



Southern Brown Bandicoot

(Isoodon obesulus)

Recovery Plan



November 2006

Department of
Environment and
Conservation (NSW)

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Cover illustration: The Southern Brown Bandicoot (*Isoodon obesulus*)
Photographer: Bert Lobert.

This plan should be cited as following:

Department of Environment and Conservation (NSW) (2006) Southern Brown Bandicoot (*Isoodon obesulus*) Recovery Plan. NSW DEC, Hurstville NSW.

ISBN: 1 74137 334 4

Southern Brown Bandicoot (*Isoodon obesulus*) Recovery Plan

Executive Summary

This document constitutes the NSW Recovery Plan for the Southern Brown Bandicoot *Isoodon obesulus*, and as such considers the conservation requirements of the species across its known range within the State. It identifies actions to be undertaken to attempt to ensure the long-term viability of the species in nature and the parties who will carry out these actions.

The Southern Brown Bandicoot, listed as Endangered (Schedule 1, Part 1) on the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Endangered on the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*, is a medium-sized (400-1600g) ground-dwelling marsupial. Like other members of the bandicoot family (Peramelidae) it has a long tapering snout with a naked nose, a compact body and short tail with a pointed end. The head has small rounded ears and small eyes. The coarsely furred dorsal surface of the body is usually dark grey with golden-brown flecks, and the softer underbelly is creamy-white. While the forelegs are short with curved claws on the digits, the hindlimbs are much longer resembling those of macropods. The hind feet are characterised by the presence of syndactylus toes, formed by fusion of the second and third digits. These are used for grooming. As an omnivore with a broad-ranging palate, the Southern Brown Bandicoot consumes a wide range of invertebrates, various plant material (leaves, fruits and seeds) and the fruit-bodies of hypogeous (underground-fruiting) fungi.

In NSW, the species has a patchy distribution along the eastern coastline and adjacent lower foothills in the southern part of the State, from the Hawkesbury River to the Victorian border. Records of the species are generally confined to heathlands or woodlands and forests with healthy understorey, typically on friable sandy soil. Current information suggests that there are only two population strongholds, one within Ku-ring-gai Chase and Garigal National Parks in the Northern Sydney Metropolitan Area, the other in the far south-east corner of the State, encompassing Ben Boyd National Park, Nadgee Nature Reserve and adjacent State Forests.

Perceived short-term threats to survival of the Southern Brown Bandicoot in New South Wales include predation by introduced carnivores such as dogs and foxes, inappropriate disturbance to its habitat, and in some areas vehicular traffic. The long-term viability of the species in the wild is made more tenuous by its patchy distribution and the consequent potential for localised population extinction.

This recovery plan aims to address threats to the Southern Brown Bandicoot and over the next five years key recovery actions for the species will include:

- (i) establishing intensive introduced carnivore control programs around known populations;
- (ii) monitoring those populations to determine the success of introduced carnivore control programs in reducing impacts on the species;
- (iii) monitoring the level of road-kill at trouble spots and erecting signs where necessary;
- (iv) implementing fire management regimes around known populations that promote favoured habitat;
- (v) ensuring that future development is carried out in a way that does not impact significantly on known populations through provision of environmental assessment guidelines;
- (vi) undertaking further survey, and
- (vii) raising community awareness of the species and involving public interest groups in various aspects of the recovery program.

In addition to these key actions, the plan advocates a number of research activities that may lead to a better understanding of the ecology and conservation requirements of the Southern Brown Bandicoot, its habitat and food resources. It is intended that the recovery plan will be implemented over a five year period. The total cost to implement the plan is \$555,870, of which \$467,370 is attributed to NSW Department of Environment and Conservation (DEC) and \$65,000 to State Forests of NSW for actions approved and partially funded under the Fox Threat Abatement Plan. Additional sources of funding will need to be found for some research actions yet to be costed fully.

The Southern Brown Bandicoot Recovery Plan was prepared with the assistance of a recovery team and two regional working groups comprising of relevant land management and research interests, and was placed on public exhibition from 10 January to 4 March 2005. We thank these people for their efforts to date and look forward to their continued involvement in the implementation of the recovery actions identified in this plan.



Lisa Corbyn
Director General



Bob Debus MP
Minister for the Environment

Acknowledgments

Several people assisted in preparation of this recovery plan by providing information on the biology and conservation management of the Southern Brown Bandicoot. In this regard, special thanks are due to Meagan Ewings (DEC Threatened Species Unit, Central Directorate), David Paull (School of Geography and Oceanography, The Australian Defence Force Academy, Canberra), Graeme Newell (Department of Natural Resources and Environment, Victoria), Damien Moloney (formerly Conservation Strategy Branch, Department of Environment, Queensland) and Dimitri Young (Shoalhaven City Council). Lorraine Oliver, Threatened Species Education Officer with the NSW DEC Southern Directorate, prepared Figure 1. Members of the State Recovery Team commented on earlier drafts of this document.

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1 Introduction

Bandicoots, like many of the small to medium-sized marsupials of Australia, have undergone several species extinctions and significant contractions in distribution since European settlement. Of the estimated 12 species of bandicoot present on the continent at that time, approximately half are now either extinct, threatened with extinction or extremely rare. The ongoing decline of a once common species like the Southern Brown Bandicoot, *Isoodon obesulus*, is therefore a cause for serious concern. This species was once widespread in southern New South Wales, but now appears to be restricted to a few disjunct locations along the coastal fringe of the State, south of the Hawkesbury River to the Victorian border. In view of its extremely limited distribution and low abundance within the State, the Southern Brown Bandicoot is considered endangered and is listed on Schedule 1 of the *Threatened Species Conservation Act 1995* (TSC Act). The effect of the State listing is that a recovery plan may be prepared which considers the conservation requirements of the species across its known range. The plan must also identify actions to be taken to ensure the long-term viability of the species in nature and the parties who will carry out these actions.

This document constitutes the formal New South Wales State Recovery Plan for the Southern Brown Bandicoot. 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 an associated Recovery Team.

2 Legislative Context

2.1 Legal Status

In view of its extremely limited distribution within the State, the Southern Brown Bandicoot is considered endangered and is listed on Schedule 1 of the *Threatened Species Conservation Act 1995* (the TSC Act). In addition, the south-eastern mainland Australian sub-species, *Isoodon obesulus obesulus*, which is represented in New South Wales, is listed as endangered under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*.

Among the consequences of listing as a threatened species on the TSC Act are that

a recovery plan may be prepared, that consideration be given to the species in assessing the impacts of developments and activities with the aim of minimising adverse impacts, and that actions that are likely to result in the harming or picking of that species or damage its habitat are licensed.

2.2 Recovery Plan Preparation

The TSC Act enables the Director-General of Department of Conservation and Environment to prepare recovery plans for all species, populations and ecological communities listed as endangered or vulnerable on the TSC Act schedules. The TSC Act includes specific requirements for both the matters to be addressed by recovery plans and the process for preparing recovery plans. This plan satisfies these provisions.

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 are 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 implement those actions. In addition, the TSC act specifies that public authorities must not make decisions that are inconsistent with the provisions of the plan. Public authorities currently relevant to this plan are the New South Wales Department of Environment and Conservation (DEC), Roads Traffic Authority (RTA) and State Forests of New South Wales (SFNSW), together with the following councils: Baulkham Hills, Bega Valley Shire, Eurobodalla Shire, Hornsby, Ku-ring-gai, Pittwater, Shoalhaven and Warringah. Other public authorities may be included in the future as surveys for the Southern Brown Bandicoot are completed. The actions outlined for each of the current relevant agencies must be implemented as described in this plan.

2.4 Relationship to other legislation

The lands on which the Southern Brown Bandicoot has been recorded include those that are owned or managed by the DEC, SFNSW, and also private land in the Northern Sydney Metropolitan Area. Relevant legislation includes:

- *National Parks and Wildlife Act 1974*
- *Environmental Planning and Assessment Act 1979*
- *Local Government Act 1993*

- *Rural Fires Act 1997*
- *Forestry Act 1912*

The interaction of these Acts with the TSC legislation is varied. The most significant implications are described in Section 2.7 below.

2.5 Critical Habitat

The TSC Act makes provision for the identification and declaration of Critical Habitat for species, populations and ecological communities listed as endangered. Once declared, it becomes an offence to damage Critical Habitat (unless the TSC Act specifically exempts the action) and a Species Impact Statement is mandatory for all developments and activities proposed within Critical Habitat. To date, Critical Habitat has not been declared for this species under the TSC Act.

2.6 Key Threatening Processes

Five key threatening processes listed under Schedule 3 of the TSC Act are of direct relevance to the Southern Brown Bandicoot:

- (i) Predation by the European Red Fox *Vulpes vulpes* (Linnaeus, 1758),
- (ii) Predation by the Feral Cat *Felis catus* (Linnaeus, 1758),
- (iii) High frequency fire resulting in disruption of life cycle processes in plants and animals and loss of vegetation structure and composition
- (iv) Clearing of native vegetation, and
- (v) Infection of native plants by *Phytophthora cinnamomi*.

This species is specifically mentioned in text relating to the final determination of each of these processes.

As identified in Section 4 of this plan, the Red Fox is a key predator of the Southern Brown Bandicoot in its mainland Australian range. So too, potentially, is the Feral Cat but data are limited. Also, too frequent fire may result in opening of dense understorey vegetation, which the Southern Brown Bandicoot requires for nesting and protection from predators. The clearing of native vegetation clearly relates to the loss and modification of habitat for this species, a threat to all species. *Phytophthora* has been listed as an infectious disease that results in the death of plants, the reduction of habitat complexity and potentially the loss of habitat. Particular species and communities impacted are woodlands and heath habitats and understorey species such as *Xanthorrhoea* spp and *Banksia* ssp. which

are habitats characteristic of the Southern Brown Bandicoot.

2.7 Environmental Assessment

The TSC Act amendments to the environmental assessment provisions of the *Environmental Planning and Assessment Act 1979* (EP&A Act) require that consent and determining authorities and the Director-General of NSW DEC, as a concurrence or determining authority, consider relevant Recovery Plans when exercising a decision making function under Parts 4 & 5 of the EP&A Act. Decision-makers must also consider known and potential habitat, biological and ecological factors, and the regional significance of individual populations. Any other activity not requiring development consent under the EP&A Act, and which is likely to have a significant impact on the Southern Brown Bandicoot, requires a Section 91 licence from DEC under the provisions of the TSC Act. In addition, a scientific licence under s.132(c) of the NP&W Act is required to 'harm' the southern brown bandicoot or 'damage' its habitat for scientific, education or conservation purposes. Such licenses can be issued with or without conditions, or can be refused.

The following public authorities are currently known to have a decision making function in relation to the Southern Brown Bandicoot:

- NSW DEC, as manager of land which has the species present, and where a concurrence role under the EP&A Act is required or where a Section 91 Licence (under the TSC Act) is required;
- SFNSW, in relation to managing State Forests where the species has been recorded, and;
- Baulkham Hills, Bega Valley Shire, Eurobodalla Shire, Hornsby, Ku-ring-gai, Pittwater, Shoalhaven and Warringah. Councils, as consent authorities for development and/or as the owners of land which contain potential habitat for the species.

Additional public authorities may have responsibilities if the species is located in other areas in the future.

3 Species Information

3.1 Description

The Southern Brown Bandicoot, *Isodon obesulus* (Shaw and Nodder 1797), is a medium-sized (400-1600g) ground-dwelling marsupial. Like other members of the bandicoot family (Peramelidae) the species

has a long tapering snout with a naked nose, a compact body and short tail with a pointed end. The head has small rounded ears and small eyes. The coarsely furred dorsal surface of the body is usually dark grey with golden-brown flecks, and the softer underbelly is creamy-white. While the forelegs are short with curved claws on the digits, the hindlimbs are much longer resembling those of macropods. The hind feet are characterised by the presence of syndactylus toes, formed by fusion of the second and third digits. These are used for grooming.

