adults reach a length of between 25 and 30 mm. There are a number of differences between the Southern and Northern Corroboree Frogs, including considerable genetic divergence (Roberts and Maxson 1989; Osborne and Norman 1991), differences in colour-pattern and morphology (Pengilley 1966; Osborne *et al.* 1996) and skin biochemistry (Daly *et al.* 1990).

All *Pseudophryne* lay large eggs that are individually surrounded by tough, transparent capsules. When hydrated the egg capsules swell to a relatively large size. The eggs of Southern Corroboree Frogs are amongst the largest in the genus (Tyler 1989); measuring approximately 3.4 mm in diameter, with a capsule that swells to up to 8.0 mm in diameter when hydrated.

The tadpoles are generally well advanced when they hatch, measuring about 15 mm in total length. Hatching generally occurs at about Gosner (1960) stage 27. Osborne (1991) provides a simple key to identify tadpoles that may occur sympatrically with both Southern and Northern Corroboree Frogs. Considerable skill is required to correctly identify the species at the tadpole stage. It is not possible to distinguish between the tadpoles of the two species of Corroboree Frogs although Osborne *et al.* (1996) noted that *P. pengilleyi* had a greater number of blotches on the tail-fin. The mouth parts of the two species are identical.

3.2 Distribution

The Southern Corroboree Frog has a limited geographic distribution (Figure 1). All known historic sites of occurrence are shown in Figure 2. The species occurs only in Kosciuszko National Park from Smiggin Holes in the south, and northwards to the Maragle Range, about 5km west of Cabramurra. This constitutes a linear range of 51km. The broadest part of the range (24 km) occurs near Mount Jagungal. The species occupies a relatively narrow altitudinal strip between about 1300 and 1760 m, occupying an area of about 400 km^2 (Osborne 1989). The Southern Corroboree Frog is separated from populations of the Northern Corroboree Frog (Figure 1) by the comparatively dry and wind-swept Kiandra and Coolamine Plains. These areas consist of broad stretches of cold, treeless plain that are devoid of sheltering tall heath and woodland. The plains have slightly lower annual precipitation than the nearby mountain ranges (Adomeit *et al.* 1987). This may act as a barrier to the dispersal of the frogs, effectively

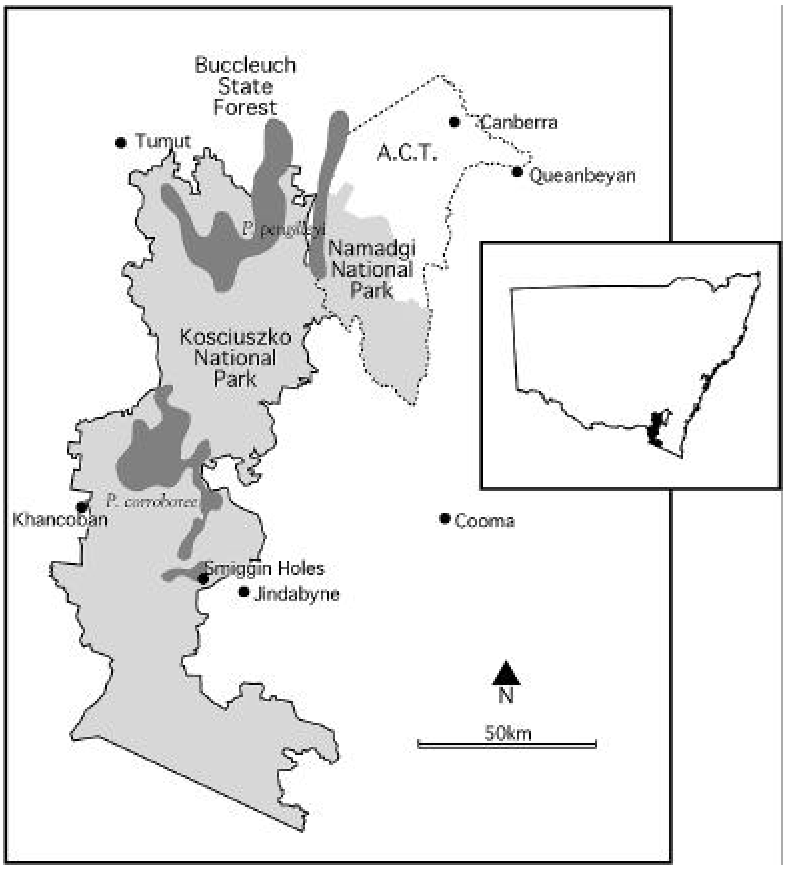

Figure 1. The distribution of *P. corroboree and P. pengilleyi* in

isolating the two species.

Extensive surveys were undertaken across three summers (1996-1998) to determine the current extent of the Southern Corroboree Frog (Hunter *et al*. 1997 and in prep.). Of the approximately 160 potential breeding sites surveyed during this period (which included 60 sites where the species was recorded to be formerly present by Osborne 1989), only 63 sites were found to still support the frogs (Figure 3). Of the 60 former sites surveyed, only eight were found to still have frogs (Figure 3). At sites where frogs still occur, the numbers of adult males remaining was very low. Fifty of the 63 sites had fewer than six adult males present. Only one large population remains (95 adult males in 1998). The overall geographic range of the species has now contracted (Figure 3), and includes extensive areas where the frogs are now either extinct, or in very reduced numbers (particularly Pretty Plain, Happy Jacks Plain, Finns Swamp, Whites River and the Smiggin Holes and the Guthega area south of the Snowy River).

3.3 Land Tenure

All known and historical populations of the Southern Corroboree Frog occur within Kosciuszko National Park, an area managed by the NPWS. The security of this National Park tenure is governed by the provisions of the *National Parks and Wildlife Act 1974* (NPW Act). The land is zoned 8a - National Park. Existing populations are managed within the provisions of the Kosciuszko National Park Plan of Management. Small populations of the Southern Corroboree Frog previously occurred in the Perisher-Smiggins and the Guthega resort areas within the park (Osborne 1988).

3.4 Habitat

Southern Corroboree Frogs utilise two distinct habitat types: a breeding season habitat associated with pools and seepages in sphagnum bogs, wet tussock

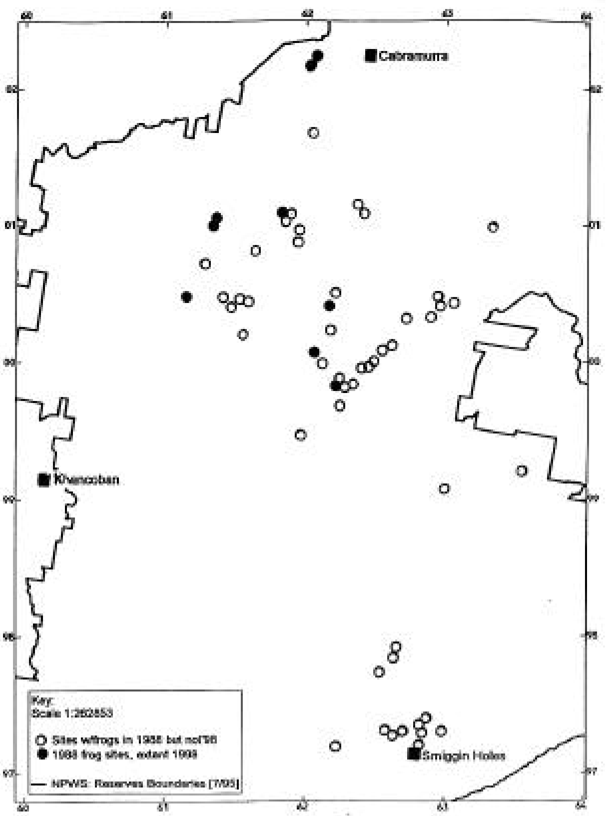

Figure 2. Map of part of Kosciuszko National Park showing sites where *P. corroboree* was recorded in 1986/87 by Osborne (1989) (all sites shown on the map) and the results obtained from resurveying the same sites during 1996 to 1998 (Closed circles, sites with *P. corroboree* in 1986/87 which still supported the frogs in 1996-1998).

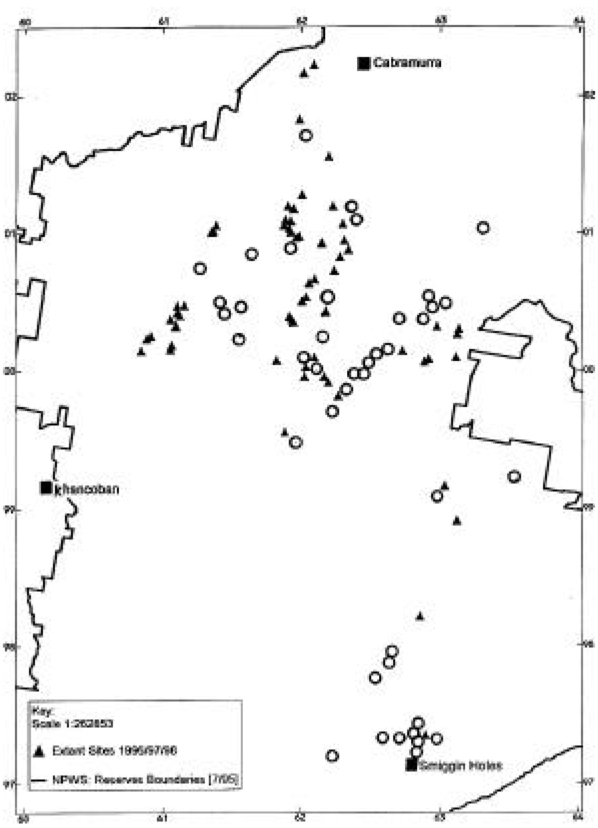

Figure 3. Distribution of all remaining sites where *P. corroboree* was recorded at least once during extensive surveys conducted during 1996 to 1998. Triangles represent sites where *P. corroboree* were found during extensive surveys during 1996-1998; open circles, sites where *P. corroboree* previously occurred and are no longer considered to be present. The species has disappeared from parts of its former range near Smiggin Holes, Happy Jacks Plain, Pretty Plain and Tooma Dam. Numbers of adult males at most sites shown were extremely small.

grasslands and wet heath; and a terrestrial non-breeding habitat in forest, sub-alpine woodland and tall heath adjacent to the breeding area (Plate 1). During the summer, the adult frogs breed in shallow pools and seepages within the breeding area, before returning to the adjacent woodland and tall moist heath at the end of the breeding season (Pengilley 1966). Osborne (1988 and unpublished) found that, following breeding, adults are capable of dispersing over 300 metres into the surrounding woodland.

