Approved Recovery Plan

Recovery plan for the brush-tailed rock-wallaby (*Petrogale penicillata*)

March 2008

Department of **Environment & Climate Change** NSW

Acknowledgments
A large number of people have contributed to the survey, research and management of the brush-tailed rock-wallaby (BTRW) over a number of years. Much of the background and preliminary information in this recovery plan draws from, or has been adapted from, existing population management plans for the Warrumbungles and Shoalhaven BTRW populations and other unpublished documents prepared for the Northern NSW populations. Particular thanks in this regard are due to Vera Wong, Ian Jackett and Paul Bayne for allowing use of their material in this plan.

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Executive summary

The brush-tailed rock-wallaby *Petrogale penicillata* is a distinctively marked medium-sized wallaby and one of the larger rock-wallabies. It is listed in Schedule 1 of the NSW *Threatened Species Conservation Act 1995* as endangered.

This document, which constitutes the formal NSW recovery plan for the brush-tailed rock-wallaby:

- outlines the animal's ecology
- describes its past and current distribution and abundance
- explains the reasons for its decline
- sets out actions to recover the species across its known range in NSW.

The Department of Environment and Climate Change NSW (DECC) believes many interrelated factors contribute to the continued decline of the species. These factors include predation by and competition from introduced and other native species, habitat modification and destruction due to the spread of weeds and clearing of vegetation, fire, drought, disease and inbreeding. DECC is working to control these threats at a number of sites throughout the state.

The long-term objectives of the recovery program are to:

- halt the decline of the brush-tailed rock-wallaby
- recover the species from its status as endangered.

However, these objectives are not achievable within the timeframe of this plan. Therefore, this plan's specific objectives are to ensure the sustainability of priority populations and to prevent the extinction of the brush-tailed rock-wallaby in the wild in NSW. This objective can be achieved by:

- arresting further population decline
- increasing populations at all priority sites in NSW
- ensuring the species' range does not contract further.

As not all populations of brush-tailed rock-wallabies can be managed through this plan, the priority will be to manage certain regional populations at priority sites where their survival can be ensured.

Recovery actions include:

- continuing existing and introducing new predator and introduced herbivore control programs
- surveys to improve knowledge of the distribution and abundance of the species
- maintaining and enhancing captive breeding programs for identified regional populations
- continuing and expanding community-based conservation programs.

Given the broad geographic range of the species, there will also be some overall biodiversity benefits from implementing this plan.

The brush-tailed rock-wallaby is an iconic species that occurs on public and private lands. The successful implementation of recovery actions relies on the participation of all sectors of the community. DECC welcomes opportunities to work with Catchment Management Authorities, community groups and private corporations who wish to contribute to implementing this recovery plan.

Lisa Corbyn
Director General

Verity Firth MP
Minister for Climate Change and the Environment

1 Introduction

The Director General of the Department of Environment and Climate Change NSW (DECC) may prepare recovery plans for conservation of species listed in Schedules 1, 1A and 2 of the *Threatened Species Conservation Act 1995*.

This recovery plan is a key step in conserving the brush-tailed rock-wallaby (*Petrogale penicillata*) in NSW. It identifies the actions that will be taken to ensure the long-term survival of this species in the wild and the parties responsible for implementing these actions.

Availability of funds and other constraints imposed on parties involved in the process will determine the sequence, timing and extent of recovery actions undertaken. The information given in the plan is considered accurate at the date of publication. However, the plan may require amendment at a later date if new research or findings warrant changes.

2 Legislative context

2.1 Legal status

The brush-tailed rock-wallaby (BTRW) is currently listed as endangered in the NSW *Threatened Species Conservation Act 1995* (TSC Act) and vulnerable in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The BTRW is also listed as vulnerable in Queensland, extinct in the Australian Capital Territory, and critically endangered in Victoria.

Before this species was listed as endangered in the TSC Act, the population of BTRWs in the Warrumbungle Ranges in the Coonabarabran District in central northern NSW was listed as an endangered population in the Act. A recovery plan for that population has been prepared and is being implemented (NPWS 2003).