In southern New South Wales the Southern Brown Bandicoot is most easily confused with the Long-nosed Bandicoot (*Perameles nasuta*) and Long-nosed Potoroo (*Potorous tridactylus*), both of which may occur in the same or similar habitats. However, the Southern Brown Bandicoot is generally smaller than the other two species and has relatively small ears, particularly compared to the Long-nosed Bandicoot. In addition, the fur colour on the feet of the Southern Brown Bandicoot is brown and that on the Long-nosed Bandicoot white. The Long-nosed Potoroo on the other hand can be differentiated from the two bandicoot species mainly on the basis of its thick, 'wallaby-like' tail.

The closely related Northern Brown Bandicoot (*Isoodon macrourus*) is very similar in appearance to the Southern Brown Bandicoot, but the distribution of the two species is not thought to overlap: the former species occurring north of the Hawkesbury River and the latter species south.

3.2 Distribution

The Southern Brown Bandicoot is found in south-eastern mainland Australia, south-western mainland Australia, Tasmania, Cape York Peninsula, and a few islands in South Australia. Strahan (1995) formally recognises five sub-species of *I. obesulus*, with each sub-species being geographically distinct. While the validity of these taxonomic distinctions is currently being questioned by recent genetic studies (i.e. Pope *et al.* 2001), formal taxonomic revisions are yet to occur. That being the case, the sub-species breakdown indicated by Strahan (1995) is used here.

Within New South Wales *Isoodon obesulus obesulus* is apparently rare and almost exclusively restricted to the coastal fringe of the State, from the southern side of the Hawkesbury River in the north to the Victorian border in the south. More specifically, the sub-species is considered to occur primarily in two areas: (i) Ku-ring-gai

Chase and Garigal National Parks just north of Sydney, (Figure 1) and (ii) in the far south east corner of the State including Ben Boyd National Park, East Boyd State Forest, Nadgee Nature Reserve, Nadgee State Forest, South East Forests National Park, Timbillica State Forest and Yambulla State Forest. In between these two areas the species has been found in a small number of National Parks (Blue Mountains and Budderoo) and State Forests (Maroota, Mumbulla, Nalbaugh, and Nullica) (Figure 2). Two records of *I. obesulus obesulus* also have been reported from private land in the Northern Sydney Metropolitan Area (Atkins 1999).

Isoodon obesulus obesulus is also primarily distributed in coastal regions in Victoria, although isolated populations occur inland in the Dandenong Ranges, the Grampian Ranges and central western Victoria (Menkhorst and Seebeck 1990). The species appears to be more abundant in the south-west than in the east of the State. Menkhorst and Seebeck (1990) consider that the species is not under threat in Victoria because suitable habitat for it is well represented in conservation reserves.

In South Australia both *I. obesulus nauticus* and *I. obesulus obesulus* occur (Kemper 1990). *Isoodon obesulus nauticus* is reasonably common on Franklin Island but rare on St. Francis Island, in the Nuyts Island Archipelago Conservation Park (Jones 1924; Kemper 1990). The sub-species is considered threatened because of its limited and isolated distribution. *Isoodon obesulus obesulus* was once believed to be the most common bandicoot in southern Australia (Krefft 1866), but by the 1920's it was considered rare (Jones 1924). Today, the sub-species is patchily distributed and uncommon, being found on Kangaroo Island, in the Mount Lofty Ranges including the Fleurieu Peninsula and in the lower south-eastern portion of the State (Kemper 1990; Paull 1995).

Isoodon obesulus peninsulae is an uncommon inhabitant of eucalypt woodland, grassland and heathland on the Cape York Peninsula in Queensland (Gordon *et al.* 1990). It does not appear to be under threat as extant populations occur primarily on land listed for National Park inclusion.

In Tasmania *I. obesulus affinis* remains widespread and abundant, and also occurs on Bruny Island, Maria Island and a few small Bass Strait Islands (Rounsevell *et al.* 1991). However, Hocking (1990) considered that populations of the sub-species were potentially at risk because much of the land in

Tasmania containing suitable habitat occurs on private land.

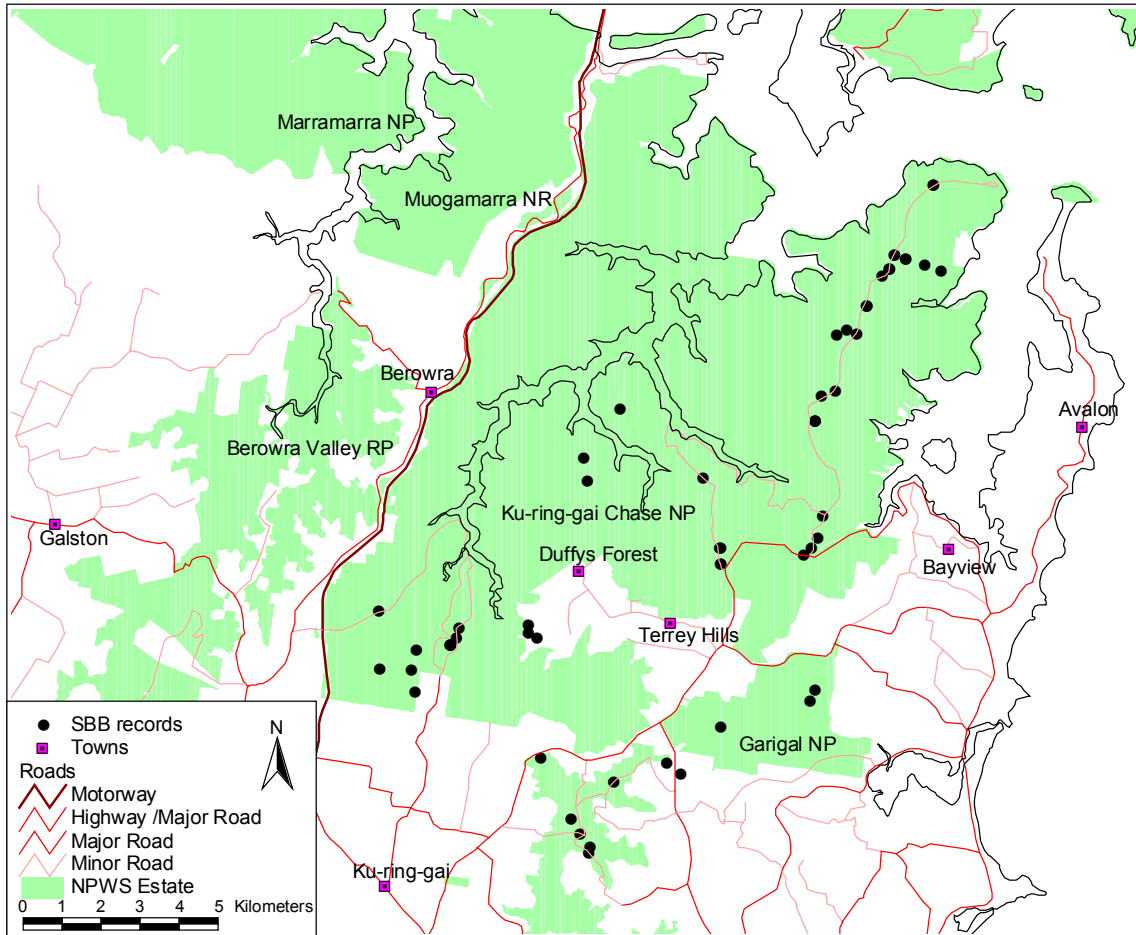


Figure 1: Map of the Northern Sydney Metropolitan Area illustrating sites at which the Southern Brown Bandicoot has been recorded.

Records of *I. obesulus fusciventer* in Western Australia are restricted to higher rainfall areas in the south-west of the State (Friend 1990), where the species may be sometimes locally common (ie. Nagy *et al.* 1991). Friend (1990) considered that this sub-species had not undergone severe decline in distribution since settlement by Europeans, having disappeared only from areas in which its native habitat had been totally removed.

3.3 Current Conservation Status

Available evidence suggests that the Southern Brown Bandicoot has undergone a marked reduction in range and abundance, particularly in New South Wales. Prior to the turn of the century Gould (1845) (cited in Ashby *et al.* 1990) described the species as 'one of the very commonest of Australian mammals'. At that time the species occurred well inland within the State, occupying the Murray-Darling Basin (Krefft 1866). In the early 1890's the species was also apparently abundant in the Bega Valley on the south coast, but has since disappeared from that area following broadscale clearing of habitat for agricultural purposes (Lunney and Leary 1988).

Road-kill records of the Southern Brown Bandicoot within Ku-ring-gai Chase National Park, immediately north of Sydney, indicate that the population there has persisted through at least the last three decades. However, these records provide no real indication for population numbers over time. A small number of juvenile animals have recently been captured within the same geographic area (Sutherland 1998), suggesting that a breeding population still exists, but further long-term monitoring is required to establish population trends. Only one population of the Southern Brown Bandicoot has ever been studied over any length of time in New South Wales, within Yambulla State Forest in the south-east corner of the State. At the time of study this population comprised less than a dozen individuals, which were mainly adult male animals (Claridge *et al.* 1991). The current status of this albeit small population is unclear since recent live-trapping surveys conducted in the same area failed to record the species (Mills 1999). In addition, the same worker failed to trap the species at several other sites in south-eastern New South Wales where the species had been

variously recorded in recent historic times. Despite this failure, live-trapping studies conducted by SFNSW in the past two years have resulted in several new records of the species, from East Boyd, Timbillica and Yambulla State Forests.

Elsewhere in the State there are relatively few recent records of the species. Those that have been made are generally of single or few animals, recorded at one location at one point in time (DEC Wildlife Atlas, unpublished data). These records are patchily distributed and mainly occur along the eastern seaboard (see Ashby *et al.* 1990).

Given the above, the Southern Brown Bandicoot can be considered as rare throughout the State. No population strongholds for the species can currently be nominated. It is clear that future survey to identify remaining extant populations, protection of these populations and careful management of existing suitable habitat will be necessary to reverse the situation.

3.4 Land Tenure

The Southern Brown Bandicoot has so far been recorded from within six National Parks, one Nature Reserve, eight State Forests and two private pieces of land (for details see sub-section 3.2 above).

3.5 Habitat

The Southern Brown Bandicoot occurs in a variety of habitats in south-eastern Australia, including heathland, shrubland, dry sclerophyll forest with heathy understorey, sedgeland and woodland (Hocking 1990; Kemper 1990; Menkhorst and Seebeck 1990; Rounsevell *et al.* 1991). In Tasmania the species has also been recorded in temperate rainforest (Green 1979).



Plate 1: Damp Sclerophyll habitat (Claridge, 2001)

Many of the habitats occupied by the species are prone to fire (Braithwaite 1983;

Lobert 1990) and some authors have suggested that the species prefers to occupy early seral stages following disturbance (ie. Menkhorst and Seebeck 1990). In heathland at Cranbourne, Victoria, a series of researchers (Braithwaite and Gullan 1978; Stoddart and Braithwaite 1979; Opie 1980) found that animals favoured regenerating habitat of between 4-8 years of age following bulldozing activity, relative to other available habitats of between 10-12 and >25 years of age. This was particularly the case for large, lactating female animals with the greatest energetic requirements. The difference in preference was thought to reflect changes in habitat complexity, with many bandicoots occupying younger structurally simple heathland rather than older structurally complex heathland (Braithwaite and Gullan 1978). In a study undertaken at the same site some 15 years later, Lobert (1985) found no such pattern, with animals predominantly occupying older (14-18 years) rather than younger (3-4 years) heath. Furthermore, this preference was consistent across the population regardless of sex or age class.

Despite these conflicting findings, Menkhorst and Seebeck (1990) considered that the Southern Brown Bandicoot displayed a true preference for newly regenerating heathland habitat, making the species amenable to active ecological management. They suggested the use of controlled fires to produce a mosaic of areas of different ages, such that favoured seral habitat was constantly being created. This variable mosaic not only would enable mature animals to utilise high quality habitat as it becomes available, but also allow newly emerged pouch young the chance to successfully disperse into new habitat, leading to population stability (Stoddart and Braithwaite 1979).

The characteristics of early seral habitats that might favour the species are poorly understood. They may be related to the high productivity of this type of habitat (Stoddart and Braithwaite 1979). During early plant succession, plant diversity and nutrient availability can be relatively high and the vegetation is capable of sustaining an abundant and diverse invertebrate fauna (Braithwaite 1983; Lee and Cockburn 1985). Recently burned sites have also been found to support large populations of beetle larvae, a preferred food item for the species (Opie 1980).