There have been no published studies of the breeding habitat of Corroboree Frogs, but detailed quantitative information is provided by Osborne (1990). Breeding sites usually consist of temporary pools and seepages, in areas with level, to gently sloping topography. Sites used by the frogs occur on granitic and volcanic substrates, but porous rock types, including shale and limestone, are generally avoided. The vegetation present at breeding sites varies considerably, ranging from bog and wet-heath at higher altitudes to wet sod-tussock grassland in some low-lying valleys.

Breeding sites are characterised by the presence of spreading rope-rush *Empodisma minus*, peat moss *Sphagnum cristatum*, and the shrubs *Baeckea gunniana* and *Epacris paludosa*. Several other plant species, including sod-tussock grasses *Poa* spp., candle heath *Richea continentis*, the rush *Restio australis* and the sedge *Carex gaudichaudiana* commonly occur at breeding sites. The breeding pools are characteristically shallow, and have relatively large surface areas, low water flow rates, and have a long duration (Osborne 1990). This allows the water in the preferred pools to become warmer during the day, possibly enhancing tadpole development. The breeding pools are the most sensitive feature of the breeding habitat of the Southern Corroboree Frog and protection of the catchment area of the pools and seepages is essential for their long-term persistence as breeding sites.

Litter, logs and dense ground cover in the understorey of snow gum woodland provides over-wintering habitat (Pengilley 1966). Plant species typical of this habitat include *Bossiaea foliosa*, *Prostanthera cuneata*, *Oxylobium* spp. and *Phebalium* spp.

3.4.1 Seasonal movements and over-wintering sites

Frogs typically undertake annual movements from non-breeding habitats to ponds and other breeding sites (Duellman and Trueb 1986). Osborne (1988) conducted a two-year program of pitfall trapping Northern Corroboree Frogs at Ginini Flats in the ACT.
Ginini Flats is a large Sphagnum bog surrounded by dry *Bossiaea foliosa* heath and subalpine woodland. The results of this study indicated that at the end of the breeding season adult males and females undertake a seasonal movement away from the bog, upslope into surrounding heath and woodland. The dispersal distances measured at this time were up to 300 m. Pengilley (1992) also found that Northern Corroboree Frogs moved between woodland and low-lying heath and grassland breeding sites at Coree Flats in the Brindabella Range. It is likely that the Southern

Plate 1. Typical breeding habitat used by Southern Corroboree Frogs. Woodland and heath in the distance provides non-breeding season habitat for adults and juveniles. Photograph: Pavel German

Corroboree Frog undertakes similar movements and the few observations available support this view.

The over-wintering sites of Southern Corroboree Frogs are not known. Pengilley (1966) found large numbers of adult and sub-adult Northern Corroboree Frogs near Coree Flats in the northern Brindabella range "under logs, leaf litter and vegetation in the forest". Osborne (1988) also searched for over-wintering frogs at Coree Flats and Ginini Flats, but found only 15 individuals, all sheltering beneath logs. The frogs were found at distances ranging from 15 to 155 m from the nearest breeding pools. It is likely that any ground-layer litter and debris, including logs, rocks, fallen bark and grass thatch, will provide over-wintering sites for the frogs. Because of the importance of suitable over-wintering habitat to the frogs, protection of habitat should include those areas adjacent to the breeding sites, which may provide shelter and food for sub-adults and adults throughout the year.

3.5 Life-history and ecology

3.5.1 Breeding biology

Like most frogs, Southern Corroboree Frogs have two stages in the life-cycle; an aquatic tadpole stage and terrestrial post-metamorphic juvenile and adult stage. However, they differ from other frogs in that their eggs are laid out of the water in a terrestrial nest, and the embryos develop to an advanced stage within the egg capsule before hatching.

Adult males move into the breeding areas in early summer, and call during January and February. The males call from small chambers in moss or other soft vegetation at the edges of the breeding pools. The frogs have three call types; an advertisement call, threat call, and courtship call (Pengilley 1971b). The advertisement call and courtship call are used to attract females to the males calling site, whereas the threat call serves as a warning to other males (Pengilley 1971b). Stimulating the males to give threat calls has been recommended as a reliable procedure for monitoring the number of calling males (Osborne 1991). Advertisement call intensity varies depending on the weather, with more calling occurring during warmer overcast conditions, and during late afternoon (Pengilley 1971b).

Females only enter the bogs briefly to lay their eggs in the terrestrial oviposition site, and then leave the breeding site. The males continue calling for a number of weeks, presumably to continue mating. They then leave the bogs during late February to return to the over-wintering habitat (Pengilley 1966; Osborne 1988). The eggs are laid in small clutches of 16 to 38 eggs from January to mid February (Pengilley 1973). The eggs are amongst the largest in the genus (Tyler 1989), measuring about 3.5 mm in diameter; the transparent capsules swelling to about 8 mm in diameter when hydrated (Osborne 1991). Tadpole development initially occurs within the egg and the relatively advanced tadpole emerges from the eggs at Gosner (1960) stage 27, measuring about 15 mm. At this stage the tadpoles are well-developed with the first sign of the hind limb showing as a small bump on the body near the base of the tail.

Hatching is thought to occur during autumn and winter during periods of high rainfall or snow melt. The tadpoles wriggle to the nearby pools where they live for the remainder of the larval period, feeding on algae and other organic detritus in the water. The tadpoles show little growth during winter, when temperatures at the breeding sites are very low and snow often covers the ground. The water in the pools at this time may be below 1°C and the surfaces of exposed pools regularly freeze if exposed to the air on cold nights (Jacobson 1963). At the end of winter, when snow has melted from the breeding sites, the tadpoles continue growing slowly until metamorphosis in early summer.

Reliable autumn precipitation is critical to the over-winter survival of the tadpoles. It appears that if the nests are not submerged during this period, then the eggs either do not hatch, or hatch prematurely in the nest site, with the tadpoles becoming stranded in the dry vegetation surrounding the nest. For example, in the autumn and winter of 1997 precipitation was not high enough to cause the flooding of nests at many sites and there was extensive mortality of tadpoles of both species of Corroboree Frogs (D. Hunter, University of Canberra, unpublished observations). The pre-metamorphic period is also critical even if the tadpoles manage to move to the pools because they are vulnerable to pool-drying at this time.

3.5.2 Post-metamorphic behaviour and diet

Very little is known about the life history of the frogs after they leave the pools as juveniles. Pengilley (1966, 1971a, and pers. comm.) 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 1971a). Food intake is greatly reduced during winter, with many individuals apparently not feeding. Frogs that have a predominance of ants in their diet are considered to be specialised (Duellman and Trueb 1986).

3.5.3 Population demography

The particular reproductive strategy of the Southern Corroboree Frog - low clutch size and prolonged period of larval development - is suggestive of an evolutionary adaptation to an environment that is predictable, with little long term variation. The breeding pools must have water in them from the time when the tadpoles hatch and enter the pool (thought to be late autumn and winter), to mid-summer (December and January) when the newly emerged froglets leave the pool (Pengilley 1966; Osborne 1991).

Pengilley (1966) suggested that individuals reached sexual maturity in about three years (ie. one year as an embryo and tadpole, and two years as a juvenile). In addition, based on the results of a mark-recapture study of Northern Corroboree Frogs, Pengilley (1966, 1992) suggested that there was a high mortality of adults between years, with few adults that had already mated being recaptured in successive years. However, there was a severe drought during the middle of his study which may have increased mortality. Recent research undertaken by David Hunter indicates that the survival rate of Northern Corroboree Frogs is higher than found by Pengilley and that adults may live to eight years. Now that the techniques for marking and ageing frogs have been validated (D. Hunter unpublished data) this research will be extended to include the Southern Corroboree Frog.

Amphibians typically experience high levels of mortality during their pre-metamorphic life-history stages (Wassersug 1975). However, the level of pre-metamorphic mortality may be highly variable between species and appears to be related to the life-history characteristics of individual species (Duellman & Trueb 1986). Whether mortality is greatest during embryonic or larval development also appears to be related to the life history characteristics of a species (Duellman and Trueb 1986). Species that lay their eggs terrestrially, such as those within the genus *Pseudophryne*, often have greater embryonic survivorship than those species that lay their eggs in an aquatic environment (Duellman & Trueb 1986).