2.2 Recovery plan preparation

The TSC Act provides a legislative framework to protect and encourage the recovery of threatened species, populations and ecological communities in NSW. The Act includes specific requirements for issues which must be addressed in recovery plans and the administrative process for preparing them. This plan satisfies these requirements and sets the priorities for and direction of BTRW conservation and management in NSW.

A draft recovery plan was prepared and publicly exhibited in August 2005. A report on the submissions made regarding the draft recovery plan was prepared for the Minister for Climate Change, the Environment and Water as required under section 62 of the TSC Act. Advice received from the NSW Scientific Committee appears in Appendix 2 as required under section 66A of the TSC Act. The approved recovery plan has been amended in response to the public submissions, new information and changes to natural resource management in NSW.

This recovery plan has been prepared with the assistance of a recovery team who represent a non-statutory group of interested parties with relevant expertise. Components of the plan do not necessarily represent the views or the official positions of all the individuals or agencies represented on the recovery team. The information in this recovery plan was accurate to the best of the knowledge of the recovery team on the date it was approved.

2.3 Recovery plan implementation

The TSC Act requires that a government agency must not undertake actions inconsistent with a recovery plan. The NSW government agency responsible for implementing this plan is the Department of Environment and Climate Change NSW (DECC). DECC will liaise with other government agencies and authorities regarding assistance, and approval, for specific implementation measures. Other parties relevant to this plan are the NSW Department of Primary Industries (Forests NSW) and Rural Lands Protection Boards.

The TSC Act binds the Crown (section 142) and requires public authorities to implement any recovery plan (section 69). Section 50 binds public authorities to have regard to any declared critical habitat. The regulations may prohibit certain actions by any person or body on critical habitat (section 51).

2.4 Relationship to other legislation

The following legislation is relevant to this recovery plan:

- *Crown Lands Act 1989*
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- *Environmental Planning and Assessment Act 1979*
- *Forestry and National Park Estate Act 1998*
- *Local Government Act 1993*
- *National Parks and Wildlife Act 1974*
- *Native Vegetation Act 2003*
- *Noxious Weeds Act 1993*
- *Rural Fires Act 1997*
- *Rural Lands Protection Act 1998*
- *Threatened Species Conservation Act 1995*
- *Wilderness Act 1987*.

The interaction of these Acts with the TSC Act varies. The most significant implications are described in section 2.5.

2.5 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 consider relevant recovery plans when making decisions under Parts 4 and 5 of the EP&A Act. Therefore, all government agencies and local councils who have jurisdiction over BTRW sites or habitat are required, as consent or determining authorities, to consider the conservation strategy set out in this plan when considering direct and indirect impacts of any activity or development within known or potential habitat of the BTRW.

Any activity not requiring a consent or approval under the EP&A Act, and which is likely to affect the BTRW, requires a section 91 licence from the Director General of DECC under the provisions of the TSC Act. Such a licence can be issued with or without conditions, or can be refused. If a significant impact is unlikely, the Director General of DECC will issue the applicant with a section 95(2) certificate that acts as a defence against prosecution under sections 118A–D of the *National Parks and Wildlife Act 1974* (NPW Act).

A scientific licence issued under section 132C of the NPW Act is required to 'harm' the BTRW or damage its habitat for scientific, educational or conservation purposes.

2.6 Critical habitat

The TSC Act makes provision for identifying and declaring critical habitat for species, populations and ecological communities listed as critically endangered and endangered. Critical habitat is habitat that is critical for the survival of a listed threatened species or listed threatened ecological community. Once critical habitat has been declared, it becomes an offence to damage it, unless the action is specifically exempted by TSC Act. A species impact statement is mandatory for all developments and activities proposed within critical habitat. To date, no critical habitat has been identified for the BTRW. The declaration of critical habitat in NSW is not considered a priority for the species at this stage as other mechanisms provide for its protection.

The EPBC Act provides for the identification and declaration of critical habitat. It is an offence under the EPBC Act for a person to knowingly take an action that will significantly damage critical habitat, unless the Act specifically exempts the action. This offence only applies to Commonwealth areas. However, an action which is likely to have a significant impact on a listed species or community is still subject to referral and approval under the EPBC Act.