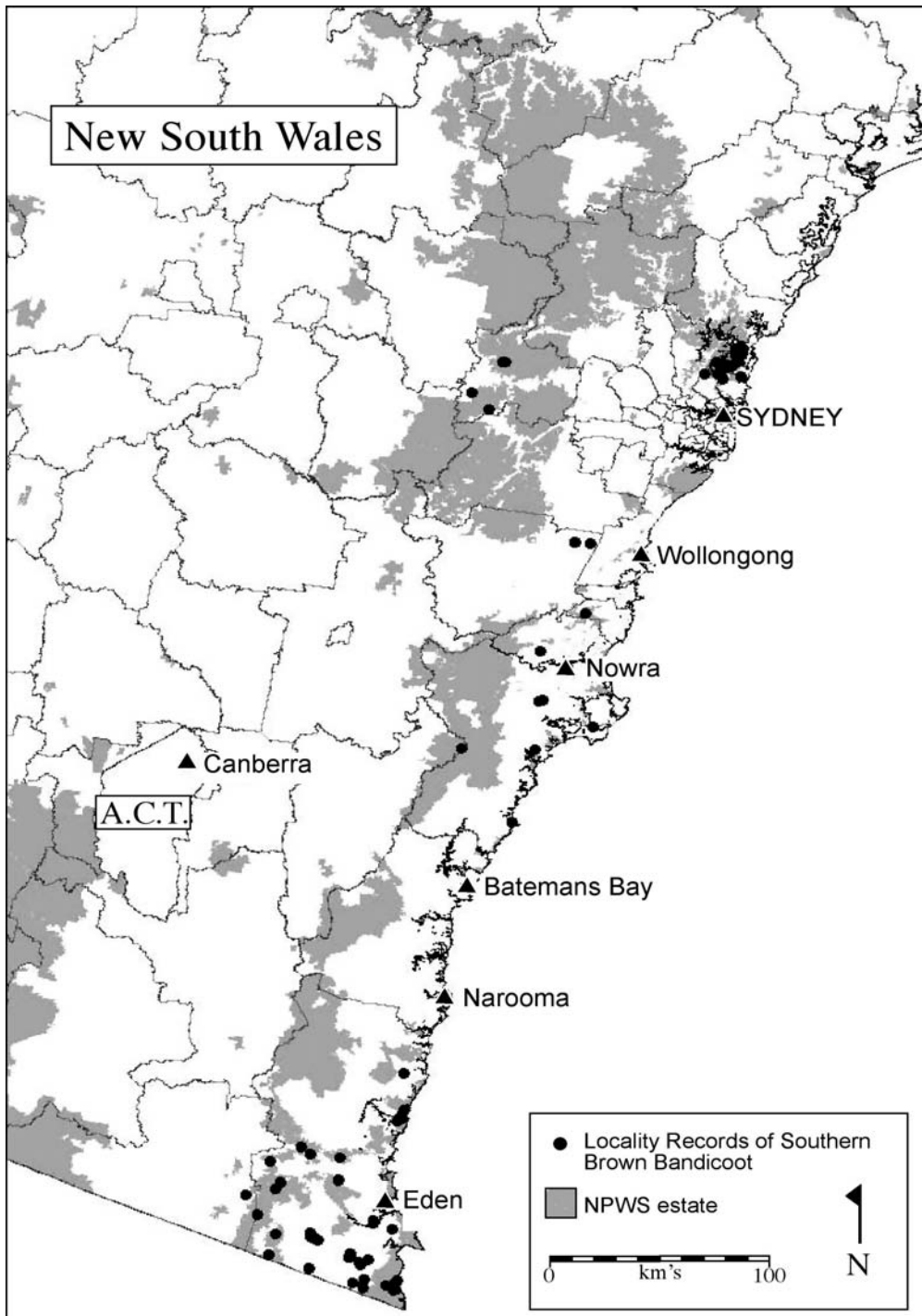


Figure 2: Map of the southern New South Wales illustrating sites at which the Southern Brown Bandicoot has been recorded.

In Tasmania it seems that habitat structure is more important in influencing habitat use by the species than habitat type or seral stage (Heinsohn 1966). Moloney (1982) believed that the close proximity of dense vegetative cover was essential before animals moved into open areas. Quin (1985) observed the species in a variety of habitats but all were generally in the vicinity of dense vegetation. These observations are particularly interesting given the relative absence of foxes in Tasmania. Clearly, more research is needed on the habitat preferences of the Southern Brown

Bandicoot in relation to fire and time since disturbance (Claridge *et al.* 1991).

Bandicoots usually nest in a shallow depression in the ground covered by leaf litter, grass or other plant material (Rayment 1954; Ride 1970; Gordon 1974). The upper surface of this covering may be mixed with earth to waterproof the inside of the nest (Stodart 1983; Gordon 1983). Internally, the nest comprises a hollow chamber, often lined with grass and leaves with no distinct entrance or exit.



Plate 2: Sydney Sandstone Ridgetop Woodland
Cottage Point (Visser, 2004)

There have been few studies of the nesting habits of wild animals. In the most extensive study to date, Lobert (1990) found that heathland-dwelling animals utilised a small number of shelter sites, all under dense vegetation. Nests usually comprised oval-shaped mounds of leaf litter and soil. At each end were openings which led into a central chamber lined with twigs and leaves. In south-eastern New South Wales, McNee *et al.* (1989) found that a single radio-tracked animal consistently sheltered in a dense thicket of *Acacia floribunda*, surrounded by open vegetation. Unlike other ecological studies of bandicoots, McNee *et al.* (1989) found that the animal did not form nests, instead resting under dense clumps of vegetation or, in one case, within a hollow log.

Finally, in the south-east of South Australia, Paull (1993) found that the majority of nests of the Southern Brown Bandicoot were located under mature *Xanthorrhoea australis*. The structure of these nests was similar to that reported by other studies. In the absence of *Xanthorrhoea*, other structures such as blackberry (*Rubus* spp.) thickets and rabbit burrows offered alternative shelter (Paull 1993).



Plate 3: *Xanthorrhoea* nest habitat (Claridge, 2001)

3.6 Life History and Ecology

The Southern Brown Bandicoot is thought to have a gestation period of less than 15 days, a remarkably short time (Lobert and Lee 1990). Neonates have a pouch life of approximately two months (Stoddart and Braithwaite 1979), and it is during the latter stages of pouch life that juvenile mortality is greatest (see Copley *et al.* 1990). If the pouch young survives the weaning period, the new emergent gains independence almost immediately (Stoddart 1966; Gordon 1974). Lobert and Lee (1990) determined that the weight of young at this time is between 105-140g. Female bandicoots are capable of resuming oestrus and becoming pregnant before the completion of suckling of the previous litter (Lyne 1964; Close 1977). This allows one litter to immediately follow another in the pouch, affording a potentially high reproductive capacity.

Although adult females are capable of producing up to 6 young per litter (Braithwaite 1983), the mean litter size is typically between 2-4 young (Heinsohn 1966; Stoddart and Braithwaite 1979; Copley *et al.* 1990; Lobert and Lee 1990). Because the pouch has 8 teats the unused teats allow one litter to immediately succeed another without waiting for used and enlarged teats to revert to normal size (Stoddart 1977; Hall 1983). Thus, bandicoots have the potential to produce multiple litters during the year. The number of such litters depends primarily on the duration of the breeding season. In Tasmania, *I. obesulus affinis* breeds for approximately eight months of the year with females capable of producing up to four litters per annum (Heinsohn 1966). The breeding season corresponds well to the time of maximum food abundance, usually following heavy rainfall. In Victoria the breeding season of *I. obesulus obesulus* is two to three months shorter than in Tasmania. While the breeding season in New South Wales (Northern Sydney), is between the two States (Wilson, 2004). The onset of breeding has been found to be highly predictable (Stoddart and Braithwaite 1979; Lobert and Lee 1990) with females entering oestrus synchronously. This synchronicity has been linked to predictable environmental factors such as photoperiod, rather than ephemeral factors such as rainfall and prey abundance (Stoddart and Braithwaite 1979). Similar findings have also been made for the closely related Northern Brown Bandicoot (Barnes and Gemmell 1984). Lobert and Lee (1990) found that breeding season of *I. obesulus*

obesulus was correlated with the annual peak in prey (soil invertebrate) abundance. In contrast to populations in Victoria and Tasmania, populations of *I. obesulus nauticus* on the Franklin Islands, South Australia, reproduce throughout the year with females capable of producing five litters per annum (Copley *et al.* 1990). Onset of reproductive activity usually coincides with higher rainfall and concomitant increases in food supply. *Isoodon obesulus fusciventer* is also thought to reproduce throughout the year in Western Australia (Thomas 1987). The near absence of long-term population studies of the Southern Brown Bandicoot makes it difficult to estimate survivorship of individuals over time. On the Franklin Islands, Copley *et al.* (1990) found that survivorship of individuals post-birth was extremely low: approximately 20% of pouch young died before weaning, about 50% appeared to be lost as newly-independent juveniles and few of the remaining 30% were later recorded as sexually mature animals. On the mainland, recruitment rates of locally-born young into populations of *I. obesulus* also appears to be low. Stoddart and Braithwaite (1979) found that between 12-18% of young remained on their heathland study site. Thus, about 80% of new animals entering the trappable population came from elsewhere. On the same site, only several years later, Lobert (1985) found slightly higher local recruitment rates (36%). Heinsohn (1966) observed that newly independent animals rapidly established themselves in home ranges removed from their place of birth. This pattern of juvenile dispersal is critical to the species being able to exploit spatially and temporally ephemeral habitats, such as those subject to episodic fire (Cockburn 1990). If local extinction of bandicoot populations is inevitable as habitat matures (Lee and Cockburn 1985), the survival of the species is enhanced by the dispersal of offspring into adjacent, better quality habitat. High dispersal rates have associated low survival rates, so the reproductive season is necessarily prolonged in order to maximize the likelihood of population survival (Cockburn 1981; Lee and Cockburn 1985). Male bandicoots are highly pugnacious and mainly solitary from a young age (Moloney 1982; Thomas 1990). Aggressive behaviour is normally expressed as visible threats, chases, or avoidance of one sort or another (Moloney 1982). Scarring is also typical (Claridge 1988). Individuals apparently nest alone supporting suggestions of social intolerance (Stoddart and Braithwaite 1979).

Extensive home range overlap and a lack of aggression between individual males has been observed but this was attributed to high population densities (Watts 1974). In contrast to male-male interactions, female-female and male-female interactions are rarely antagonistic. Interactions between male and female animals appears to be restricted to that necessary for successful reproduction (Moloney 1982). In Tasmania, *I. obesulus affinis* reaches reproductive maturity at a minimum of four and six months of age for females and males, respectively (Heinsohn 1966). This compares to a minimum of seven months in some Victorian populations (Lobert 1985; Lobert and Lee 1990). Tasmanian animals grow faster and weigh more as adults (Heinsohn 1966; Moloney 1982) than Victorian animals (Lobert and Lee 1990). In south-eastern New South Wales, it seems that forest-dwelling animals grow larger than Victorian heathland animals, although data is limited (Claridge 1988). The average longevity of individuals in the wild is unknown. Using mark-recapture data, Heinsohn (1966) estimated that most bandicoots live for at least two years provided they first reach sexual maturity. Individuals up to 3.5 years of age have been reported from field-based studies (Lobert and Lee 1990). Home range studies of the Southern Brown Bandicoot are limited and comparisons can be tenuous due to methodological biases (see Lobert 1990). Ecological factors such as site productivity and habitat structure may also influence home range size (Moloney 1982). Despite these limitations, the majority of home range studies of the species have reported similar estimates, ranging from 0.5 to 9.0 ha (Heinsohn 1966; McKenzie 1967; Moloney 1982; Copley *et al.* 1990; Lobert 1990; Paull 1993, Ecotone 2003, Wilson 2004). There is some evidence of differences in home range size according to gender and habitat use but the results are inconclusive (eg. Heinsohn 1966; Lobert 1990, Ecotone 2003, Wilson 2004). The internal dynamics of home range of animals are not fully understood, although Gordon (1974) identified two functional units for the closely related Northern Brown Bandicoot: areas of high food abundance, and nest sites. The local distribution of Southern Brown Bandicoots is thought to vary mainly with the distribution of food, with concentrations of individuals coinciding with abundant food supply. It is unclear whether animals establish territories. The results of Copley *et al.* (1990) and Lobert (1990), which

demonstrate overlap in home ranges of animals, are at odds with the findings of Heinsohn (1966) and McKenzie (1967), who found that home ranges of animals were non-overlapping. Moloney (1982) postulated that if the Southern Brown Bandicoot exhibits territoriality at all, it is in the form of passive avoidance. The pugnacious behaviour of the species (Jones 1924; McKenzie 1976; Moloney 1982; Claridge 1988), and the overlap of home ranges observed in the studies of Copley *et al.* (1990) and Lobert (1990), are consistent with this mode of spacing (Lobert 1985).