Pre-metamorphic mortality in *Pseudophryne* has been investigated previously by Woodruff (1975) and Pengilley (1966, 1992) who focused primarily on embryonic mortality. Woodruff (1975) found embryonic mortality in the laboratory to be less than 5% for *Pseudophryne bibroni*, *P. dendyi* and *P. semimarmorata*, although he did observe much higher mortality in the field as a result of desiccation when a breeding season was followed by an abnormally dry period. Pengilley (1992) studied field embryonic mortality in *P. corroboree* and *P. pengilleyi* (then recognised as *P. corroboree*). He also found relatively low embryonic mortality, except during a drought year when the majority of egg clutches exhibited 100% mortality. These results support the generalisation that species which lay their eggs terrestrially exhibit low embryo mortality except when faced with catastrophic events.

Very little research has been conducted on tadpole mortality in *Pseudophryne*. This is mainly due to the logistical problems associated with accurately sampling the aquatic life-history stage. The tadpoles frequently hide in thick pond vegetation or bury themselves in silt at the bottom of the pools (D. Hunter and W. Osborne, pers. obs.). Pengilley (1966) determined the mortality rate of the Southern Corroboree Frog tadpoles in three pools based on the number of eggs originally present. The results varied with mortality rates of 50%, 86.5% and 93.6% being calculated for the different pools. Pengilley (1966) suspected that the mortality he detected was predominantly due to predation by dragonfly larvae (although this statement was not qualified). The highly ephemeral nature of the breeding sites for both species of Corroboree Frogs also renders them susceptible to pool drying (Osborne 1990). These observations suggest that there is the potential for high levels of mortality at the tadpole stage, which is consistent with the mortality levels observed in most amphibians which possess an aquatic larval stage (Duellman & Trueb 1986).

3.5.4 Predators and parasites

During three years of field-based research, Osborne (1990) saw no evidence of predation on Corroboree Frogs. Although tadpoles of many frog species are subject to very high rates of predation from fish and invertebrates (Heyer *et al.* 1975; Caldwell *et al.* 1983; Duellman and Trueb 1986), these organisms are scarce in pools used by Corroboree Frogs. Vertebrates, such as herons and snakes, which may prey on juvenile and adult frogs, are also very uncommon at high montane and subalpine altitudes (Green and Osborne 1994) and are unlikely to influence populations in this area. Other potential predators of adult and sub-adult frogs include predatory beetles and reptiles which are common in subalpine woodland, however it is likely that the frogs are unpalatable to these smaller predators (W. Osborne and D. Hunter, unpublished observations).

Parasites of frogs include protozoans, helminths, leeches, mites and the larvae of flies (Tyler 1976; Duellman and Trueb 1986). Whilst many parasites are not lethal to their hosts, massive infestations by sporozoans have been observed to cause high mortality in adults and tadpoles in other countries (Duellman and Trueb 1986). In Australia, *Pseudophryne* spp. are parasitised by the dipteran genus *Batrachomyia* or frog flies, protocephalid cestodes and oxyuroid nematodes (Pengilley 1966, Tyler 1976). Pengilley (1966) thought that heavy infestations of *Batrachomyia* spp. may have caused the death of juvenile and sub-adult *P. pengilleyi*, however this was not observed directly. Pengilley noted that the low percentage of adults infected with small larvae may have indicated that adults are less susceptible to infection. *Batrachomyia* sp. was found to parasitise both *P. pengilleyi* and *P. corroboree* but was not observed in adults from the subalpine zone (Pengilley 1966). Since the decline in the size of the frog population, the number of parasitised frogs has apparently been reduced markedly. Of 226 frogs examined in 1986/1987 by W. Osborne and M.Lau, only one individual (a *P. pengilleyi*) was found to be parasitised (W. Osborne, unpublished data). Although there has been little direct research on the topic, it is unlikely that parasites have had a major role in the declines of these populations.

The onset of rapid declines in undisturbed populations of frogs in high altitude areas has given grounds for concern that the declines may be attributable to a particularly virulent pathogen. Initially it was suggested that the cause of the population crashes was most likely to be a virus (eg. Laurance *et al*. 1996), however recent evidence from dying frogs collected in pristine areas strongly implicates a skin fungal disease (Chytridiomycosis) in the deaths of frogs in both Australia and South America (Berger and Speare 1998).

Further discussion on this issue is provided in Section 4.2.3

3.6 Ability of Species to Recover

If the continuing decline of populations can be prevented, it is highly likely that, with correct management of habitat, local populations will recover. However, it seems unlikely at present that the species will recover throughout its geographic range.

4 Management Issues

Observations made between 1955 and 1970 indicate that the Southern Corroboree Frog was abundant within its limited geographic range. High numbers of individuals were frequently recorded at suitable breeding sites (see Osborne 1988 for a historical review). However, by 1986 it was apparent that the species had declined considerably in abundance (Osborne 1989). Subsequent monitoring over a thirteen year period (1986-1999) indicated that the populations continued to decline and that remaining populations are now severely depleted (Hunter *et al*. 1997; Osborne and Davis 1997, Osborne *et al*. in press). The species has disappeared from 70% of the sites at which it formerly occurred, and the number of remaining adult males is estimated to be in the order of 300-400 individuals (Hunter *et al*. 1997; Hunter in prep.).

4.1 Extent of decline

In the summers of 1985 and 1986 Osborne (1988, 1989) undertook the first extensive surveys of the distribution and relative abundance of the Southern Corroboree Frog. He delineated the geographic distribution of the species and compared current population levels to observations made by earlier workers (including his own observations in the late 1970's). Osborne (1988, 1989) concluded that the numbers of frogs present at most breeding sites were very low; at 74% of the sites in the Snowy Mountains ten or less calling males were recorded at each site. Choruses estimated at greater than 25 calling males were recorded at only 15% of the sites with frogs. These larger sites occurred near Mt Jagungal and along the Toolong Range south of Round Mountain in the Jagungal Wilderness area.

For many of the historical records of the Southern Corroboree Frog in the Snowy Mountains there is little information available on numbers of individuals observed. In such cases any assessment of changes in population status can only compare the present distribution to past known occurrences. At best this can provide an indication of broad changes in distribution. However, additional information on relative abundance is available for a number of sites (summarised in Osborne 1988, 1991) providing a baseline against which an assessment of whether or not the species is declining can be made.

Population monitoring programs at several locations have been under way for twelve years (1986-1998) (Osborne 1991, Hunter *et al*. 1997; Osborne and Davis 1997; Osborne and Hunter unpublished data). This has indicated that populations have not recovered, and that there has been a gradual loss of local breeding aggregations and a corresponding contraction of geographic range (Figures 2 and 3). In the Smiggin Holes and Guthega region all eleven remaining breeding sites (see Osborne 1991 for further details) have been monitored using non-invasive techniques annually since the summer of 1985/86. Each of these small local populations has declined to extinction. This pattern of severe declines has been repeated at most other sites subject to monitoring. Of the 60 former sites surveyed only eight were found to still have frogs. At sites where frogs still occur, the numbers of adult males remaining is very low; 50 of the 63 sites had fewer than six adult males present in 1996-98. Only one large population remained in 1998 (95 adult males in 1998).

Amphibian populations may undergo significant natural fluctuations in time and space. Detection of frogs can vary markedly with season or local climatic conditions, which may affect calling and other activity levels (Duellman and Trueb 1986). Studies undertaken overseas indicate that amphibian populations may exhibit considerable fluctuation over several years, and that patterns of population change can vary between species (Berven 1990; Pechmann *et al.* 1991). The initial cause of the decline in the Southern Corroboree Frog was thought to be the 1982-83 drought (Osborne 1989), and a recent analysis of the long-term trends in precipitation indicates that declining autumn and winter precipitation (particularly snow cover) may have been implicated in the decline (Osborne and Davis 1997). However, the link to precipitation is not readily obvious and the actual cause of the decline is still not known, particularly since the populations have not recovered in response to more-favourable weather conditions.

Understanding what constitutes natural population changes due to normal climatic or environmental variation is necessary before the significance of the decline in the Southern Corroboree Frog can be fully assessed. This can only be achieved by monitoring relative abundance of populations over time periods long enough to establish the extent of ecological stability or expected patterns of fluctuation. This is generally considered to be at least one generation turnover (Connell and Sousa 1983; Blaustein *et al.* 1994; Pechmann and Wilbur 1998). It is likely that the Southern Corroboree Frog takes three years to reach reproductive maturity (Pengilley 1966 and pers. comm.; Osborne 1991; D. Hunter pers. comm.), and may live for up to eight years (D. Hunter pers. comm). Thus, the current monitoring which includes 12 consecutive years is likely to be long enough to have detected demographic changes. It also includes a complete El Nino cycle. It is highly unlikely that the extent of decline in the Southern Corroboree Frog is simply a reflection of a normal population fluctuation.

What is not known is whether the observed decline is part of a very long-term population cycle, although this seems unlikely given the disappearance of the frogs from so many sites, including from regions that would be difficult to re-colonise (eg. south of the Snowy River where the species now appears to be extinct). Long-term monitoring is required to determine if population declines are continuing, or are part of a long-term cycle. Such monitoring is also essential for determining the success of any experimental trials involving habitat manipulation, recruitment enhancement or translocation.