3 Conservation status

BTRW sites are recorded in 15 Interim Biogeographic Regionalisation for Australia bioregions. BTRWs are thought to be extinct in six bioregions, in severe decline in four bioregions, and in decline in five bioregions, as indicated in Table 1 and Figure 1. The species is known to occur in seven Catchment Management Authority regions, and is thought to be extinct in five others (see Table 2).

Table 1. Status of the brush-tailed rock-wallaby in Interim Biogeographic Regionalisation for Australia bioregions

Bioregion	Status
Australian Alps	Extinct
Brigalow Belt South	Decline
Cobar Peneplain	Extinct
Darling Riverine Plain	Extinct*
Murray–Darling Basin	Extinct*
Nandewar	Decline
New England Tableland	Decline
NSW North Coast	Decline
NSW South Western Slopes	Severe decline
Riverina	Extinct*
Sydney Basin	Severe decline
South East Corner	Severe decline**
South Eastern Highlands	Severe decline
South Eastern Queensland	Decline
Victorian Midlands	Extinct

* While sighting records are either non-existent or problematic for these bioregions, the proximity of known sites would indicate there is a reasonable chance that the species once occurred there.

** Thought to remain in Victoria only

Table 2. Status of the brush-tailed rock-wallaby in Catchment Management Authority regions

Bioregion	Status
Border Rivers/Gwydir	Decline
Central West	Severe decline
Hawkesbury–Nepean	Severe decline
Hunter–Central Rivers	Severe decline
Lachlan	Extinct
Murray	Extinct*
Murrumbidgee	Extinct
Namoi	Decline
Northern Rivers	Decline
Southern Rivers	Severe decline
Sydney Metropolitan	Extinct*
Western	Extinct

* While sighting records are either non-existent or problematic in these regions, the proximity of known sites would indicate there is a reasonable chance that the species once occurred there.