Most studies of the activity cycle of the species have revealed a nocturnal habit. Heinsohn (1966) observed that wild animals usually emerged from their nest after sunset and suspected that animals returned to their nest at or before sunrise. These observations were corroborated by McNee *et al.* (1989), who radio-tracked a single animal in dry sclerophyll forest in south-eastern New South Wales. Moloney (1982) noted that semi-captive animals were strictly nocturnal. In contrast, Lobert (1990) found that heathland-dwelling animals were primarily diurnal during the autumn and winter. It was hypothesised that this behaviour was due to the almost impenetrable vegetation where the bandicoots occurred, which afforded protection from mammalian and avian predators (Lobert 1990). Equally, it may also have been energetically advantageous for animals to be diurnal during autumn and winter when night time temperatures were low (Lobert 1990).

The Southern Brown Bandicoot is omnivorous, opportunistically exploiting a wide variety of food resources such as invertebrates, plant material and fungi (Stoddart and Braithwaite 1979; Lee and Cockburn 1985; Lamont *et al.* 1985). Bandicoots obtain food by either searching and probing the litter and ground vegetation, or by digging in the soil (Stodart 1966; Gordon 1974). Food in the soil is located by olfactory means (Moloney 1982).



Plate 4: Truffle-like fungal food, *Zelleromyces daucinus* (Claridge, 2001)

The foraging activity of the Southern Brown Bandicoot is indicated by the presence of characteristic scratch marks in the soil, often conical in shape and several centimetres deep. These forage-diggings cannot be distinguished from those made by other bandicoot species such as the Long-nosed Bandicoot. The holes are dug with the forefeet, and are usually large enough to accommodate the animal's snout when it is searching for food (Stodart 1983). A single animal may dig multiple holes in a small area if food is locally concentrated resulting in the soil-litter cover being severely pock-marked.

The subterranean food extracted by the species varies seasonally. In Tasmania, Heinsohn (1966) found that animals fed primarily on earthworms in the winter and lepidopteran larvae and pupae during the summer. Opie (1980) and Lobert (1985) reported that *I. obesulus obesulus* in Southern Victoria mainly fed on a range of invertebrates during summer and autumn while during winter and spring the fruit-bodies of hypogeous (underground-fruiting) fungi were favoured. In other studies, invertebrates formed the most significant component of the diet year-round, with some plant material also consumed (Watts 1974; Moloney 1982; Quin 1985).

In south-eastern New South Wales, Claridge *et al.* (1991) found that sympatric populations of Southern Brown and Long-nosed Bandicoots had very similar diets, feeding mainly on ants, beetle larvae and plant material. Seeds and the fruit-bodies of hypogeous fungi were also consumed on a seasonal basis. There was some partitioning of the fungal species eaten.

The availability of free water does not influence habitat use by the species since animals may occur large distances from suitable sources (Moloney 1982). Instead, bandicoots obtain sufficient water from dew and dietary items such as fungal fruit-bodies (Lobert 1985). Water in food may completely account for the total daily water needs of the species (Nagy *et al.* 1991).

3.7 Ability of Species to Recover

The potential for the Southern Brown Bandicoot to recover from low population levels is, in theory, high. The remarkable fecundity exhibited by the species suggests that it may be capable of rapid increases in numbers, given appropriate conditions. At a broad habitat scale these conditions appear to be absence of introduced predators, an

adequate supply of subterranean food resources, dense understorey vegetation and sufficient area of contiguous habitat to contain a mosaic of seral stages.

An important consideration in the ability of the species to recover is the degree of fragmentation of existing populations. Aspects of the species reproductive biology and life history suggest that genetic bottlenecks are not as serious as for other, less fecund species. However, there is currently no information regarding the relationship between fragmentation and genetic variation and viability of populations of the species.

4 Management Issues

Key factors thought responsible for the decline of the Southern Brown Bandicoot across parts of its historical range include predation by introduced carnivores, habitat loss and, perhaps, inappropriate fire regimes (Braithwaite 1983). Each of these factors is described in more detail immediately below.

Community perceptions of bandicoots also influence the management of this species. Two common misconceptions relating to bandicoots are: (i) they are identified as pests and (ii) they cause the spread of ticks. These misconceptions are also discussed.

4.1 Introduced Predators

Natural predators of the Southern Brown Bandicoot include quolls, snakes and a variety of diurnal and nocturnal raptors (Heinsohn 1966; Lobert 1985). The species is also preyed upon by Red Foxes and Wild Dogs, and presumably by cats (Claridge *et al.* 1991; Paull 1999). Domestic pests, particularly dogs, also prey upon this species (Ecotone, 2003).

The relative absence of the Red Fox in Tasmania is thought to be a factor contributing to the widespread distribution and abundance of the species (Hocking 1990), while in South Australia the presence of this introduced predator coincided with the disappearance of bandicoots from several areas (Preiss 1966; Hornsby 1984). There is also some evidence to suggest that foxes affect the sex ratio of Southern Brown Bandicoot populations, with female animals being more susceptible to predation than male animals (Dickman 1988).

As stated previously, predation by the Red Fox is listed as a threatening process for the Southern Brown Bandicoot under the TSC Act. So too is predation by the Feral Cat,

although there are few data indicating animals having actually been preyed upon.

4.2 Habitat Loss and Modification

The clearance of native habitat for agricultural and pastoral use has been implicated in the local extinction of populations of the Southern Brown Bandicoot across several States, including Victoria (Seebeck 1977; Menkhorst and Seebeck 1990), Tasmania (Moloney 1982) and South Australia (Aitken 1983). Also, in southern New South Wales, clearing of the Bega Valley in the early part of this century led to massive decline in the number of bandicoots, although there is some question mark over whether these were Southern Brown or Long-nosed Bandicoots (Lunney and Leary 1988).

4.3 Inappropriate Fire Regime

The effects of wildfire on the Southern Brown Bandicoot are poorly known, although anecdotal information suggests that the species may respond positively to such disturbance in some instances. In Tasmania, populations of the species recovered well after wildfire (Hemsley 1967). Similarly, at Nadgee Nature Reserve in southern New South Wales, bandicoots (*I. obseulus* and/or *P. nasuta*) were seen to increase in numbers four to five years after a severe wildfire and then decrease (Catling and Newsome 1981). In the same general area, following a repeat fire of similar intensity, bandicoots did not reach peak abundance until 14-15 years post-disturbance (Peter Catling, CSIRO Wildlife and Ecology, pers. comm.). To some extent, the rapidity with which bandicoots recover post-fire may depend on how quickly ground vegetation re-establishes. In some cases ground cover does not develop quickly enough, leading to the demise of populations. For example in the Mount Lofty Ranges in South Australia, wildfire caused a long-term reduction in the area of dense ground cover and localised extinctions of the Southern Brown Bandicoot occurred (Anon. 1989; Thompson *et al.* 1989).

Braithwaite (1983) has hypothesised that the decrease in frequency of fire following European occupation of south-eastern Australia has led to an overall decline in the distribution and abundance of the species. This hypothesis is at odds with the recent listing of frequent fire as a threatening process for the Southern Brown Bandicoot under the TSC Act. The view put forward by Braithwaite stems largely from observations

made by Stoddart and Braithwaite (1979) at a single Victorian site, where animals were found to preferentially occupy young regenerating heathland. Research on the distribution and habitat preferences of the Southern Brown Bandicoot in South Australia, conducted by Paull (1993; 1995), supports the observations of Stoddart and Braithwaite (1979), in so far as animals were more likely to be found in areas with recent (5-7 year) evidence of fire. However, this seral stage of habitat was by far the most commonly represented across study sites, and bandicoots were also present in very recently burnt (1-2 year) and long unburnt (> 20 year) habitats. Although it appears that the species may be favoured by the careful and strategic use of prescribed fire, more information is required on the scale, intensity and timing of burning that might best suit animals.



Plate 5: Frequent Fire (Claridge, 2001)

4.4 Logging Regime

In south-eastern New South Wales, suitable habitat for the Southern Brown Bandicoot is subject to intensive (integrated) logging practices. There have been no long-term studies examining the effects of such practices on the species. Richards *et al.* (1990) considered that in the short-term the species was potentially at risk immediately following logging through loss of ground cover and increased predation. Significantly, Claridge *et al.* (1991) noted anomalies in a population of the species in Yambulla State Forest, in unlogged patches of forest adjacent to recently logged coupes. At the time of their study, the population mostly comprised old male animals and there was no indication of breeding activity among the only female sampled. This was in contrast to observations of a range of sex and age classes of animals from the same population made by the (then) Forestry Commission of New South Wales prior to logging. Later trapping at the same sites failed to record the presence of the species

(Mills 1999), although animals have recently been detected elsewhere in Yambulla State Forest by SFNSW.

Other observations indicate that the Southern Brown Bandicoot is capable of successfully recolonising previously logged forest, leading some authors to suggest lack of deleterious impact (Recher *et al.* 1980; Fanning and Mills 1989; Fanning and Rice 1989). In Tasmania, Green (1982) reported the species re-inhabiting five year old regrowth forest. Significantly though, introduced predators were largely absent.

4.5 Roothing

As previously mentioned, there are several road-kill records of the Southern Brown Bandicoot within Ku-ring-gai Chase National Park, immediately north of Sydney, and a smaller number from elsewhere in the southern part of the State. This indicates that where roading intersects suitable habitat, animals may be harmed by vehicular traffic when moving around their home ranges. The level of road-kill of the species elsewhere throughout the greater Northern Sydney Metropolitan Area is unknown since relevant mortality registers have not yet been kept. However, as indicated later in this plan, these will soon be implemented.



Plate 6: Roothing (Claridge, 2001)

4.6 Risks faced by small populations

Small populations are at typically at greater risk of extinction than larger ones because they are more susceptible to unpredictable events or changes to factors that influence population dynamics. In small populations,

this greater sensitivity to stochastic processes can cause, among other matters, changes (sometimes irreversible) to age structure and sex ratios of populations, which in turn can severely limit a population's ability to recover from a catastrophic event.

Habitat for the Southern Brown Bandicoot within Garigal National Park is small in area, highly fragmented, fire-prone and within close proximity to residential development. When these attributes are taken together, the remaining habitat is potentially threatened by repeated habitat modification in the form of hazard reduction burning and/or wildfire, or erosion through clearing. This population is also excluded from predator control as part of the Fox Threat Abatement Plan as discussed in section 5.4. In addition, animals within this population are showing signs of inbreeding depression (Johnston *et al* 2002). Therefore, the Garigal National Park population is considered at high risk of extinction.

The relative importance of factors potentially causing the decline of Southern Brown Bandicoots in NSW remain to be defined. Furthermore, without a clear understanding of the species distribution and population size, it is difficult to assess with any degree of rigour the viability of the species across the State. Given this scenario, it is considered necessary to investigate the feasibility of establishing a captive breeding program as potential insurance against the risk of catastrophic events leading to irreversible decline of the species.

4.7 Community perceptions of bandicoots

Bandicoots, including the more common Long-nosed Bandicoot (*Parameles nasuta*) and the endangered Southern Brown Bandicoot (*Isodon obesulus*), are commonly mistaken for pest species and are often described as a "rat like" animal. In a recent community survey of residents in North Turramurra and visitors to Ku-ring-gai Chase National Park, 18% of resident respondents and 6% of park visitor respondents identified the bandicoot as a pest species (Vella, 2005).