4.2 Threats

The cause of the present serious decline in populations of the Southern Corroboree Frog is unknown. As mentioned above, it was originally assumed that the decline was the result of drought that affected the region in the early 1980's, and that once conditions had improved, the frog population would recover (Osborne 1989). However, this has not been the case; local populations have continued declining, or remained low, during a decade which has included many potentially good breeding seasons (Osborne and Davis 1997). The frog is faced with a considerable risk because of its specialised life history and its high degree of breeding habitat specificity. It has a very low clutch size, each female breeds only once each season, and the tadpoles are slow-growing, spending over six months in the shallow pools. Such a strategy reduces the ability of the species to recover quickly during favourable seasons, and places it at risk from any long-term disturbance which affects the breeding sites.

Whilst the principal cause of the population decline and range contraction has not been identified, it is clear that its effect is acting at least on a regional basis since all high altitude populations, and some low altitude populations, of Northern Corroboree Frogs are also in decline (ACT Government 1997; Hunter and Osborne unpublished data). Whilst activities such as ski-resort development, road construction and the operation of a hydro-electrical scheme undoubtedly had major localised influences on frog breeding habitat in KNP (see below), the likely cause of the current decline is obviously a response to a wider-reaching phenomenon.

4.2.1 Climate change

Concern about global warming (Pearman 1989; Galloway 1989; Whetton *et al.* 1996) has a particular significance for the conservation of cool-adapted species such as the Southern Corroboree Frog (Bennett *et al.* 1991). Due to its restricted subalpine distribution the species is likely to be particularly susceptible to climate change. Global warming has the potential to alter the breeding season and change the period required for eggs and tadpoles to develop; this may lead to these events occurring earlier or later than at an optimum time. A change in regional temperature and precipitation is also likely to influence the hydrology of the breeding pools, and affect the growth and dynamics of vegetation in the breeding habitat.

During recent monitoring of breeding sites in the Snowy Mountains, it has been observed that some pools within breeding sites have become overgrown by *Sphagnum* moss. Although such hummock-hollow development in bogs is a natural part of the bog dynamics (Clark 1980), other factors including reduced snow cover, and warming may allow the moss to grow more prolifically (Tallis 1994). It should be noted that loss of breeding pools (at least the larger, more obvious pools) is not yet evident at most of the sites monitored in the Snowy Mountains, although this needs to be examined in detail during further surveys. Perhaps of greater importance is the possibility, as mentioned above, that with warmer temperatures, or longer periods of drier weather during spring and early summer, the pools still containing tadpoles may dry (Osborne 1990; Pengilley 1992).

Of equal importance would be a shift in the seasonality of precipitation or a decline in winter snow cover. A preliminary analysis of long-term trends in snow-cover, precipitation and temperature indicated that declining winter snow cover and precipitation may be a factor contributing to the decline (Osborne and Davis 1997; Osborne *et al.* 1998). In 1997 over-winter survival of developing encapsulated tadpoles of the Southern Corroboree Frog and of subalpine populations of Northern Corroboree Frog was extremely low, with tadpoles surviving through the winter at only a few of the sites where eggs were observed in the previous summer (Hunter, *et al.* 1999). The reason for this high mortality is not known, but two hypotheses have been proposed: (1) due to reduced snow cover, tadpoles were exposed to sub-zero temperatures; and (2) due to a low water table and minimal autumn and winter precipitation nest sites did not flood and hatched tadpoles were unable to move to the nearby pools. Testing of these hypotheses requires further research, which directly compares tadpole survivorship with hydrological and meteorological measurements.

4.2.2 Increased Ultraviolet Radiation

Ultraviolet radiation (UV-B) has increased significantly in recent years due to increasing ozone (eg. Jones and Shanklin 1995), and is likely to increase as reduction in ozone in the upper atmosphere continues. Some amphibians are known to have increased levels of developmental abnormalities after exposure to artificial UV-B (Grant and Licht 1995; Licht and Grant 1997) and increased ultraviolet radiation is implicated in frog declines at high altitudes where there is less atmosphere for UV-B to pass through (Blaustein *et al.* 1994). Recent research indicates that the developing eggs of some alpine amphibians are damaged by ambient ultraviolet radiation (Blaustein *et al.* 1994, 1995).

It is well known that UV-B radiation causes developmental abnormalities in amphibians (see review by Grant and Licht, 1995) but few field-based studies have addressed the possible effects. Experiments in North America (Blaustein *et al.* 1994; Blaustein *et al.* 1995) demonstrated species-specific differences in the ability of eggs to repair radiation damage to DNA and differential hatching success of embryos exposed to solar radiation at natural egglaying sites when compared to controls shielded from UV radiation. Blaustein *et al.* (1994) argue that at high elevations, development times in amphibians may be extended because of lower ambient temperatures, thereby exposing the developing eggs and tadpoles for longer periods. Moreover, high altitude amphibians are often heliothermic and actively seek out sunlight to increase developmental temperatures (Stebbins and Cohen, 1995). Although higher elevation populations may be more resistant to UV or may have behavioural adaptations to minimise UV damage, these may be insufficient to cope with the dramatic increases in UV levels currently experienced at high altitudes (Blaustein *et al.* 1995).

Ultraviolet radiation can reach significant depths in natural waters (Smith, 1989), and in clear freshwater lakes potentially harmful intensities of UV-B radiation can penetrate to several metres (Schindler *et al.* 1996). With respect to the potential for causing damage to biological organisms, shallow alpine lakes, pools and streams are likely to be of greatest concern, as they are likely to have very low amounts of dissolved organic carbon and are exposed to high levels of ambient UV-B. In the shallow, extremely clear pools found in alpine regions, high levels of UV-B are likely to penetrate to all depths used as egg development sites by amphibians.

In a study conducted along an elevational gradient at Thredbo in Kosciuszko National Park, Broomhall *et al.* (in press) found that newly-hatched tadpoles of a declining frog (Alpine Tree Frog *Litoria verreauxii alpina*) showed significantly higher levels of mortality when not protected by UV-B filters, when compared to tadpoles protected by mylar UV-B filters. Moreover, a non-declining species used as a control (Common Eastern Froglet *Crinia signifera*) had significantly lower mortality under all treatments. Whilst it could be argued that ultraviolet radiation is unlikely to affect the adults or eggs of *P. corroboree* because they are hidden within the moss and are unlikely to be exposed, the larval life stage of the frog may be at risk because they are confined to highly-exposed shallow, clear pools. Research on the susceptibility of the Southern Corroboree Frog eggs, embryos and tadpoles should be undertaken.

4.2.3 Diseases

As mentioned in section 3.5.4 the decline in both species of Corroboree Frog could also be a result of disease. The hypothesis that at least some declines in amphibians have been caused by pathogens (eg. Carey

1993; Laurance 1996; Laurance *et al.* 1996) has recently gained favour, amongst at least some researchers (however, see Hero and Gillespie 1997; Alford and Richards 1997), following identification of a highly virulent fungal pathogen (Chytridiomycosis) in moribund frogs at sites where declines have occurred (Berger and Speare 1998; Berger *et al.* 1999).

Chytridiomycosis has been detected in Spotted Tree Frogs (*Litoria spenceri*) that have died in the field in the Snowy Mountains (G. Gillespie pers. comm.) and the carcasses of captive adult Northern Corroboree Frogs that died over winter at the Amphibian Research Centre in Melbourne were found to contain a range of pathogens including a fungus similar to Chytridiomycosis (G. Marantelli pers. comm.). Nevertheless, it is likely that partially decomposed carcasses will contain a range of microbial decomposers, so that this observation is not unexpected.

Rick Speares (James Cook University, pers. comm.) has recently detected the pathogen in museum specimens of the Southern Corroboree Frog collected in 1992 and 1993. However, there is no field evidence to date that either species has suffered rapid population decline as a result of fast-acting pathogens. Some researchers suggest that it is likely that more than one causal agent is involved in frog declines in Australia (and elsewhere) and that these may in fact act in a synergistic manner. A fast-spreading disease is less-likely to be the cause of the decline in Northern Corroboree Frogs because the decline has occurred slowly, with populations gradually becoming depleted before local extinctions have occurred (Osborne *et al.* in press). There is, however, very good reason for concern. As further information on disease in Australian frogs comes to light, tests should be made to examine the susceptibility of both species of Corroboree Frogs.

4.2.4 Bushfires and fuel reduction burning

An extensive experimental bushfire at Bushrangers Catchment in the Brindabella Range eliminated a very small local population of Northern Corroboree Frogs (Osborne, unpublished data). However, near Round Mountain, and in the Maragle Range in Kosciuszko National Park, subalpine bushfires that burnt to near the edges of Sphagnum bog pools during the breeding season did not prevent the frogs from returning to the pools the following season. These fires occurred at a time when adult males and females were in or near the moist breeding habitat and thus their immediate impact on adults may not have been great. However, autumn fires burning through woodland and heath surrounding breeding sites are likely to have a greater potential influence. At this time adult and sub-adult frogs have moved distances of up to 300 m or more, away from the bogs, to feed and to find suitable over-wintering sites. Extensive burning of understorey litter and grass cover in these areas, such as occurs during prescribed burns, is likely to reduce the shelter available to the frogs and make them more vulnerable to dehydration or freezing. Earlier this century, an increased frequency of autumn burning in association with grazing activity may have had a significant impact (K. McDougall, pers. comm.).