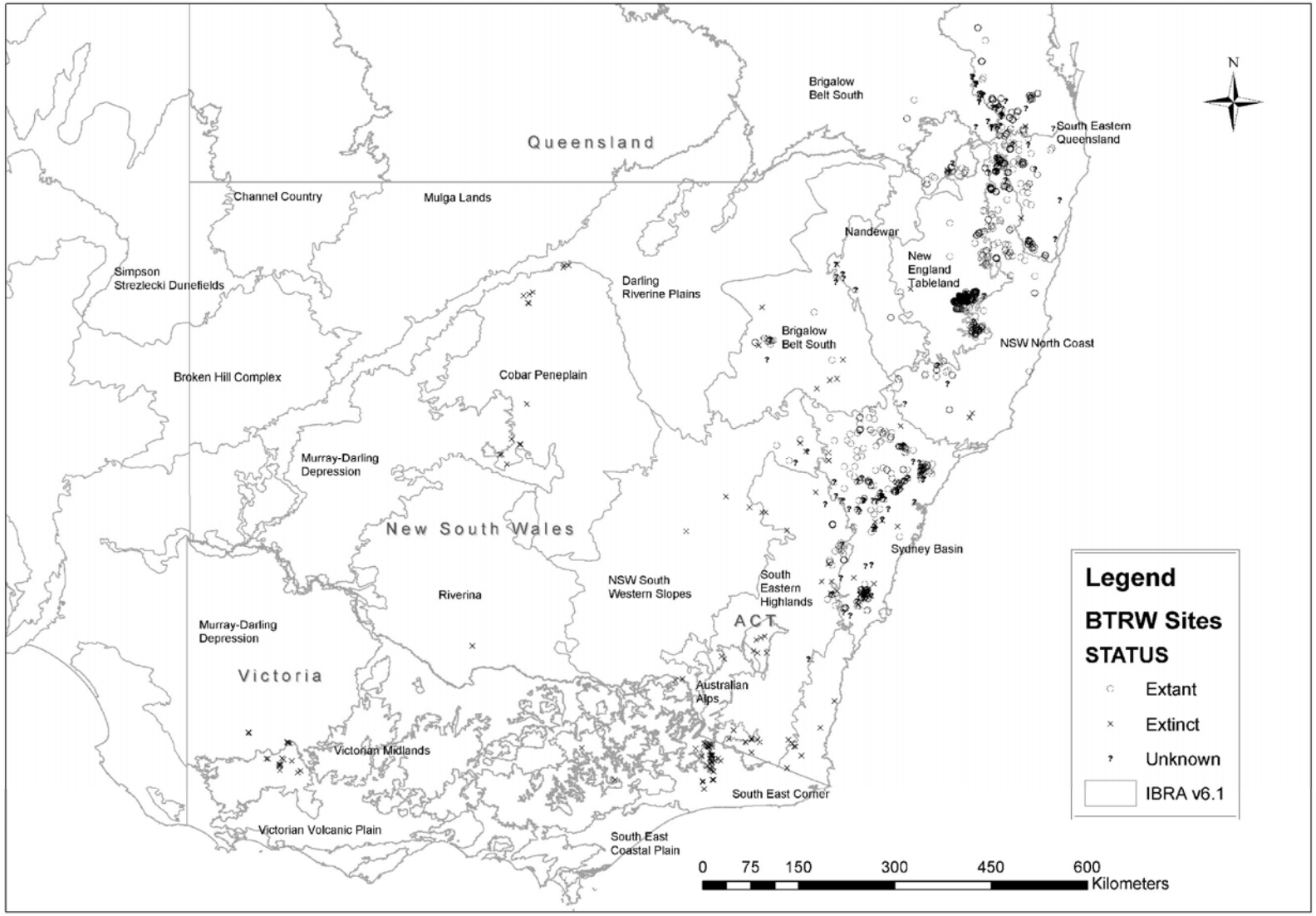

Figure 1. Recorded brush-tailed rock-wallaby sites and Interim Biogeographic Regionalisation for Australia bioregions

A detailed assessment of BTRW records was undertaken in 2004. There are 962 nationally recorded BTRW sites, of which approximately half are in conservation reserves (see Figure 2). Most of the other sites are on private lands, while fewer than 10% of sites are on state forest or vacant Crown land. In NSW, there are 876 recorded sites. Of these, 42% are in reserves, 30% are on freehold lands (see Figure 3), and the rest are in state forests, on Crown land or on leasehold lands.

The distribution of extinct and extant sites by tenure (i.e. ownership of the land, whether public or private) is similar for reserved and private lands when considered across the species' range, as illustrated in Figure 4. However, the proportion of recorded sites in reserves increases from 46% in the north to 79% in the south of the species' range (see Figure 5). In the centre of the species' range, the proportion of extant to extinct sites is substantially higher in reserves than in other land tenures (60% compared to 40%). The small number of extinct sites in the north and extant sites in the south means comparisons of status by tenure across the species' range are problematic on the basis of recorded data alone.

While overall the proportion of extinct sites in reserves is greater than the proportion of extant sites, the difference is not statistically significant. It should be noted that there is likely to be a bias in the records for extinct sites due to an under-recording of extinct sites on private land. Many of the records of extinct sites on private lands are old, and what were once suites of colonies have often been recorded only once before extinction. This is particularly true of sites where early museum records are the only indication of the existence of a site. In contrast, records in reserves are often of multiple sites within complexes of colonies, and often result from recent, more detailed surveys. Loss of some of these sites – and hence records of extinction – are therefore not necessarily records of loss of the entire colony or suite of colonies.

In NSW, there are past or present records of the BTRW in 40 DECC-managed reserves, which comprise 28 national parks, nine nature reserves and three state recreation areas (see Table 3). In these reserves, the BTRW appears to have become extinct in 12 reserves, while remaining in 28 reserves which comprise 20 national parks, five nature reserves and three state recreation areas. In addition, there are two timber reserves in northern NSW where extant BTRWs have been recorded. The distribution of these reserves is illustrated in Figure 6.