The bandicoot's foraging behaviour is also unpopular with certain members of the community as they make conical diggings in lawns and gardens in search of food such as invertebrates, fungi fruiting bodies and other plant material. Another common community complaint links bandicoots with the presence

and spread of ticks within bushland and suburban backyards.

The local media, Council and DEC officers often deal with the issue of ticks and their management, particularly in northern Sydney (M. Hall, pers. comm.). Ticks, particularly the more common paralysis tick (*Ixodes holocyclus*), often cause health problems to both humans and animals, including pets when they attach themselves on hosts for a blood meal. There has been some suggestion that the paralysis tick is host to Lyme disease, however the presence of this disease in Australia has not been confirmed (Doggett *et al* 1997).

These misconceptions and negative images of this species hinders the conservation and management of the species and its habitat. One objective for the education and community awareness campaign for this species is to address and dispel the misconceptions about this species to ensure that the recovery program is successful.

5 Previous Recovery Actions

5.1 Survey

Few targeted surveys have been conducted for the Southern Brown Bandicoot in New South Wales. In the first such study, undertaken during the mid-1970's, Dixon (1978) attempted to live-capture the species in several National Parks and Nature Reserves on the eastern seaboard south of Sydney to the Victorian border. Despite considerable trapping effort no captures of the species were made, although the Long-nosed Bandicoot was recorded in several locations.

McNee *et al.* (1989) surveyed for the species using cage trapping across a broad area within Yambulla State Forest south-west of Eden. Although animals were detected at the same sites used by Claridge *et al.* (1991) as part of an ecological investigation of the species, individuals were not captured elsewhere. Atkins (1998) surveyed for bandicoots in 16 forest remnants of varying size (3-18000 ha) in the Greater Sydney Metropolitan Area using a combination of hair-tubing and cage trapping. The Southern Brown Bandicoot was recorded in hair-tubes located in three of eight large remnants (Garigal East and West National Parks and Ku-ring-gai Chase National Park), but in none of the smaller (< 40 ha) remnants. In contrast, the Long-nosed Bandicoot was recorded in eight of the 16 remnants, including the smallest one. These results were paralleled by less

intensive cage trapping work undertaken at the same study sites.

Mills (1999) recently revisited known historical localities for the species in the south-east corner of the State. Despite cage trapping at these sites the species was not detected, although the Long-nosed Bandicoot and Long-nosed Potoroo were captured in a few localities, most notably within Nadgee Nature Reserve. No evidence of the Southern Brown Bandicoot was found in Yambulla State Forest where a small population had been the subject of ecological research a decade earlier (Claridge *et al.* 1991).

Under broad-area licensing conditions for timber harvesting in State Forests of the South-East and South Coast Regions, SFNSW are required to carry out hair-tubing surveys for the Southern Brown Bandicoot within a 2 km radius of existing records of the species and/or where apparently suitable habitat occurs. While these conditions have been operating for several years, only a few additional records of the species have been obtained from these surveys, all from the far south-eastern corner of the State. In addition to undertaking hair-tubing surveys, SFNSW have more recently used wire cage traps, with greater success, to record the Southern Brown Bandicoot at a number of new localities south and south-west of the township of Eden (SFNSW unpublished data).

There have been a number of general surveys for ground-dwelling mammals in south-eastern New South Wales, some of which have covered part of the potential range of the species. Three sampling techniques have been variously used in this work: live-trapping, hair analysis from predator scats and hair analysis from hair-sampling tubes. Summaries are provided below for some of the more relevant studies. In the early 1980's, CSIRO Division of Wildlife and Ecology (CSIRO DWE) undertook a survey of vertebrate fauna across Yambulla State Forest, south-west of Eden. Some cage trapping was conducted as part of this work, resulting in the capture of a single animal (Braithwaite *et al.* 1984). Lunney and Barker (1986, 1987) further demonstrated in the intensive five forests study to the north of Eden, near Bega, that the species was virtually absent from forested habitat in the local area. Despite using a variety of survey techniques, including trapping, collection of road kills and scat analysis, the Southern Brown Bandicoot was only recorded once from

hairs in a Spotted-tailed Quoll (*Dasyurus maculatus*) scat.

In 1986, DEC undertook a survey of ground-dwelling mammals in foothill and montane forests in the Eden Region using predator-scat analysis. Although the Long-nosed Bandicoot was frequently recorded in dog and fox scats, no positive evidence for the Southern Brown Bandicoot was found, although two scats contained material from bandicoot which could not be assigned to species status (NSW National Parks and Wildlife Service 1986).

During a flora and fauna survey of the Rockton section of Bondi State Forest, Fanning and Mills (1989) and Fanning and Rice (1989) recorded the widespread presence of characteristic bandicoot diggings, but were unable to distinguish whether they were made by Long-nosed or Southern Brown Bandicoots. Of interest, neither species was positively recorded from predator scats or hair samples from hair tubes collected during their survey. In the same general area, however, the (then) Forestry Commission of New South Wales recorded the presence of the latter species in a section of Yambulla State Forest using live-trapping techniques. Over several trapping sessions, a small population was recorded as occupying a dry sclerophyll eucalypt community with a mainly heathy understorey. McNee *et al.* (1989) and Claridge *et al.* (1991) later studied this population in order to get ecological information on the species, but they had difficulty trapping animals.

During the early 1990's intensive hair-tubing surveys were conducted for the Long-footed Potoroo (*Potorous longipes*) across a range of State Forests and National Parks in the South East Forests Region of New South Wales (Saxon and Noble 1993). While the survey was successful at recording a large range of ground-dwelling fauna, including that potoroo at several localities, the Southern Brown Bandicoot was only recorded at a single hair-tube site. It should be noted that in this survey sampling effort focussed on wetter forest types and gullies where the latter species was less likely to occur.

Also in the early-1990's CSIRO DWE surveyed for ground-dwelling fauna in a variety of vegetation types in the Batemans Bay area. They found that bandicoots were rare, as adjudged by the very low frequency of tracks left behind in soil plots by these animals (P. Catling, pers. comm. 1992). The soil track technique is limited, because it is unable to discriminate whether tracks are made by Long-nosed or Southern Brown

Bandicoots. Other records of bandicoots from tracks left in soil plots were made by the Division during its long-term investigation of the recovery of ground-dwelling mammals after wildfire in Nadgee Nature Reserve in the far south-east corner of the State (see Catling and Newsome 1981). Within the reserve, bandicoots are considered to be well distributed and reasonably common. Recent live-trapping and predator scat analysis work conducted there indicates the presence of Long-nosed but not Southern Brown Bandicoots (Mills 1999).

Chapman (1995) undertook surveys for critical-weight-range ground-dwelling mammals in Ben Boyd National Park, just north of Eden. Cage traps and Elliot traps were utilised. Although the survey effort was relatively low (200 cage-trap-nights and 516 Elliot-trap-nights), there were no captures of Southern Brown Bandicoots. Abundant diggings were recorded, but these were attributed to Long-nosed Bandicoots and Long-nosed Potoroos which were caught in cage traps.

Recently, as part of the Commonwealth-State Regional Forest Agreement (RFA) process, hair-tube, live-trapping and incidental predator scat surveys were conducted at several hundred sites distributed across southern New South Wales, from the coast to the tablelands. At least some of these sites covered habitat types potentially suitable for the species. Despite this major effort no live Southern Brown Bandicoots were recorded. The species was detected at a single location from grooming hairs found in bandicoot scats collected in Ben Boyd National Park in the far south-east of the State (DEC Wildlife Atlas, unpublished data).

Finally, in a study of the effects of fire on small mammal population dynamics in Ku-ring-gai Chase National Park, Sutherland (1998) incidentally captured several juvenile Southern Brown Bandicoots in Elliot traps. A single adult animal was also live-captured in a wire cage trap in the same general area.

5.2 Research and Monitoring

Little ecological research has been conducted on the Southern Brown Bandicoot in New South Wales. That which has been undertaken was on a single population occurring within Yambulla State Forest, south-west of Eden. This population was first located in the late 1980's by the (then) Forestry Commission of New South Wales, who were examining the impact of logging and burning practices on various fauna and flora. Claridge *et al.* (1991)

studied the general ecology of animals within this population immediately after disturbance treatments were applied, comparing habitat utilisation patterns and diet with that of sympatric Long-nosed Bandicoots. At that site, the Southern Brown Bandicoot was found to occur more frequently on slopes and ridges, while the Long-nosed Bandicoot was found more commonly in gullies. Both species differed slightly in the range of dietary items consumed, particularly the types of hypogeous fungi eaten.

McNee *et al.* (1989) radio-tracked a single animal from the same population as that studied above, recording activity and nesting patterns. The animal was found to be strictly nocturnal and occupied several nest sites, including under thickets of vegetative ground cover and within a hollow log.

Recent research on the species has been undertaken in south-east South Australia (Paull 1993, 1995, 1999) and south-western Victoria (Rees 1997). These investigations have mainly focussed on locating extant populations of the species and identifying what environmental factors are responsible for the presence, absence and abundance of animals. Results from this set of studies, which are continuing at the time of writing of this plan (D. Paull, School of Geography, Australian Defence Force Academy, Canberra, pers. comm.), may help provide direction for conservation management of the species in New South Wales.

Until recently there were no formal programs established to monitor long-term trends in population numbers of the Southern Brown Bandicoot in New South Wales. This situation has now changed with intended long-term trapping programs being established during early 2000 in Ku-ring-gai Chase and Garigal National Parks in the Northern Sydney Metropolitan Area, and in Ben Boyd National Park and East Boyd State Forest in the far south-east of the State. In both areas, population numbers of the species are being closely monitored in relation to intensive fox and dog control (1080 poison-baiting) work (see sub-section 5.4 below).

5.3 Management of Habitat

National Parks and Nature Reserves contain both occupied and potentially suitable habitat for the Southern Brown Bandicoot. The principal means by which DEC conserve fauna within these lands is through reservation of habitat, as opposed to formal prescriptions for the management of wildlife (Ashby *et al.* 1990). Conservation of

bandicoots has never been the primary aim for management in any reserve in the State. Fire Management Plans, either formal or in draft stage, have been written for the majority of National Parks and Nature Reserves which contain suitable habitat for the Southern Brown Bandicoot in New South Wales. These plans generally call for the strategic use of prescribed (controlled) burning to reduce the potential for severe wildfire, with the intention of protecting neighbourhood life and property and helping to conserve biodiversity values. In limited cases fire is used to manipulate habitat to create patches of varying regeneration age (ie. Ben Boyd and Ku-ring-gai Chase National Parks and Muogamara Nature Reserve): these are thought to promote the diversity of plant species and vegetation structures over the broader area, and potentially might benefit the Southern Brown Bandicoot. At this stage none are applied with the habitat requirements of the species in mind.

State Forest land managed by SFNSW also contains sites where the species has been recorded as well as potentially suitable habitat. These forests are managed for multiple uses including timber harvesting, recreational use and wildlife conservation. The arrangement of management units or coupes within these forests is such that logged areas are bordered by areas of unlogged habitat. This unlogged habitat is designed to act as a refuge for fauna while the logged area regenerates. In time the regenerating forest may also serve as suitable habitat for many species. SFNSW also utilise other means to enhance the persistence of wildlife populations within multiple-use forests. Current harvesting systems retain an extensive network of corridors and streamside filter strips which link to unlogged coupes and larger protected areas such as National Parks and Nature Reserves. Other areas deemed as having significant values, such as rare or endangered taxa, are variously set aside from logging or are subject to special prescriptions that minimise impact during and after harvesting.

Prescribed burning is carried out routinely across State Forests in south-east New South Wales. This is undertaken to: (i) reduce the risk of wildfire in unlogged and regrowth forest, (ii) aid harvesting, (iii) promote seedling regeneration in logged coupes, and (iv) protect life and property. It is not currently used as a management tool to create habitat for any species of fauna.