4.2.5 Former livestock grazing

Livestock grazing may also have been a historical cause of habitat deterioration. Pengilley (1966) suggested that the Snowy Mountains had been the most severely affected by modification of its breeding habitat due to livestock grazing. He considered that it was possible that some contraction of the range of the frogs may have occurred as a result of drainage of sphagnum bogs and their conversion to grazing land. This suggestion is reinforced by well documented observations of a deterioration in vegetation cover and a significant increase in soil erosion during the grazing era in the Snowy Mountains (Byles 1932; Costin 1954; Wimbush and Costin 1979; McDougall 1989). Costin (1954) noted that trampling by livestock rapidly breaks the ground surface in moist peatlands leading to incision of the bogs with deeper drainage channels. These deeper channels then hasten the drying out and humification of the peat, which may be further degraded by wind and water erosion. Grazing in subalpine grasslands and bogs was often accompanied by burning, which probably further reduced the protective cover in both the breeding habitat and non-breeding habitat of the frogs.

Given the importance of shallow seepage and bog pools as breeding sites for the frogs, it is likely that disturbance to these areas during the high-country grazing era (1889 to 1958) resulted in the loss of some local populations. It is now over 30 years since the cessation of grazing and the condition of bogs and other potential breeding habitats is reported to have improved (A.B. Costin pers. comm.; R.B. Good pers. comm.), and the effects are now likely to be greatly diminished. Nevertheless, long-term monitoring studies such as those of Wimbush and Costin (1979) should be encouraged as they provide valuable information on the recovery of these areas. For example, it is possible that, due to extensive former disturbance, incision and lowering of the water table, seepages and bogs no longer support the range of pools that existed before stock grazing. This hypothesis requires further consideration and could be tested experimentally by construction of a variety of artificial pools and monitoring of their suitability.

4.2.6 Construction activities associated with operation of the Snowy Mountains Hydro-Electric Scheme

Significant losses of Southern Corroboree Frog breeding habitat probably occurred during the construction of the Snowy Mountains Hydro-Electric Scheme between 1948 and 1972. Near Smiggin Holes, Pipers Saddle, Wragges Creek and Guthega, extensive road-making, aqueduct construction and other activities influencing drainage are likely to have resulted in the drying out of some areas, particularly where water was diverted away from suitable breeding habitats or where the water table was lowered. The gradual loss of some populations may have been exacerbated by run-off of road silt and gravel. Areas impacted upon by construction have now been stabilised by soil conservation measures and natural rehabilitation and, unless substantial new earth works are proposed, are unlikely to present an additional impact to frog populations.

4.2.7 Construction activities associated with ski resort development

Southern Corroboree Frogs were once common in at least three ski resort areas: Smiggin Holes, Blue Cow and Guthega (Osborne 1988). They almost certainly also occurred at Perisher Valley but there have been no reliable records of the species from this area. Osborne (1988 and 1991) presents a detailed account of the potential impacts of ski developments on the frogs; this will not be repeated here. It now seems certain that the Southern Corroboree Frog no longer occurs in any resort areas (W. Osborne unpublished data; see also Osborne 1988), but the disappearance of the frogs from these areas is obviously symptomatic of the more widespread decline.

Apart from direct mechanical impacts on habitat, the construction activities outlined in Osborne (1991) may have other impacts that apply to a wider range of situations. These are: (1) increased erosion and siltation, (2) increased nutrient run-off, and (3) stream or seepage diversion or drainage. These are briefly discussed below:

<u>Erosion and siltation</u>

Erosion and subsequent siltation resulting from construction activities would be expected to have a significant impact on breeding sites. The pools used by Southern Corroboree Frogs as breeding sites are generally shallow, clear pools with few dissolved ions and a moderately low pH. Any sediment run-off and increase in turbidity in the pools would potentially threaten tadpoles by mechanically blocking their gills, smothering the detritus in the pools which provide the food source of the tadpoles, or filling the pools with sediment to the extent that they no longer contain water.

<u>Increased nutrient run-off</u>

Fertilisers are commonly used during rehabilitation of disturbed areas when agronomic plant species are being sown for revegetation. There is often considerable run-off of nutrients from these sites as evidenced by the spread of exotic plant species down drainage lines below buildings, roads and carparks. The influence of higher levels of nutrient input into breeding pools is not known, but would probably present problems if the native vegetation cover was replaced by taller plants which shaded the pools, or if the higher nutrient levels caused excessive algal build-up and eutrophication of the pool.

<u>Stream diversion and wet area drainage</u>

Ski-slope development and hydro-electric construction may alter the drainage characteristics of an area, commonly initiating erosion and drainage of bogs and wet heaths. Activities such as the construction of underground sewers, the laying of buried cables and the building of drains could detrimentally affect the frogs if the construction diverts water away from breeding sites, causes a lowering of the water table in the breeding area, or leads to a concentration of the flow.

Given the potential influences described above, it is unlikely that the Southern Corroboree Frog can be maintained in areas that have been extensively disturbed as a result of ski resort development. Osborne (1991) suggests a need to protect the hydrological integrity of the breeding habitat by maintaining an extensive protective buffer around breeding sites. The requirement for a total prohibition on disturbance within the breeding areas would be difficult to meet given the present extent of development in the resort lease areas.

Suitable breeding sites still occur within the resort lease boundaries, although the condition of potential breeding habitat in these areas varies considerably (Osborne 1988). Pools remote from groomed ski runs and roads appear to be in relatively good condition and provide potential habitat. These sites have been mapped (unpublished maps prepared by W.S. Osborne and held by NPWS at the Snowy Mountains Regional Office, Jindabyne). Pools close to, or within, ski slopes and lift lines, and near roads, are usually highly disturbed and do not provide potential breeding habitat. Many of these pools within summer-groomed ski slopes, close to lift lines and near roads, have been highly disturbed as a result of past developments and do not provide potential breeding habitat. They may contain rubbish, grooming rubble and tree cuttings. Vehicle activity has also damaged some of the sites and some pools appear to contain sediment washed from nearby roads or lift access tracks. While current practices for ski resort development (eg. Perisher Blue Pty Limited 2000b) are aimed at protecting Southern Corroboree Frog habitat from further disturbance, those pools which have suffered past impacts are unlikely to recovery in the foreseeable future.

Although the prospects for Corroboree Frogs in the more intensively developed areas of ski resorts appear to be poor, intact areas of habitat remain in other parts of the resort areas. It should be noted that, until recently, at Mt. Baw Baw in Victoria the endemic Baw Baw Frog, *Philoria frosti*, still occurred in and near managed ski slopes (Malone 1985). Therefore, the possibility of a recovery of Corroboree Frog populations in the Smiggin Holes-Guthega-Blue Cow area should not be excluded completely, and conservation plans for the species should include a consideration of potential breeding sites in the resort areas. Such provisions are included in the Ski Slope Plan for the Perisher Blue Ski Resort (Perisher Blue Pty Limited 2000a).

4.2.8 Collecting by humans

The Southern Corroboree Frog is an attractive species and because of its appeal is often searched for, and sometimes removed, by visitors. However, because of their specialised diet the frogs may be difficult to maintain for long periods in captivity and thus have low potential value for the pet trade.

The physical intervention involved in searching for Corroboree Frogs usually results in disturbance to the nest site. After being disturbed, males often begin calling again at the same site or move a short distance away (D. Hunter unpublished data). However, the activities of people trying to find the frogs could be expected to seriously disrupt reproductive success at sites with low numbers of frogs. In addition, the pulling apart of moss and other vegetation by people searching for frogs may expose some of the clutches to dehydration during dry summer conditions.

The second aspect of collecting is the potential for over-collecting for scientific purposes. In the past very large samples of Corroboree Frogs have been removed from various readily accessible sites in Kosciuszko National Park and in the Brindabella Range (see comments in Osborne 1988). However, these early scientific collections apparently did not permanently affect the size of local breeding groups, with most collecting sites at a later stage still supporting large numbers of frogs (Dr. R.K. Pengilley pers. comm.; D.J. Wimbush pers. comm.; Dr. R.E. Barwick pers. comm.). It is possible that intense illegal collecting could deplete local populations, but it is unlikely that scientific collecting would be undertaken without application first being made for research permits. Under the present extremely low population numbers any research on the Southern Corroboree Frog that involves removal of specimens has the potential to disturb already seriously depleted populations, including the possibility of introducing exotic diseases. Therefore, any new research proposals that involve removal of frogs require careful consideration by the NPWS and by the Recovery Team.

4.2.9 Weed invasion

Sites supporting Southern Corroboree Frogs are currently virtually free of weeds. Plantings of exotic trees, such as willows *Salix* spp., for soil conservation purposes by the Snowy Mountains Hydro-Electricity Authority, have been widespread in the Snowy Mountains. These plantings occur along roads, aqueducts and other areas disturbed during construction activities. Although no breeding sites are directly threatened by willow invasion, in the longer-term the spread of willows by sexual reproduction and the production of seed and also through vegetative growth along seepages and streams may present a problem for the management of some sites. In Victoria, some bogs are being invaded by *Mimulus moschatus*, *Mentha spicata* and *Juncus effusus* (K. McDougall, pers comm.). Of these, *Mimulus moschatus* appears to be the biggest threat as it grows well in the sphagnum and may form quite large patches. All three species are present in Kosciuszko National Park.

4.2.10 Feral animals

Feral Pigs (*Sus scrofa*) sometimes damage breeding areas used by Southern Corroboree Frogs. They may also damage over-wintering habitat by overturning shelter sites such as logs and destroying dense ground cover. This is mainly confined to areas between Kiandra and Mt Jagungal and on the Toolong Range, but pigs appear to be slowly spreading to other subalpine areas (C. Smith NPWS pers. comm.). Additional research on the interaction between pigs and Corroboree Frogs would be useful to better predict the likely impacts.