Research into the genetic distinctiveness of individual populations indicates there are three distinctive taxonomic groups of BTRW centred in:

1. north-eastern NSW and south-eastern Queensland
2. central NSW
3. Victoria.

While it is clear that the genetic differentiation between these three groups is significant, the degree of differentiation at a taxonomic level is yet to be determined. In the interim, these groups will be provisionally referred to as Evolutionary Significant Units, or ESUs. An ESU is defined by Moritz (1994) on the basis of a genetic criteria based on both mitochondrial DNA and nuclear alleles. The basis for defining an ESU as defined by Moritz is 'to ensure that evolutionary heritage is recognized and protected and that the evolutionary potential inherent across the set of ESU is maintained'. This is consistent with the objectives of the TSC Act which are 'to conserve biological diversity' where biological diversity is made up of genetic diversity, species diversity and ecosystem diversity. The three genetic groups within the total BTRW population will be referred to in this plan as the Northern ESU, Central ESU and Southern ESU respectively. There are extant sites in 16 reserves and the two timber reserves in the Northern ESU, and in 12

reserves in the Central ESU. Ten of the reserves where it would appear that the species has become extinct are in the Central or Southern ESUs, and only two are possibly in the Northern ESU.

These figures reflect the decline and contraction of the species in the south of its range (Short and Milkovits 1990). Details on the status of the BTRW in individual reserves are presented in Table 4.

Table 3. Status of the brush-tailed-rock-wallaby in conservation reserves in NSW

Reserve category	Extant	Presumed extinct	Total
National parks	18	9	27
Nature reserves	5	3	8
State recreation areas	3	0	3
Timber reserves	2	0	2
Total	**28**	**12**	**40**

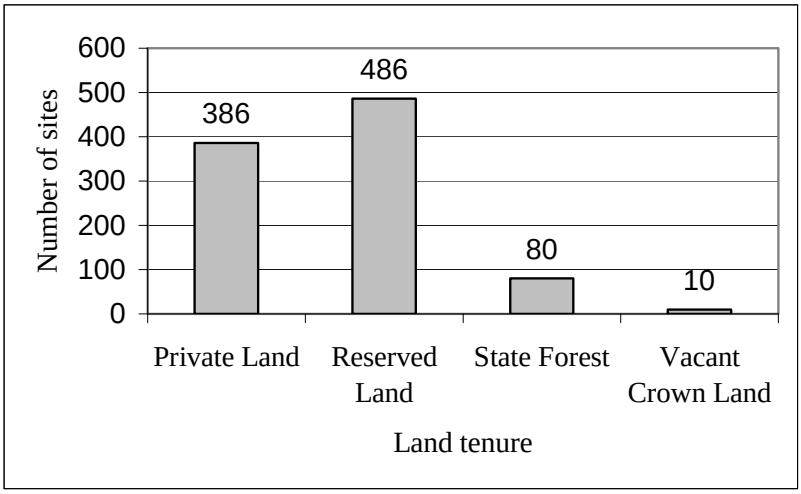

Figure 2. Tenure of recorded brush-tailed rock-wallaby sites across Australia

Table 4. Status of the brush-tailed rock-wallaby in NSW reserves

Reserve	Status	ESU
Deua NP	Extinct	Central/Southern*
Kosciusko NP	Extinct	Central/Southern*
South East Forest NP	Extinct	Central/Southern*
Avisford NR	Extinct	Central
Blue Mountains NP	Extant	Central
Bungonia SRA	Extinct	Central
Burragorang SRA	Extant	Central
Cambewarra NR	Extant	Central
Coolah Tops NP	Extinct	Central
Gardens of Stone NP	Extinct	Central
Goulburn River NP	Extant	Central
Kanangra-Boyd NP	Extant	Central
Manobalai NR	Extant	Central
Morton NP	Extant	Central
Parr SRA	Extant	Central
Warrumbungle NP	Extant	Central
Watagan NP	Extant	Central
Weddin Mountains NP	Extinct	Central
Winburndale NR	Extinct	Central
Wollemi NP	Extant	Central
Yathong NR	Extinct	Central
Yengo NP	Extant	Central
Gundabooka NP	Extinct	Northern/Central*
Banyabba NP	Extant	Northern
Boonoo Boonoo NP	Extant	Northern
Demon NR	Extant	Northern
Gibraltar Range NP	Extant	Northern
Guy Fawkes River NP	Extant	Northern
Mann River NR	Extant	Northern
Mount Kaputar NP	Extant	Northern/Central*
Nymboida NP	Extant	Northern
Oxley Wild Rivers NP	Extant	Northern
Sherwood NR	Extant	Northern
Tooloom NP	Extant	Northern
Toonumbar NP	Extant	Northern
Warrabah NP	Probably extinct	Northern
Washpool NP	Extant	Northern
Wingen Maid NR	Extant	Northern
Woko NP	Extant	Northern
Yabbra NP	Extant	Northern