Many of the management strategies undertaken by SFNSW to help conserve

wildlife, including retention of habitat trees and streamside filter strips, are aimed at the conservation of arboreal mammals (Claridge *et al.* 1991). Recently, however, as part of broad area licence conditions for harvesting in the South-East Region, SFNSW were required to protect habitat for a 200 ha area around locality records for the Southern Brown Bandicoot (New South Wales Government 2000). This prescription originally applied until 15 such management zones were identified, a number at which was exceeded during 2001. Having reached that trigger point, SFNSW and DEC are currently reviewing the strategy. Similar prescriptions have been jointly agreed to in the adjacent South Coast Region, where so far no exclusion zones have been determined.

Historically, vehicular traffic has been responsible for mortality of the Southern Brown Bandicoot on several of the major public access roads within Ku-ring-gai Chase National Park. These road-kill specimens have occurred, variously, over a number of decades. In view of the potential for continued impact, DEC have recently erected high visibility bandicoot signs on the side of roads in key locations within the Park. The major purpose of these signs is to alert public travelling by vehicle about the presence of bandicoots, hopefully reducing road-kill mortality in the future. The signs are based on those currently used at North Head to promote awareness of the endangered population of Long-nosed Bandicoots.

5.4 Control of Introduced Predators

Control of introduced predators using the toxic compound sodium fluoroacetate (Compound 1080) is routinely undertaken throughout most of the State Forests and National Parks where the Southern Brown Bandicoot has been recorded. The primary purpose of this activity is to: (i) reduce numbers of wild dogs and foxes so as to benefit native fauna that fall prey to these introduced carnivores, and (ii) reduce kills of domestic stock on adjoining private property. While the duration, intensity and frequency of baiting varies across the landscape, there are general consistencies in what baits are used and the way in which baits are deployed. Firstly, 1080-laced baits tend to be either fresh meat or the manufactured animal-based product 'FOXOFF' (Animal Control Agencies Pty Ltd, Brooklyn, Victoria). Secondly, current programs use the 'mound-baiting technique', in which baits are buried at depth in mounds of soil or fine sand. This is done to reduce possibilities for

consumption of baits by non-target fauna such as the Spotted-tailed Quoll which are thought less likely to excavate soil when searching for food. To further decrease the risk of poisoning non-target fauna a period of 'free-feeding' is undertaken beforehand, during which non-poisoned baits are buried in the same mounds. This enables earlier identification of tracks left behind by visiting animals. Poison baits are then laid only when it can be demonstrated that dogs and/or foxes are responsible for removing baits. The consumption of one poisoned bait is usually considered lethal for these target fauna. Once this is achieved 'free-feeding' is resumed until further evidence of visitation is obtained. Other methods are also utilised to reduce introduced predator populations. These include live-trapping where problem animals do not eat baits, as well as the opportunistic shooting of animals. Although these various introduced predator control strategies are thought to benefit native fauna, empirical evidence to support the notion is largely absent. The frequency of 'bait takes' over time by the target predators is the usual performance indicator in most such programs, but very few regimes have included monitoring the response of the native fauna as the number of introduced predators decreases.

Until recently there were no introduced predator control programs specifically directed toward protecting populations of the Southern Brown Bandicoot anywhere in the State. This situation has recently changed in Ku-ring-gai Chase and Garigal National Parks, where remnant populations of the species are thought to be under threat from wild dogs and foxes. There, an intensive baiting program has been underway since early 2000 and plans are to continue this effort for the foreseeable future. This program is linked to other baiting programs on adjacent Council Lands, some of which contain potentially suitable habitat for the Southern Brown Bandicoot. That work being conducted on National Park Estate is being funded primarily through the Fox Threat Abatement Planning Process (hereafter Fox TAP).

Similar targeted efforts have also been undertaken in Ben Boyd National Park and East Boyd State Forest in the far south-east of the State. This program, a collaborative effort between DEC and SFNSW in an area with very recent live-trapping records of the Southern Brown Bandicoot, is part-funded through the Fox TAP. In the future, targeted poison baiting of foxes and dogs may occur elsewhere if new populations of the Southern Brown Bandicoot are found.

5.5 State Recovery Process

A recovery team for the Southern Brown Bandicoot was established in April 1999. Current members include staff from the DEC, SFNSW, Local Government, relevant conservation organisations and the broader scientific community. Collectively, the recovery team comprises a non-statutory group of interested parties with relevant expertise, established to discuss issues relating to the formulation and implementation of the plan. Components within the plan do not necessarily represent the views or the official position of all the individuals or agencies represented on the recovery team.

5.6 Public Education and Awareness

An interpretive display featuring aspects of the ecology and conservation management of the Southern Brown Bandicoot was developed in the first half of 2000, using funds from the DEC Threatened Species Budget. This display is exhibited at the Kalkari Visitors Centre, Ku-ring-gai Chase National Park, Sydney. An associated information pamphlet has also been prepared. This pamphlet has been disseminated to all landholders on the boundary of Ku-ring-gai Chase and Garigal National Parks. It includes a record sheet for members of the public to fill-in in the event of sighting an animal. It is hoped that this sheet will provide a means of documenting the distribution of the species outside of the conservation reserve system in the Northern Sydney Metropolitan Area.

Conservation of the species has also been promoted through education and training of staff in various land management agencies and local government. This training has focussed on identifying habitat, appropriate survey techniques and assessing likely impact of proposed activities or developments on the species.

There has been considerable media attention on the species in recent times, particularly on remnant populations in the Northern Sydney Metropolitan Area including the one occurring in the Ku-ring-gai Chase National Park. This has resulted in special features appearing on ABC National Television as well as in the print media, including an article in the *Sydney Morning Herald*. The primary focus of this media effort has been to highlight the conservation requirements of the species, together with current efforts by DEC to manage its habitat.

As previously mentioned in section 4.7, a community survey was recently conducted

in northern Sydney (Vella 2005). This survey investigated levels of community awareness of DEC management of the Southern Brown Bandicoot of visitors to Ku-ring-gai Chase National Park and residents on North Turramurra. The survey noted a certain portion of the community, particularly local residents, are poorly informed with regards to the management of bandicoots. The report also recommended that the current education and community awareness program could be diversified to reach different audiences to further dispel myths and misconceptions. Two issues of particular importance were the identification of bandicoots as a pest animal and a vector for the spread of ticks.

6 Proposed Recovery Objectives, Actions and Performance Criteria

The overall objective of this recovery plan is to improve the conservation status of the Southern Brown Bandicoot and maximise the opportunity for viability of this species in the wild in New South Wales. In order to achieve this a number of actions will need to be carried out. Each of these actions is described immediately below.

Specific Objective 1: To Continue State-Wide Recovery Team and Establish Regional Groups to Enable Efficient Implementation of Recovery Program.

Action 1.1: Continuation of State-Wide Recovery Team for the Southern Brown Bandicoot (Priority 1).

This plan advocates continuation of the existing State-wide Recovery Team for the Southern Brown Bandicoot to enable efficient implementation of the recovery program. However, the State-wide Recovery Team will be streamlined to only include representatives from DEC and SFNSW. Representatives from Local Government and public interest groups will already have input into the recovery process through representation on each of the two Regional Working Groups indicated below (Action 1.2). DEC will be responsible for administrative matters relating to the State-wide recovery effort, including the issue of contracts for components of the program, and obtaining relevant permits to enable work to proceed. Major costs for management of the recovery program will also be met by DEC.

Action 1.2: Establish Regional Working Groups for the Southern Brown Bandicoot in Key Areas of the State (Priority 1).

Based on current information, extant populations of the Southern Brown Bandicoot are distributed patchily along the east coast of New South Wales, south of the Hawkesbury River to the Victorian border. Two key areas for active management have been identified in this plan: (i) in the Northern Sydney Metropolitan Area, mainly within Ku-ring-gai Chase and Garigal National Parks, and also in adjacent Council Lands, and (ii) the far south-east corner of the State, encompassing Ben Boyd National Park, Nadgee Nature Reserve and adjacent State Forests.

Given the large geographic distance between these two areas it is prudent to establish separate Regional Working Groups to better co-ordinate recovery actions at a local level. This plan advocates the establishment of these two groups. The Northern Sydney Metropolitan Area Regional Working Group will ultimately comprise members from DEC, RTA, each of Baulkham Hills, Hornsby, Ku-ring-gai, Pittwater and Warringah Councils, and other interested parties. The South Coast Regional Working Group will ultimately comprise members from DEC, SFNSW, each of Bega Shire, Eurobodalla Shire and Shoalhaven Councils, as well as other interested parties. One delegate from each of these groups will report directly back to the State-wide Recovery Team to facilitate the broader process. DEC will be responsible for coordinating each of these two groups.

Performance Criterion 1

Actions identified in this recovery plan are effectively implemented by the responsible parties, as coordinated by the State-wide Recovery Team and Regional Working Groups.

Specific Objective 2: To Identify and Implement Land Management Practices That Assist in the Recovery of the Species.

Action 2.1: Undertake Intensive Control of Introduced Predators around Extant Populations of the Southern Brown Bandicoot (Priority 1).

The greatest threat to persistence of remaining populations of the Southern Brown Bandicoot may be predation by introduced carnivores such as foxes, wild

dogs and feral cats. Where populations of the species are identified, intensive control of introduced predators using Compound 1080 and the mound baiting technique will be conducted. The duration, frequency and concentration of baiting around bandicoot populations will be determined by the Recovery Team, in conjunction with appropriate specialist consultants if necessary.

At this point in time only two populations of the Southern Brown Bandicoot can be defined: one in Ku-ring-gai Chase and Garigal National Parks in the Northern Sydney Metropolitan Area, the other in the far south-east corner of the State, encompassing Ben Boyd National Park, Nadgee Nature Reserve and adjacent State Forests.

Intensive control of introduced predators is already underway across both of these areas, with programs being concurrently run by DEC, some of the Councils in the Northern Sydney Metropolitan Area listed above and SFNSW. Costs associated with these programs are covered by recurrent funding from each of the collaborating organisations with additional financial assistance through the Fox Threat Abatement planning process (hereafter referred to as Fox TAP). Costing for protection of other (as yet unknown) populations will need to be factored into the recovery process for the species if and when the situation arises.

In addition to these more targeted measures, this plan advocates continuation of existing broadscale introduced predator control programs undertaken by DEC and SFNSW, among others. While recognising that these programs may not be specifically directed toward protecting the Southern Brown Bandicoot, they nonetheless have potential flow-on benefits for the species.

Action 2.2: Monitor the Response of Southern Brown Bandicoot Populations to Intensive Control of Introduced Predators (Priority 1).

The response of the Southern Brown Bandicoot to intensive control of introduced predators will be monitored in both of the areas identified in Action 2.1 above. This will be to establish whether the predator control being applied is benefiting local bandicoot populations. For Ku-ring-gai Chase and Garigal National Parks, live-trapping grids have been established and will continue to be monitored for the lifetime of this recovery plan. DEC will be responsible for maintaining these monitoring activities. For the far south-east corner of

the State, encompassing Ben Boyd National Park, Nadgee Nature Reserve and adjacent State Forests, a combination of techniques will continue to be used to monitor the bandicoot population, as well as that of the introduced predator population. This will continue to involve live-trapping of animals, as well as measuring the frequency of occurrence of tracks of these animals on sand plots situated across minor roads and trails across the baited area (as per Catling and Newsome 1981). For both areas, control sites in which no poison baiting is undertaken will be established. This will enable the effectiveness of the baiting programs to be quantitatively examined. Financial assistance for each monitoring program will be provided through the Fox TAP and existing (recurrent) resources.

Performance Criterion 2

Intensive control of introduced predators is undertaken for the lifetime of this recovery plan around all known populations of the Southern Brown Bandicoot and the efficacy of this measure is assessed through a long-term monitoring program.

Action 2.3: Establish Mortality Register for Roads within Ku-ring-gai Chase National Park to Assess Whether Signage is Reducing Level of Road-Kill of Southern Brown Bandicoot (Priority 1).