5 Previous Recovery Actions

- Considerable research has already been published on the biology of both species of Corroboree Frogs. Much of this research was originally carried out in the mid-1960's by Ross Pengilley (Department of Zoology, ANU; see references below) who focused mainly on describing the reproductive biology, calling behaviour and diet of both species (then recognised only as the northern and southern forms of *P. corroboree*). More recently, Will Osborne (Department of Zoology, ANU and Applied Ecology Research Group, University of Canberra) has undertaken research specifically aimed at improving our knowledge of the conservation biology of both species. Osborne's work examined distribution and abundance, morphology, genetics and climate (see references below). A product of this work was the publication of a paper supporting recognition of the northern form as a full species - *P. pengilleyi* (Osborne *et al*. 1996).

- A Species Management Report and accompanying Management Plan was published in 1991 (Osborne 1991). This report recommended research and management actions for both species of Corroboree Frogs. Some of these actions have now been completed (eg. implementation of an annual monitoring program, analysis of long-term weather patterns) or are currently underway (monitoring of habitat change at breeding sites; breeding response of very small populations).
- Funding to support recovery actions has been obtained for four years (1997-2000) from the Federal Endangered Species Program.
- In the last three years new research specifically aimed at understanding the metapopulation processes affecting both species has been undertaken by David Hunter (Applied Ecology Research Group, University of Canberra). Hunter is examining the ecological processes that affect the demography of small populations of this species. Specifically, he is examining population age structure, reproductive success, and levels of embryonic and larval mortality in populations of different sizes and with different degrees of isolation. At a broader scale, he and Osborne are examining the extent of decline throughout the range of both species, and attempting to relate the decline to biogeographic processes such as regional climate.
- A management and monitoring program for both species of Corroboree Frog has been implemented by the NSW National Parks and Wildlife Service in conjunction with the University of Canberra. This program was recently reviewed after consideration of experimental design factors and the number of sites to be monitored has increased to allow for different hypotheses concerning the population declines (see section 6 below for more details).
- A survey of a large number of known and potential breeding sites (including known extinction sites) has been completed. This work, carried out over several breeding seasons to allow for seasonal variation in the abundance of frogs, has made it possible to assess the size and geographic distribution of breeding populations. It has also permitted comparisons to be made with results of earlier surveys to assess the extent of any changes in population size and to determine whether declines are continuing and the extent of contraction in the geographic range of the species.
- Data have been collected on the habitat features at a range of sites including topographic position, hydrological characteristics, soil moisture, litter depth, and vegetation structure and floristics. Analysis of these data will enable comparisons to be made between successful, declining/poor and former breeding sites. Once key habitat variables associated with successful breeding sites have been identified, it may be possible to recommend management actions that can be undertaken to arrest declines at selected experimental sites (see Action 3.3 – Breeding pool manipulation).
- A study is being concluded to identify aspects of climate such as temperature, precipitation, snow depth and duration which may have had an effect on the breeding or non-breeding habitat of the species. Analysis of data for the past 30 years (encompassing periods when the frogs were abundant and in decline) now being undertaken may, for example, link decline to abnormally lengthy dry periods which could have affected survival of tadpoles through pond drying.
- The Perisher Blue Ski Slope Plan proposes to retain existing areas of Southern Corroboree Frog habitat within the resort wherever practicable (Perisher Blue Pty Limited 2000a). While the Corroboree Frog currently appears to be absent from the resort, this approach has been adopted in the hope that the species may make a recovery in the future.

6 Proposed Recovery Objectives, Actions and Performance Criteria 1999-2003

The recovery objectives, actions and criteria listed below are based on the need for determining the cause of the ongoing population decline in the Southern Corroboree Frog. The approach taken is both experimental and proactive; the general philosophy follows that of Caughley and Gunn (1996). Caughley and Gunn state that "*the effectiveness of treating a decline depends on the accuracy with which its causes have been diagnosed. More than one factor may be driving a decline which increases the need for an experimental investigation. A shotgun approach with a suite of recovery treatments is seldom, if ever, the answer. Diagnosis will reveal the magnitude of how different factors are affecting the decline and that, in turn, will guide priorities for the treatments*". Once such a diagnosis has been made, management actions additional to the general management prescriptions proposed for populations in Kosciuszko National Park by Osborne (1991) can be implemented. These may include, for example, artificial maintenance of breeding pools or deliberate flooding of oviposition sites to reduce mortality in the early life-history stages.

Overall Objectives

In the long term, the overall objective of the recovery program is to downlist the species from critically-endangered to endangered within ten years (based on IUCN criteria of population size and trends, extent of occurrence and probability of extinction). The immediate objective is to prevent the continuing decline in population numbers and through experimental management increase the size of selected representative populations across the geographic range of the species.

Overall Criterion

Populations of Southern Corroboree Frog stop decreasing and remain stable or increase directly due to recovery actions at six key sites over five years.

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.

The design will include the following treatments: altitude, precipitation, pool abundance, catchment size, original population size, breeding habitat, non-breeding habitat and metapopulation position. Monitoring will include tadpoles to determine whether breeding has been successful.

Population monitoring is an important component of the recovery process for threatened frogs in Australia (Tyler 1997). However, a lack of long-term studies has hampered efforts to determine the full extent of decline in amphibian populations, and the question as to whether population declines are indicative of a population collapse, or simply part of longer-term fluctuations in response to local weather patterns, or some other cyclical phenomena remains unresolved for many species (Pechmann *et al.* 1991; Pechmann and Wilbur 1998).

Recovery Criterion 1.1

Implementation of an effective program to monitor representative populations, including known extinction sites, for twenty years.

Action 1.2 Identify the life-history stage contributing most to demographic failure and leading to decline.

Research will be undertaken to identify the most sensitive period of the life-history. This research is essential for the undertaking of any form of population viability estimation, and will include determining at what stage the highest mortality is experienced. Research initially will focus on the pre-metamorphic stage (eggs, tadpoles) because this is the stage that usually suffers the highest levels of mortality through predation, competition and pond-drying (Wilbur 1980; Duellman and Trueb 1986).

Because of the already seriously depleted size of most local populations of the Southern Corroboree Frog, studies of embryonic and tadpole mortality will have to be undertaken somewhat opportunistically. To reduce disturbance to egg clutches, embryonic mortality will be assessed only in conjunction with the collection of eggs to be used in recruitment enhancement research (see Action 2.1). Similarly, tadpole mortality studies will be undertaken at the recruitment enhancement sites. This will involve partitioning sections of each experimental pool (chosen randomly) in order to allow for an accurate census. Since the aim of the population enhancement project is to reduce early life history mortality the use of enclosures is desirable because tadpoles can be easily gathered and moved to safer waters if the pools start drying. It will also allow for a direct comparison of survival rates of field-hatched tadpoles compared to tadpoles hatched in the laboratory and maintained over winter (Action 1.3) . Embryonic mortality will be determined by checking randomly located egg masses just prior to hatching.

Recovery Criterion 1.2

Research completed which determined which life-history stage is contributing most to the current demographic failure and decline.

Action 1.3 Develop techniques and obtain preliminary information on the age structure of the adult breeding population.

It will be almost impossible to undertake direct research on juvenile frogs and adults in the field because of their small size (difficult to fit transmitters or other electronic marking devices) and because they are likely to disperse into extensive areas of thick heath and woodland where there is little likelihood of finding individuals.

Although it may be difficult to undertake direct studies of survivorship in juveniles and adults it will be possible to compare the age structure of breeding adults present in the populations now with samples of adults collected and preserved in museums prior to the decline. In recently completed preliminary research funded by the University of Canberra, D. Hunter successfully examined the age structure of adult breeding males of Northern Corroboree Frogs from a number of low altitude and high altitude sites. Individual males were toe-clipped to obtain bone material for ageing, and their throat pattern was sketched for individual identification. Other data collected included sex, weight, snout-urostyle length, tibia length, whether the males had been successful in mating, and the number of eggs in nest sites. Information was also obtained on the effect of disturbing males in their nest site.

Recovery Criterion 1.3

Information on the age structure of the adult breeding population obtained.

Action 1.4 Determine sensitivity of the Southern Corroboree Frog to UV-B radiation.

Serious declines affecting many species of frogs have occurred at high altitudes in undisturbed mountain environments (eg. Crump *et al*. 1992; Carey 1993; Fellers and Drost 1993; Kagarise, Sherman and Morton 1993; Gillespie *et al*. 1995). The global distribution of declines in such habitats suggests causal agents that exert their influence on a global scale. One plausible explanation for the declines is that exposed tadpoles or eggs are being damaged by UV-B radiation as a result of ozone layer depletion (Blaustein *et al.* 1994). High elevation regions have experienced the greatest increase in solar Ultraviolet-B (UV-B) radiation (Herman and Larko 1994) and for this reason the potential effects of UV-B on the survival of the Southern Corroboree Frog will be investigated.

Recovery Criterion 1.4

Field experiments determining the sensitivity of eggs, embryos and tadpoles of the Southern Corroboree Frog to ambient ultraviolet radiation completed.

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.

The premise behind this action is that the high egg and tadpole mortality observed during the over-winter phase is significantly contributing to the current regulation of population size. The first phase of this action is to investigate possible techniques which may be used to increase over-winter survival. The second phase will involve monitoring the number of breeding males between mortality-reduced populations and control populations to investigate the potential for this procedure to increase the breeding adult population size.