(NP = national park, NR = Nature reserve, SRA = state recreation area)
*ESU boundary indeterminate

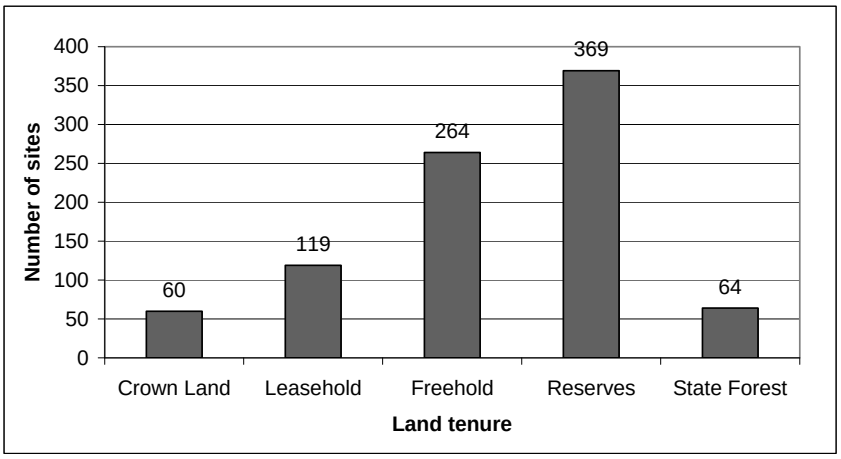

Figure 3. Tenure of brush-tailed rock-wallaby sites in NSW

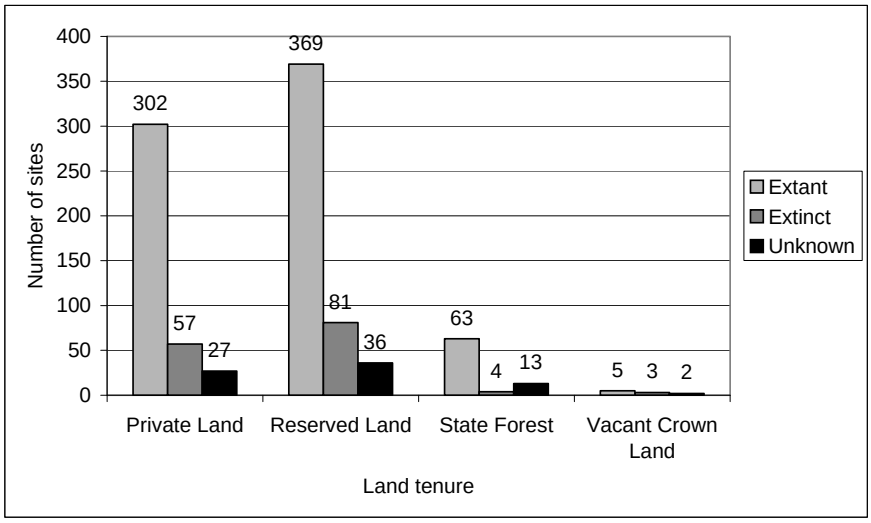

Figure 4. Number of recorded sites according to tenure on which the brush-tailed rock-wallaby is extinct or extant, or its status is unknown