To assess the effectiveness of the signs established as part of Action 2.4 above, DEC will develop and maintain a road-kill mortality register for the Southern Brown Bandicoot in Ku-ring-gai Chase National Park. This register will be maintained for the lifetime of this recovery plan, in order to establish the usefulness or otherwise of this measure over the longer-term. If, after establishing these signs, road-kill mortality persists in some areas, DEC may consider other means of addressing the problem such as speed bumps or reduced speed zones.

Action 2.4: Establish Mortality Register for Public Roads in the Northern Sydney Metropolitan Area to Assess Current Level of Impact on Southern Brown Bandicoot outside of National Parks (Priority 1).

Several public roads bisect known and apparently suitable habitat of the Southern Brown Bandicoot in the Northern Sydney Metropolitan Area. This is particularly the case for Garigal National Park, which is divided by a series of major arterial roads. At this stage nothing is known about the level of impact, if any, of vehicular traffic on bandicoots attempting to disperse from one patch of habitat to another. DEC will negotiate with the RTA, as a matter of high

priority, to establish a road-kill mortality register for the Southern Brown Bandicoot in such areas. In the first instance this will provide information on the distribution and possible movement patterns of the species. Over time, it may pinpoint trouble spots where the level of road-kill on the species is unacceptably high and other ameliorative measures may need to be put in place. Other relevant organisations will also be contacted to provide additional information on the distribution of the species outside of conservation reserves. These will include Local Councils, through the Wildlife Watch Program, and WIRES.

Performance Criterion 3

The level of road-kill mortality of bandicoots in known trouble areas is reduced, while the level of road-kill in potential trouble areas is defined.

Performance Criterion 4

Additional information on the distribution of the species, outside the conservation reserve system in the Northern Sydney Metropolitan Area, is provided through liaison with relevant organisations.

Action 2.5: Ensure Fire Management Activities are Sympathetic to Conservation Requirements of the Southern Brown Bandicoot (Priority 1).

Fire, whether wild or deliberately applied, potentially plays a significant role in creation of suitable habitat for the Southern Brown Bandicoot. Inappropriate use of prescribed fire, in particular, may lead to habitat degradation for the species.

The DEC will liaise with and the NSW Rural Fire Service and State Forests NSW to develop appropriate fire management regimes around known Southern Brown Bandicoot populations. In all cases the overall objective of fire management in areas occupied by the species should be to maintain and/or enhance plant species diversity and provide an abundance of ground cover. Fire management regimes will be developed in accord with other legislative requirements, such as asset protection.

When new populations or sightings for this species are identified, the DEC will update the Atlas of NSW Wildlife with precise records (<=100m). The DEC will ensure these records are available to approval and certifying authorities (including Department of Lands, RFS and relevant Councils) and incorporated into relevant databases and management plans. The DEC will ensure that this information is presented to appropriate inter-agency committees such as the relevant Bush Fire Management Committee.

In addition approval and certifying authorities (including authorities that issue or certify bush fire hazard reduction certificates) will regularly (every 4-6 months) obtain Atlas of NSW Wildlife data for incorporation it into relevant databases and management plans.

Performance Criterion 5

Fire management activities in areas of known habitat for the Southern Brown Bandicoot are carried out in a way that is sympathetic within the conservation requirements of the species.

Precise locations for the Atlas of NSW Wildlife are made available to relevant authorities within four months of verification or discovery.

Updated Atlas of NSW Wildlife data is obtained every 4-6 months and used by approval and certifying authorities.

Action 2.6: Ensure Informed Environmental Assessment and Planning Decisions are Made (Priority 1).

Consent and determining authorities will assess developments and activities, and will prepare environmental planning instruments that avoid and minimise impacts on the species. In order to give this effect, consent and determining authorities will ensure that: (i) developments and activities are assessed with reference to this recovery plan, environmental assessment guidelines and any future advice from DEC regarding the distribution, threats, biology and ecology of the Southern Brown Bandicoot, (ii) development consent issued on land in the vicinity of known populations, is sensitive to the species, given knowledge of threats, and (iii) any relevant environmental policies, management plans and Environmental Planning Instruments are prepared or reviewed with reference to the recovery plan and any future advice from DEC regarding the distribution and ecology of the species. This action is to be carried out by Councils and the Department Planning in consultation with the DEC.

Performance Criterion 6

Conservation of the Southern Brown Bandicoot is facilitated through appropriate planning and management decisions.

Action 2.7: Improved control of companion animals, particularly dogs.

Southern Brown Bandicoot populations within close proximity to urban development are also vulnerable to predation or disturbance from domestic pets such as dogs and cats. Dogs have been reported attacking bandicoots (Ecotone 2003) and roaming off leash within identified habitat,

including within conservation reserves (Hall, 2005 pers comm). In addition bandicoot hair has turned up in dog scats (Hall 2005 pers comm). To minimise this threat DEC and relevant local government authorities will improve enforcement of regulations relating to responsible domestic/companion animal ownership and control.

Local government authorities in accordance with the NSW *Companion Animals Act 1998* govern responsible dog and cat ownership. This legislation states that owners must be able to contain their dogs within their own property and when in public they must be kept on a leash except within a designated area. Similar restrictions do not apply to cats.

In addition, dogs and cats are excluded from "wildlife protection areas". This restriction reflects s4 of the Act, which declares that an objective of the Act is to protect native birds and animals as an animal welfare issue. The Act also encourages Council to produce Local Companion Animal Management Plans, which set out strategies for the management of companion animals in individual council areas.

Council will investigate mechanisms to improve control of companion animals through either the development of a Companion Animal Management Plan or via the integration of companion animal management issues within existing management plans, local environment plans and into local order policies. Actions for consideration:

- Improved enforcement of responsible companion animal control on private and public property (eg. roaming and off leash animals) targeting areas of SBB habitat and bushland;
- Promote and facilitate the housing and containment of companion animals;
- Develop education strategies to promote the environmental benefits of containing companion animals;
- introduction of Section 88E (Conveyancing Act year) instruments to require animal containment in environmentally sensitive areas (eg SBB habitat or adjacent to SBB habitat); and
- exclusion of companion animals (dogs and cats) from new residential developments adjacent to areas of high conservation values (eg SBB habitat);

Under s9 of the *National Parks and Wildlife Regulations 2002*, dogs (and cats) are prohibited within National Parks and Nature Reserves although they are permitted on a leash within Regional Parks. However, as previously noted unleashed and roaming dogs have been reported attacking

individual SBBs and are regularly being reported on sand pads within SBB habitat during fox monitoring in Northern Sydney.

DEC will investigate mechanisms to enforce unauthorised access of animals, especially dogs, within DEC reserves. Actions for consideration:

- Improved enforcement of unauthorised animal access, targeting areas of SBB habitat.
- Consideration of exclusion of dogs within known and/or likely SBB habitat within Regional Parks (Berowra Valley)
- Work with Local Government in the development of education strategies to promote the environmental benefits of containing animals;
- Improved signage identifying park boundaries, exclusion of dogs and identification/notification of threatened species habitats

Specific Objective 3: Clarify the Status of the Species by Better Defining its Distribution and Relative Abundance.

Action 3.1: Continued Survey in National Parks and Other Tenures (Priority 1).

Further targeted survey work for the Southern Brown Bandicoot is required in southern New South Wales, particularly in under-sampled coastal environments. Such survey will better define the distribution of the species, and may locate other populations requiring active management. For National Park Estate, DEC will continue ongoing survey for the species using a combination of predator scat analysis, hair-tube sampling and live-trapping. A predictive distribution model for the species, developed during the recent Comprehensive Regional Assessment (CRA) Process for southern NSW, will be used initially to help identify potential sampling areas. Surveys may focus on predicted areas that have not been sampled and contain apparently suitable habitat based on floristic and structural attributes of the vegetation.

Outside of National Park Estate, DEC will seek ways to encourage other agencies and organisations to conduct surveys for the Southern Brown Bandicoot in areas containing suitable habitat. To some extent, these additional surveys are already being carried out through existing obligations. For example, on State Forest land, SFNSW South Coast and South East Regions are required under Broad Area Licensing Conditions to survey for the species in likely habitats or where indirect signs of animals (i.e. conical shaped forage-diggings) are found as part of pre-logging fauna

assessments. Similarly, information on the distribution of the species may also be obtained on private tenures during environmental assessment as part of development application processes.

Action 3.2: Conduct Postal Survey in Northern Sydney Metropolitan Area (Priority 1).

Further information is required on the likely distribution of the Southern Brown Bandicoot in the Northern Sydney Metropolitan Area, particularly in sites outside of major conservation reserves such as Ku-ring-gai Chase and Garigal National Parks. A cost-effective approach to acquiring such information is to conduct a postal survey, in which members of the public are provided a written questionnaire and asked to provide various details in relation to sighting of a particular threatened species.

Such postal surveys have been successfully conducted in the past by DEC and other government agencies, including Local Councils, for high profile species such as the Koala. This approach would work equally well for the Southern Brown Bandicoot. Accordingly, DEC will liaise with the relevant Councils in developing an appropriate survey questionnaire, targeting the species, and identify the best way to disseminate it. Responses will then be collated by DEC. All costs for the questionnaire will be born by DEC. Depending on the outcome of this work, follow-up survey may then be required.

Performance Criterion 7

The distribution and relative abundance of the Southern Brown Bandicoot in New South Wales is clarified through a combination of targeted survey work by relevant government agencies, and by postal survey to the public in the Northern Sydney Metropolitan Area.

Specific Objective 4: Undertake Research to Broaden the Knowledge Base on the Species, Gathering Critical Information to Assist in its Recovery.

In reviewing relevant literature on the Southern Brown Bandicoot, this plan has highlighted several gaps in knowledge of this species. Foremost among these is lack of understanding of impacts of disturbance on the species, its habitat and major food resources. As far as is practicable, DEC will seek ways to foster and encourage relevant research on the Southern Brown Bandicoot, through financial, logistic or other forms of support. Key areas of research that need to be addressed in the first instance are identified immediately below.

Action 4.1: Examine Response of Southern Brown Bandicoot to Fire (Priority 2).

The response of the Southern Brown Bandicoot to successional stage of vegetation following fire needs to be examined, either: (i) retrospectively, by surveying for the species across habitats of varying regeneration age post-fire, or (ii) opportunistically, as habitats known to be occupied by the species are subject to fire, either by deliberate (ie. prescribed burning) or natural (ie. wildfire) means. While relevant data could be collected as part of the monitoring programs identified in Action 2.2 identified above, further work across the broader landscape is required. DEC will determine ways to encourage and foster such research, either through seeking expressions of interest from students in academic institutions, or via specialist consultants. Either way, additional funding to conduct such work would need to be sourced.

Action 4.2: Identify Genetic Structure of Extant Populations (Priority 2).

Various genetic studies are needed to clarify: (i) the northernmost extent of the distribution of the Southern Brown Bandicoot in New South Wales, and (ii) the degree of genetic variation between extant populations of the species both within the State and elsewhere across mainland south-eastern Australia. Resolving the first matter is essential because at present there is confusion over where the boundary between the Southern Brown Bandicoot and its common congener, the Northern Brown Bandicoot, lies. Once this boundary is established, recovery efforts can be better focussed. The southern shoreline of the Hawkesbury River has been historically viewed as the demarcation point for the most northerly distributed populations of the Southern Brown Bandicoot (Ashby *et al.* 1990), but recent bandicoot records from areas immediately to the north have thrown doubt over this viewpoint. Also, there are unconfirmed records of the Southern Brown Bandicoot from Woy Woy (Australian Museum, unpublished records) and Myall Lakes (DEC Wildlife Atlas, unpublished data), both of which are well to the north of the Hawkesbury River. To clarify the issue this plan recommends that bandicoots be live-trapped from this general location and tissue (ear biopsy) samples taken for further DNA analysis. Samples can be obtained from animals captured during the monitoring and survey activities identified elsewhere in this plan. Samples from bandicoots north of the Hawkesbury River will be primarily

obtained fortuitously from road kill specimens (which in the recent past have been forwarded to the Australian Museum) and from animals live-trapped during fauna assessments undertaken as part of routine development application processes. DEC will notify relevant environmental consultants and help facilitate permits to allow collection of tissue samples.