Two possible techniques for reducing over-winter mortality are currently being tested. The first involves removing eggs from nest sites during autumn, rearing them in captivity through to an early stage tadpole at the Amphibian Research Centre (ARC), and returning them to their natal pools in early spring after snow melt. During the 1997, 1998 and 1999 breeding seasons, a comparison between levels of field survivorship and captive reared survivorship through to metamorphosis was undertaken. The results showed that the process of captive rearing significantly increases survivorship though to metamorphosis (for details of the methodology and results refer to Hunter *et al.* in press).

The second technique being investigated involves removing the eggs from the nest sites during autumn, after the breeding pools have filled with water, and placing them directly into the pools. Preliminary results suggest that this technique may also be used successfully to reduce early life-history mortality. An investigation will be undertaken in 2000-2001 to compare survivorship of field control, captive reared individuals and eggs placed directly into the water. This will allow the choice of the most appropriate technique for incorporation into this project.

Action 2.1 was initiated in 1997 with survivorship through to metamorphosis being increased in three remnant populations. An additional four populations were incorporated into the project during 1998 and 1999 to make a total of seven populations where recruitment enhancement is being undertaken. Since the Southern Corroboree Frog takes three years to reach reproductive maturity from the egg stage, it will probably not be until January 2002 before we will have any indication as to the success of this project. Furthermore, given that the Southern Corroboree Frog may live for up to six years as a breeding adult, successive years of recruitment enhancement may provide more conclusive results due to the cumulative effect on the breeding population size. Further populations may be incorporated into the project if the initial results prove successful.

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.

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.

Because of the major collapse of the wild population, development of a captive breeding program for the Southern Corroboree Frog is now an essential component of the recovery program. The aim of this breeding program is to provide a source of animals for future experimentation and reintroduction projects, secure the genetic diversity of the species in the event of further population declines and extinctions and provide an educational resource and focus for fund raising efforts. The initial phase of this program will involve developing adequate captive husbandry techniques for this species. The ultimate timing and scale of this program will be largely determined by the success of this initial phase.

Captive husbandry research commenced in 1997. The NPWS contracted the ARC in Melbourne to undertake private research on methods for maintaining and breeding both the Northern and Southern Corroboree Frogs in captivity. A small number of adult Northern Corroboree Frogs have been maintained in captivity for two years however breeding has not been achieved at this stage. Similarly, a small number of Southern Corroboree Frog tadpoles, which were obtained from the population enhancement program (refer to Action 2.1) during 1997, 1998 and 1999, have been successfully reared over the last three years. Because they have not yet attained reproductive maturity, their breeding potential cannot be assessed. Additional tadpoles of the Southern Corroboree Frog and adults of the Northern Corroboree Frog will be supplied to the ARC during 2000 and 2001 for further development of this program.

At present the captive husbandry program is being conducted exclusively at the Amphibian Research Centre. Because of the possibility, however remote, that a single captive population could be destroyed by accident or become infected by a pathogen, a second captive colony would be highly desirable. This possibility will be considered by the Recovery Team subject to the availability of necessary funding and sufficient numbers of captive animals from the initial captive breeding program to make it feasible.

Recovery Criterion 3.1

An increase in population numbers at sites targeted for recruitment enhancement through the captive husbandry program is achieved.

Action 3.2 Screening of captive reared individuals for pathogens prior to release.

While the effect of disease on amphibian populations is poorly known, the possibility that a disease is affecting the populations of Southern Corroboree Frog should not be ignored. Moreover, given recent concern about a particularly virulent fungal disease affecting captive frogs (Lee Berger, personal communication), the risk of introducing a disease into wild populations from captive-reared animals should be considered. Returning captive-reared animals to extant populations is considered to be highly undesirable due to the risk of introducing a disease into the population.

A prudent approach, with regard to avoiding disease transmission, would involve the screening of all individuals just prior to their release (Dodd and Seigel 1991). Therefore, a sample of both field and captive tadpoles will be tested for pathogens before the release of the captive population back into the wild.

One additional action that will be considered in the future is determining whether the chytrid fungus is currently present in the wild population.

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.

Action 3.3 Breeding pool manipulation

The specific breeding habitat requirements of Corroboree Frogs have been studied in detail by Osborne (1990). The main feature of the breeding habitat is the presence of shallow pools or seepages, which occur in open areas away from trees or large over-hanging shrubs. Because of the lengthy (6+ months) larval period of the frogs, the water bodies used as tadpole development sites necessarily must be of long duration. Osborne (1990) also found that the frogs prefer large, shallow pools which warm during the day and have an edge protected by moss and other vegetation that provides suitable calling and oviposition sites. As previously mentioned some ecologists suggest that, following the removal of grazing and associated disturbance, wetlands have undergone seral changes (generally interpreted as a form of recovery), however the hydrology of the breeding habitat and the range of pools available for breeding may differ in some unknown manner from the pre-European condition (I. Pulsford pers. comm.). Whilst we suggest that it is highly unlikely that the current decline has been brought about by these changes (in some locations the frogs have declined or completely disappeared from numerous sites with large numbers of pools present; Hunter and Osborne in prep.), it is prudent to attempt some form of habitat manipulation to test this hypothesis. This research could also be done in association with a translocation program should tadpoles be available in the future. Before any habitat manipulation was initiated, chosen sites would be checked for possible presence of *Carex raleighii* (which commonly grows in Sphagnum areas) and other threatened species.

Using an experimental design (yet to be determined but including unmanipulated control sites and manipulated experimental sites), pools will be created or modified to provide additional potential breeding habitat at selected sites. In the former instance habitat manipulation will involve the construction of artificial pools of different sizes. In the latter the provision of artificial depressions in existing pools to provide refugia for tadpoles as the pools dry out. This manipulation would only take place close to extant populations.

If suitable numbers of tadpoles are available for translocation, an attempt will be made to re-establish the Southern Corroboree Frog at a suitable site or sites, or an attempt will be made to increase the population size of breeding adults at existing experimental sites. Careful monitoring will be required to determine the success of such habitat manipulation. A research plan and appropriate experimental design will be prepared for this proposal in the near future.

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.

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.

The main Actions undertaken by NPWS are described below. Many of these Actions are undertaken routinely during normal park management activities and have not been costed in this Recovery Plan.

<u>Strict protection of all remaining breeding sites</u>
All known Southern Corroboree Frog breeding sites in Kosciuszko National Park will be given full protection from direct human disturbance. In particular, the larger remaining breeding sites in the Dargals Range, Ogilvies Creek, Jagumba Range and Round Mountain region will be accorded a very high priority. Sites in this region represent the only remaining substantial breeding aggregations that still maintain some semblance of a metapopulation structure. Because of the possible attraction of the frogs to tourists, or other potential collectors, the exact location of breeding sites in this region will not be made public. The present classification of the frogs as 'Significant Natural

Features' (NPWS 1984a) will remain, and will help with the protection of potential breeding sites in the resort areas and elsewhere.

The Kosciuszko National Park Plan of Management currently provides for the exclusion of fuel reduction burning from Southern Corroboree Frog breeding and non-breeding habitat (NPWS 1984b). Every effort should also be made to protect these areas from wildfire.

Maintain hydrological integrity of sites

Southern Corroboree Frogs are completely dependent on continued water seepage into the shallow breeding pools. During the lengthy (approximately six-month) period that the tadpoles are developing they are vulnerable to mortality if the pools dry. Consequently any activity that reduces water flow into the breeding habitat is potentially detrimental to the continued existence of the frogs at the site. Activities in the catchments of the breeding sites which may be deleterious include road construction, the laying of surface and sub-surface drains, cables and sewerage mains and the construction of aqueducts. Such activities, which may intercept and reduce water flow into breeding sites, are not compatible with the protection of the breeding habitat.

Vehicle use and excessive human trampling within the breeding habitat is likely to damage both the pools and the moss used as breeding sites by the frogs. Such activities will be prevented in order to protect the breeding pools, drainage lines and seepages.

Protection of non-breeding habitat

At the end of the breeding period adult and sub-adult frogs disperse up to 300 metres or more from the breeding pools (Osborne 1988). Most individuals leave the moist breeding habitat and spend winter in the woodland and drier heathland that surrounds the breeding sites. In these areas some frogs hibernate beneath logs but most probably shelter beneath a ground layer cover of litter, grass and other vegetation. The frogs can be expected to occur in these drier non-breeding season habitats during much of the period from May to December when the soil in these areas is relatively moist from autumn and winter rains.

Although Corroboree Frog non-breeding habitat is dispersed and extensive, when compared to the breeding areas, large scale disturbance from activities such as land clearing and burning would be potentially damaging to the frogs. Clearing of vegetation, and in particular burning of the understorey litter and grass cover, would reduce the shelter available to the frogs and make them more vulnerable to dehydration during dry weather. Because prescribed burning (control or fuel reduction burning) has the specific purpose of greatly reducing ground litter cover, and because the burns are usually carried out in autumn when the frogs have moved into woodland and heath, such programs will not be implemented near Southern Corroboree Frog breeding sites (see earlier section on protection of breeding sites).

Protection in areas managed by other authorities

Apart from the NSW National Parks and Wildlife Service, a number of other organisations and authorities operate facilities in Kosciuszko National Park (details listed in National Parks and Wildlife Service 1984b). In particular, the Snowy Mountains Hydro-Electric Authority has responsibilities that may affect the conservation of Corroboree Frogs. A number of Southern Corroboree Frog breeding sites occur near aqueducts and roads maintained by Snowy Mountains Hydro-Electricity Authority. Although the existing usage of these areas is unlikely to further damage frog breeding sites, any major new construction in areas frequented by the frogs may adversely affect their breeding habitat and would require full assessment of potential impacts.