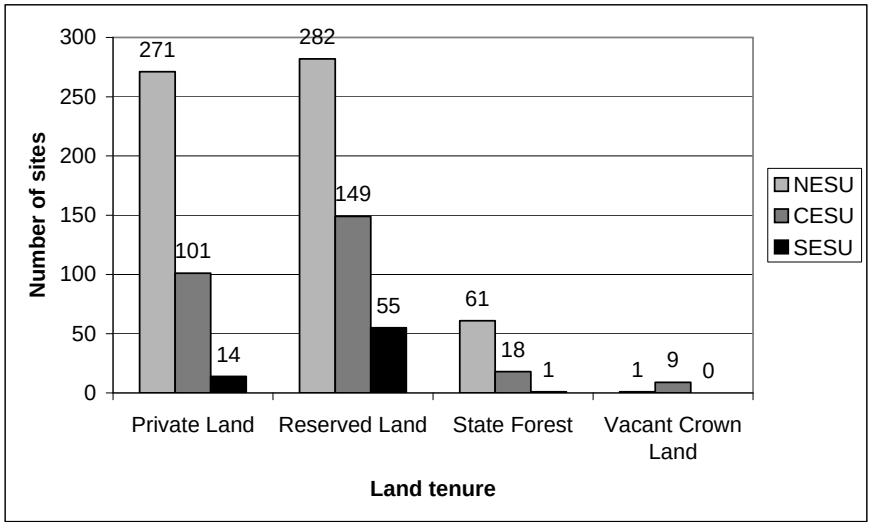

Figure 5. Number of recorded sites according to tenure in the Northern Evolutionary Significant Unit (NESU), Central Evolutionary Significant Unit (CESU) and Southern Evolutionary Significant Unit (SESU)