Genetic studies are also critical for establishing the distinctiveness of individual populations of the Southern Brown Bandicoot in south-eastern mainland Australia. Existing records suggest that these populations are highly disjunct. Resolving their genetic make-up will help guide management of the species and its habitat, not only within New South Wales but also cross-border. This information will also be useful when considering where to source animals for translocation and/or captive breeding programs, should this become necessary in the future. This plan recommends that the genetic structure of populations identified during implementation of Actions 2.2 and 3.1 be resolved, together with that of several populations in Victoria and South Australia. While not discussed further here, the arrangements for and costs associated with sampling of animals outside of New South Wales will need to be considered by the existing Recovery Team.

Action 4.3: Collect Basic Information on Life History Attributes of Southern Brown Bandicoot (Priority 2).

Basic information on various life history attributes of the Southern Brown Bandicoot needs to be collected from populations in NSW to better guide management activities. This includes measures such as population density and structure, fecundity and reproductive success, juvenile dispersal, home range requirements, diet and nesting behaviour, and micro-habitat preferences. Much of this data could be readily collected as part of the monitoring programs identified in Action 2.2, therefore minimising costs. However, some aspects of the biology of the species, such as home range requirements, could only be determined by specific research programs outside the scope of the normal monitoring activities. DEC will seek ways to encourage and foster such research, either through seeking expressions of interest from students in academic institutions, or via specialist consultants. Either way, additional funding to conduct such work would need to be sourced.

Performance Criterion 8

Informed management actions are implemented as a result of knowledge of the biology and ecology of the species.

Action 4.4: Investigate the feasibility of establishing a captive breeding program. (Priority 2).

NSW populations of the Southern Brown Bandicoot are small and highly disjunct, and therefore at a high risk of extinction. Establishment of a captive breeding program may potentially provide an insurance against the loss of populations in the wild. The establishment of such a program would be consistent with NSW government priority for the establishment of sanctuaries and captive populations as a means for threatened species conservation.

Performance Criterion 9

Options for the establishment of a SBB captive breeding are investigated and reported on and were practical established.

Specific Objective 5: Improve Community Awareness of Conservation Significance of the Southern Brown Bandicoot.

To raise community awareness of the conservation significance of the Southern Brown Bandicoot, this plan recommends that promotion of the species be undertaken through: (i) high profile media avenues, (ii) providing specific information to relevant local communities, and (iii) involving public interest groups in survey and monitoring activities.

Action 5.1: Media Publicity Campaign (Priority 3).

High profile media publicity will be sought as the recovery program is implemented.

Performance Criterion 9

Within two years, at least three high profile media-related activities are undertaken.

Action 5.2: Inform Local Communities of Conservation Significance of Southern Brown Bandicoot (Priority 2).

In areas where the Southern Brown Bandicoot is known to occur, DEC and any other relevant public authority will inform the local community of the conservation significance of the species. This will be achieved through a variety of means, including the postal survey identified in Action 3.2 above. Other mechanisms such as the Companion Animals Education Program, involving local councils in the Northern Sydney Metropolitan Area, will also be used to raise the profile of the species in the local setting. There, the focus will be on responsible domestic pet ownership in and

adjacent to areas where the Southern Brown Bandicoot occurs.

Performance Criterion 10

Relevant local communities are better informed about the distribution, status and conservation management of the species.

Action 5.3: Involve Local Community Groups in Survey and Monitoring for Southern Brown Bandicoot (Priority 2).

The involvement of volunteer conservation groups in survey and monitoring activities relating to the Southern Brown Bandicoot will be encouraged. Such groups regularly conduct surveys for a range of threatened species across the State. Predator scat searches are particularly valuable for establishing the presence of the species along with other native ground-dwelling mammals that are preyed upon by exotic predators. This type of surveying would require some coordination with DEC staff as scat samples need to be systematically collected and collated for expert analysis. These organisations could also be trained by appropriate staff within the DEC to identify characteristic forage-diggings of bandicoots to better target surveys.

Performance Criterion 11

Relevant community groups are involved in survey and monitoring activities relating to the species.

7 Implementation

Table 1 allocates responsibility for the implementation of recovery actions specified in this plan to relevant government agencies and/or parties for a period of five years from the time this recovery plan is adopted, and identifies costs associated with each recovery action. The total estimated cost for the implementation of these actions is \$585 870.

8 Social and Economic Consequences

Since the Southern Brown Bandicoot is known to occur across a range of different land tenures, there may be some social and economic impacts associated with its ongoing conservation. Such impacts are most likely to be felt on private land where development proposals are likely to impact significantly on the species. These costs cannot be currently quantified. There will also be economic costs associated with carrying out of actions identified in this recovery plan. These costs have already been outlined in Section 7 immediately above and are detailed in Table 1.

The recovery plan could have social benefits for the general public, increasing awareness of the natural heritage values of areas where the species has been recorded, such as National Park Estate. This would particularly be the case for recreational users of the relevant Parks and adjacent local communities.

9 Roles and Interests of Indigenous People

The Local Land Councils, Elders and other groups representing indigenous people in the areas where the Southern Brown Bandicoot occurs have been identified and a copy of the draft Recovery Plan sent to them. Their comments on the draft of this Recovery Plan have been sought. In addition it is the intention of the Recovery Team to consider the role and interests of these indigenous communities in the implementation of the recovery actions identified in this plan.

10 Biodiversity Benefits

Understanding factors limiting Southern Brown Bandicoot populations, together with protection and appropriate management of habitat for the species, will assist in the conservation of a range of ground-dwelling mammals in New South Wales, some of which are also threatened. Such species include the Long-nosed Bandicoot, Long-nosed Potoroo, Long-footed Potoroo, Smoky Mouse (*Pseudomys fumeus*) and White-footed Dunnart (*Sminthopsis leucopus*). In distributing the spores of mycorrhiza-forming fungi in its faeces, the Southern Brown Bandicoot may inadvertently play an important role in maintaining forest health (Claridge *et al.* 1992). Loss of this species from forests may reduce dispersal chances for these beneficial fungi. The consequences of this for long-term ecosystem productivity are unknown. Finally, through awareness of the fate of the Southern Brown Bandicoot the profile of all threatened species will be raised in the general community. This in turn will lead to greater opportunities for the conservation of species and increased protection of biodiversity.

11 Preparation Details

This Recovery Plan was prepared by Andrew Claridge, Senior Threatened Species Officer, Southern Directorate (DEC), and Douglas Mills, Consultant/Wildlife Biologist. Michael Saxon and Rob Humphries, respective

Managers of the Threatened Species Units in Southern and Central Directorates, reviewed and had editorial input into this plan.

12 Review Date

This recovery plan is to be formally reviewed and updated by the by the Department of Environment and Conservation (NSW) five years from the date of its publication.

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Draft Recovery Plan for the Southern Brown Bandicoot

Table 1: Implementation and Costing Table.

Allocation of responsibility for implementation of recovery actions specified in this plan to relevant agencies. Costing for each action are also identified. Priority is categorised as 1 (Essential), 2 (Highly Desirable) or 3 (Desirable). In the fund source column 'in kind' indicates the value of contributions offered in various forms by government agencies and other groups to implement recovery actions – including funds from recurrent sources.

Action No.	Action Description	Priority	Responsible Party	Funding Source	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total Cost
1.1	Continuation of State-Wide Recovery Team	1	DEC SFNSW	in-kind in-kind	500 500	500 500	500 500	500 500	500 500	2500 2500
1.2	Establish Regional Working Groups	1	DEC SFNSW Relevant Councils*	in-kind in-kind in-kind	500 500 1200	500 500 1200	500 500 1200	500 500 1200	500 500 1200	2500 2500 6000
2.1	Undertake Intensive Control of Introduced Predators around Known Extant Populations	1	DEC SFNSW	in-kind in-kind	28300 10000	30415 10000	32585 10000	34815 10000	36105 10000	162220 50000
2.2	Monitor the Response of Southern Brown Bandicoot Populations to Intensive Control of Introduced Predators	1	DEC SFNSW	in-kind in-kind	56500 3000	58650 3000	60900 3000	63300 3000	65800 3000	305150 15000
2.3	Establish Mortality Register for Roads within Ku-ring-gai Chase National Park	1	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
2.4	DEC negotiate with RTA to Establish Mortality Register for Public Roads in Northern Sydney Metropolitan Area	1	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
2.5	Develop Sympathetic Fire Management Programs	1	DEC SFNSW	ψ	ψ	ψ	ψ	ψ	ψ	ψ
2.6	Ensure Informed Environmental Assessment and Planning Decisions are Made	1	Relevant Councils**	ψ	ψ	ψ	ψ	ψ	ψ	ψ
2.7	Improved control of companion animals	1	Relevant Council	ψ	ψ	ψ	ψ	ψ	ψ	ψ
3.1	Survey in National Parks and Other Tenures	1	DEC	in-kind	1000	1000	1000	1000	1000	5000
3.2	Postal Survey in Northern Sydney Metropolitan Area	1	DEC	in-kind	-	1000	-	-	-	1000
4.1	Examine Response of Southern Brown Bandicoot to Fire	2	DEC	φ	φ	φ	φ	φ	φ	φ
4.2	Identify Genetic Structure of Extant Populations	2	DEC	φ	φ	φ	φ	φ	φ	φ
4.3	Collect Basic Life-History Information on Southern Brown Bandicoot***	2	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
4.4	Investigate the feasibility of establishing a captive breeding program.	2	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
5.1	Media Publicity Campaign	3	DEC	in-kind	300	300	300	300	300	1500
5.2	Inform Community of Conservation Significance of Southern Brown Bandicoot	2	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
5.3	Involve Community in Survey and Monitoring Programs for Southern Brown Bandicoot	2	DEC	ψ	ψ	ψ	ψ	ψ	ψ	ψ
Total								Grand Total		555870

Key: * = costings based on those Councils who have committed to attending Regional Working Group Meetings. ** action a routine requirement under the *Environmental Planning and Assessment Act 1979*. *** = data will be collected during monitoring and survey activities. ψ = no direct cost, however action must be considered by relevant authority. φ = action yet to be costed and will require external funding source.

Appendix 1: Summary of advice by NSW Scientific Committee

Under Section 66A of the TSC Act 1995 (NSW), a recovery plan approved by the Minister must include a summary of any advice given by the NSW Scientific Committee, details of the amendments made to the plan to take into account of that advice and statement for any departure from that advice.

Advice and comment was provided by the Scientific Committee with respect to:

Comment: Preliminary nature of population assessments and additional sources of species distribution and abundance data.

The recovery plan is only intended to provide a snapshot of the species' distribution (Section 3.2) and current conservation status (Section 3.3) at the time of plan preparation. It is not intended to provide population estimates, particularly as little information is available to provide such estimates. Liaison with NSW State Forests and other landholders with regards to gaps within the species distribution and abundance data is on-going. Additional data, particularly new records, will be entered into the NSW Wildlife Atlas and be made available as necessary. It is noted that the recent data mentioned from NSW State Forests for the far south-east of NSW has been included with in the plan on sections 3.3 and 5.1.

Comment: Acknowledgment of level of current knowledge and links with research priorities and funding.

Although the Southern Brown Bandicoot is relatively well researched compared to some other threatened species, it is not extensively researched. Research actions have been identified as highly desirable in the plan or as contributing actions within the Priority Actions Statement for this species. This reflects the importance of these actions for the recovery of the species.

Comment: Recommendation for consideration of relative importance of identified threats.

Section 4 of the recovery plan identifies different management issues or threats facing this species. Ranking of these management issues was not considered appropriate given the lack of evidence to quantify the relative impact of each of these issues to this species in NSW. However, it is noted this actions are prioritised and links are made with listed "Key Threatening Processes" (under the TSC Act) relevant to this species. This includes "Predation by the European Red Fox", "High frequency fire" and to a lesser extent historical "Clearing of native vegetation". Within the Fox Threat Abatement Plan, this species is subject to experimental fox control to quantify its response to specific threat management.

Comment: Allocation of resources and need to seek funding from external sources.

Although external funding is essential for currently unfunded actions, the recovery plan does not have any power to direct funds from external sources to these actions. However the DEC promotes the implementation of these recovery actions to external funding bodies, research institutions and other stakeholders, particularly where actions can be incorporated into broader projects such biodiversity surveys or research programs.



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