Control of feral animals

Disturbance to vegetation and soil from pig rooting by Feral Pigs (*Sus scrofa*) in some areas can be extensive, and pools containing Corroboree Frog tadpoles are sometimes used as wallows by the pigs. Although the frogs may on occasions breed in small pools caused by pig disturbance, the overall impact on Corroboree Frogs is considered to be harmful. In keeping with the general policy of KNP on feral animal control, pig numbers will be monitored and controlled in areas known to have Southern Corroboree Frogs.

Recovery Criterion 4

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.

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.

Extension and media activities will be continued and targeted at educating teachers, bushwalkers, skiers, campers and the public about the precarious situation of the frog and the importance of the recovery program. Interpretive signs or similar material will be placed at sites where visually conspicuous recovery actions are taking place near areas visited by walkers or other users (eg. at breeding sites where pools have been modified or constructed).

Training will be provided for management, field and planning staff (NPWS, SMHEA, ski resorts, etc.) to promote an understanding of the ecology and monitoring of the Southern Corroboree Frog, and ensure compliance with protection of breeding and non-breeding habitat. NPWS staff, community groups and tertiary students will be involved in the monitoring.

Support from conservation organisations and industry in the form of financial and other assistance to the recovery program will be sought.

Recovery Criterion 5

Community information brochures, interpretation signs, and informative articles prepared and representatives of relevant authorities trained to assist with appropriate research and management activities.

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.

A Recovery Team has been in existence since 1995. The Recovery Team includes participants with the range of skills necessary for determining recovery actions and for setting priorities associated with recovery research and management. Expertise on the Recovery Team includes amphibian biology and ecology, amphibian husbandry, wildlife management, national park management, human resources and project development and financial management .

The Recovery Team will be responsible for implementing the Recovery Plan, including the detailed planning required for the program, such as the identification of actions, targets, responsibilities and time-lines for completion. The Recovery Team will also monitor and assess implementation of the Recovery Plan, and will carry out administrative tasks relating the recovery effort, including preparing contracts for the components of the program, and obtaining relevant permits to enable work to proceed. The major cost for management of the recovery program will be met by NPWS. Other participating agencies will be responsible for their own costs.

Recovery Criterion 6

The Recovery Team continues to operate and recovery actions continue to the implemented.

7 Implementation

Table 1 outlines the implementation of recovery actions specified in this plan for the period of five years from publication.

8 Social and Economic Consequences

This Recovery Plan estimates that the total costs of implementing the recommended actions will be $738,750 over the five year period covered by the plan. The main contributors of these funds are the NPWS ($251,000), the University of Canberra ($160,000) and the Amphibian Research Centre ($79,000). The balance of the costs ($248,750) are unsecured; however, assistance will be sought from the Commonwealth Endangered Species Program which has provided funding for the past three years. Monitoring, research and habitat protection account for a substantial proportion of the total costs. Since the remaining populations all occur in Kosciuszko National Park there are no costs associated with land reservation or protection or foregone opportunities associated with alternative land uses.

Because the populations of the Southern Corroboree Frog occur entirely in Kosciuszko National Park, its conservation requirements can be readily incorporated with other park management objectives and it is unlikely that significant conflict would arise. It is, therefore, expected that there will be no significant social costs.

Whilst it is possible to make estimates of the economic costs with some degree of accuracy and confidence, economic benefits are much less easy to quantify. They are, nevertheless, real and need to be taken fully into account in an assessment of the relative costs and benefits of recovery planning for the Southern Corroboree Frog.

The Southern Corroboree Frog is a distinctive and striking species that has captured public attention. Its decline sends a message about the overall deterioration in the quality of our environment. If we can successfully bring this species back from the brink of extinction, there could be significant social benefits in terms of how positively we see our environment and its general health. In the longer term, also, the Southern Corroboree Frog is a part of Australia's biodiversity, and therefore deserving of efforts to preserve it for the enjoyment of present and future generations.

9 Biodiversity Benefits

A considerable proportion of the efforts of the Recovery Team are focussed on understanding the reasons for the decline of the species and the management actions required to arrest the decline in numbers. It is likely that at least part of this work will be applicable to other endangered frog species and lead to considerable benefits in terms of improving their prospects for survival. In addition, the habitat management and protection undertaken directly for the Southern Corroboree Frog will benefit other significant flora and fauna species occurring in the same environments; notably *Carex raleighii*, an endangered sedge species which occurs in habitats similar to those occupied by the Corroboree Frog in the headwaters of the Tooma and Tumut Rivers in Kosciuszko National Park. A Recovery Plan for this species has also been completed.

10 Preparation Details

Dr Will Osborne, of The University of Canberra prepared this Recovery Plan.

Dr Stephen Clark and Michael Saxon, Threatened Species Unit, Southern Directorate NPWS, finalised and edited the plan.

The plan has been formulated with the advice and assistance of a Recovery Team. The Recovery Team is a non-statutory group of expert biologists, landowners/managers and other stakeholders and has been established by the NSW National Parks and Wildlife Service (NPWS) to discuss and resolve issues relating to the conservation and management of the species.

11 Review Date

Any major changes to this Recovery Plan will require the revised Plan to be placed on public exhibition in NSW and re-approval by the NSW Minister for the Environment. The NPWS, Environment Australia or members of the Recovery Team should be contacted if it is believed any change to the Recovery Plan or to the Recovery Program should be considered. This Recovery Plan is to be formally reviewed by the NPWS in conjunction with the Recovery Team within five years from its date of publication.

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Table 1: Estimated costs of implementing the actions identified in the recovery plan are provided below.

Action	Action Description	*Priority	^Feasibility	Responsible	Fund	Cost Estimate ($'s/year)					Total Cost
No.				Party	source	1999	2000	2001	2002	2003	($'s)
1.1	Monitoring	1	100%		Unsecured	12,000	8,000	8,000	8,000	8,000	44,000
				NPWS	In Kind	12,000	12,000	12,000	12,000	12,000	60,000
				UCAN	In Kind	6,000	6,000	6,000	6,000	6,000	30,000
1.2	Determine life-history stage responsible for population decline	1	100%		Unsecured	9,000	9,000	4,500			22,500
				NPWS	In Kind	3,000	3,000	1,500			7,500
				UCAN	In Kind	6,000	6,000	3,000			15,000
1.3	Establish age structure of adult breeding population	1	100%	UCAN	In Kind	2,000	2,000	2,000			6,000
1.4	Determine sensitivity of eggs, embryos and tadpoles to ambient UV-B radiation	1	100%		Unsecured	14,250	12,000	12,000			38,250
				NPWS	In Kind	3,000	3,000	3,000			9,000
				UCAN	In Kind	42,000	8,000	8,000			58,000
2.1	Recruitment enhancement through population supplementation	1	100%		Unsecured	5,000	5,000	5,000	tbd	tbd	15,000
				NPWS	In Kind	12,000	12,000	12,000	8,000	8,000	52,000
				UCAN	In Kind	12,000	12,000	12,000	tbd	tbd	36,000
				ARC	In Kind	8,000	8,000	8,000	tbd	tbd	24,000
3.1	Captive husbandry and breeding trials	1	100%		Unsecured	10,000	10,000	10,000	10,000	10,000	50,000
				NPWS	In Kind	1,000	1,000	1,000	1,000	1,000	5,000
				UCAN	In Kind	1,000	1,000	500	500	500	3,500
				ARC	In Kind	10,000	10,000	10,000	10,000	10,000	50,000
3.2	Screening for pathogens prior to tadpole release	1	100%	ARC/CSIRO AHL	In Kind	1,000	1,000	1,000	1,000	1,000	5,000
3.3	Breeding pool manipulation	3	100%		Unsecured	5,000	10,000	10,000	2,000	2,000	29,000
				NPWS	In Kind	5,000	3,000	3,000	1,000	1,000	13,000
				UCAN	In Kind	3,000	3,000	1,000	1,000	1,000	9,000
4.1	Habitat protection	1	100%		Unsecured	10,000	10,000	10,000	10,000	10,000	50,000
				NPWS	In Kind	16,000	16,000	16,000	12,000	12,000	72,000
5.1	Stakeholder and community awareness and involvement	3	100%	NPWS	In Kind	4,500	4,500	4,500	4,500	4,500	22,500
				UCAN	In Kind	500	500	500	500	500	2,500
6.1	Operation of Recovery Team	3	100%	NPWS	In Kind	2,000	2,000	2,000	2,000	2,000	10,000
Total					**Unsecured**	**65250**	**64000**	**59500**	**30000**	**30000**	**248,750**
Total					**In Kind**	**150000**	**114000**	**107000**	**59500**	**59500**	**490,000**
Total	**Annual cost of Recovery Program**				**Unsecured + In Kind**	**215250**	**178000**	**166500**	**89500**	**89500**	**738,750**

Costings were estimated in 1999. No allowance has been made for inflation
*Priority ratings as defined by Commonwealth Recovery plan guidelines: 1 - action critical to prevent extinction, 2 - action prevents negative impact short of extinction, 3 – other actions
^Feasibility assessment reflects estimated chance of success of the action on a scale of 0-100%.

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NATIONAL
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SERVICE

43 Bridge Street
Hurstville 2220
(02) 9585 6444