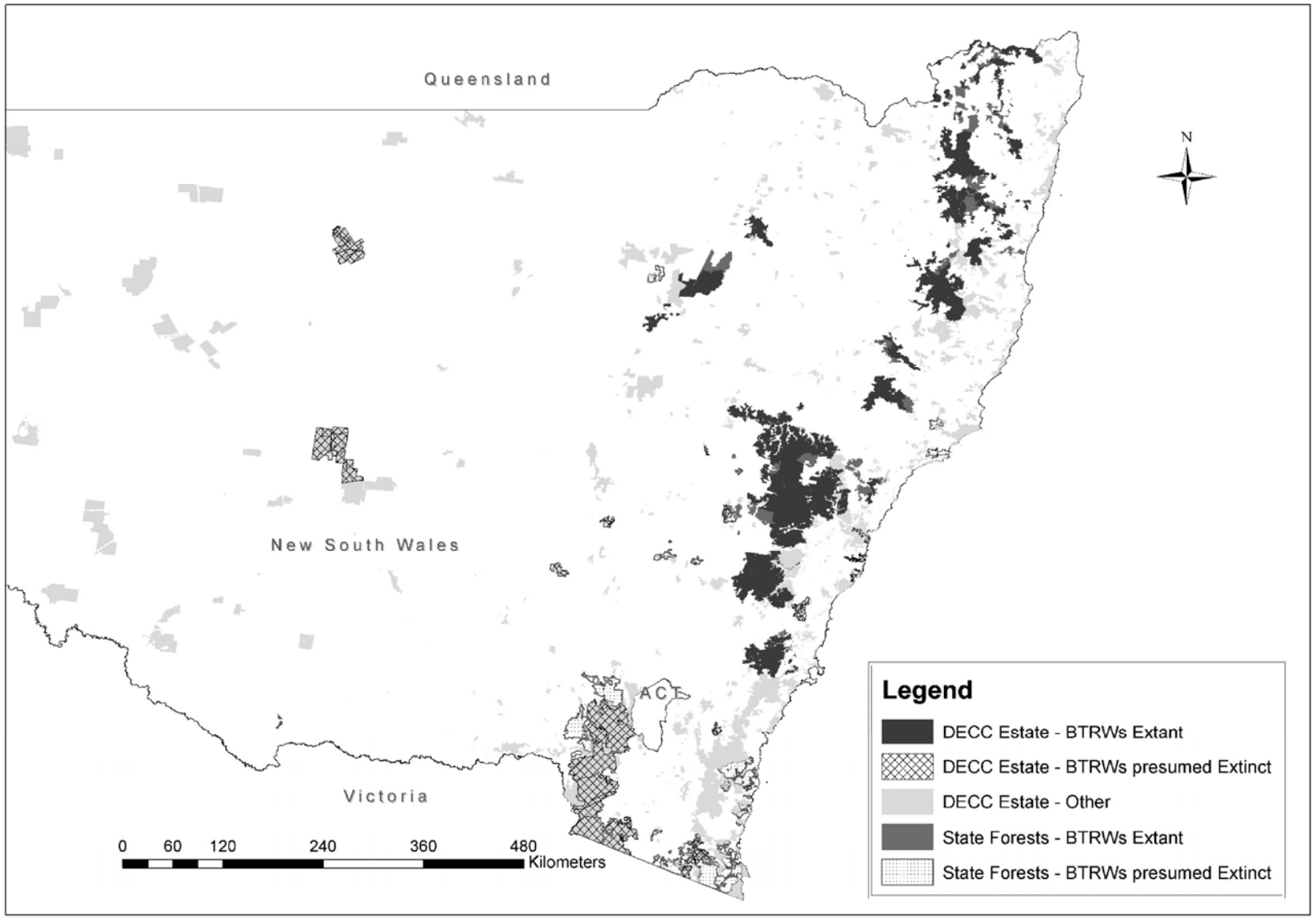

Figure 6. Brush-tailed rock-wallaby conservation status in NSW reserves

4 Description

The BTRW is a distinctively-marked medium-sized wallaby and one of the larger species of the genus *Petrogale*. Individuals average 510–586 millimetres in head to tail length and 500–700 millimetres in tail length. Females are slightly smaller on average than males, with less muscle development on the forelimbs. Body weight for males ranges from 5.5 to 10.9 kilograms and for females from 4.9 to 8.2 kilograms (Strahan 1995).

BTRWs are most commonly dull brown above, tending to reddish-brown on the rump and to grey on the neck and shoulders, and lighter underneath (Eldridge pers. comm.). The flanks are distinctly striped in pale grey and black. Although little colour variation generally occurs between the sexes, the rufous coloration of the male may be more distinctive (Jarman 1989). However, there is considerable variation in colouring and patterning among populations, and among individual wallabies within a population, such as variability in the extent and shape of white chest blazes (Bayne 1994), which often allows for individual identification. The head is marked by a light coloured cheek stripe and a black dorsal stripe from the eyes to behind the head. The posterior third of the tail is generally distinctively bushy (hence the species' common name) and is generally brown to black but can be paler (Eldridge pers. comm.). Colours tend to be lighter and tails less bushy in the north of the BTRW's range (Close 1993), and juveniles are more brightly marked than adults. The hind feet are comparatively short. The foot pads have rough surfaces and the central toes bend more freely than those of other long-footed wallabies (Troughton 1944). The toes do not extend as far beyond the toe pad as they do with other wallabies (Close pers. comm.).

Rock-wallabies are agile animals that can move swiftly and confidently, with highly precise bounds, through very rugged and precipitous areas. The rock-wallabies' great agility has been attributed to their long flexible tail used for balance, and their short, flexible, well-padded, and rough textured feet which give 'remarkable traction' (Maynes and Sharman 1983).

Brush-tailed rock-wallaby

Photo: S. Ruming

5 Distribution

5.1 Range

The historical range of the BTRW extended from the Grampians in western Victoria to Nanango in south-eastern Queensland, roughly following the line of the Great Dividing Range (see Figures 1 and 7). However, there has been a decline in numbers and a reduction in the species' range, with the decline being greatest in Victoria, and in western and southern NSW (Short and Milkovits 1990, Dovey et al 1997, Lunney et al 1997). The species' range is now fragmented, particularly in the south where BTRWs are now mostly found as small isolated populations dotted across their former range.

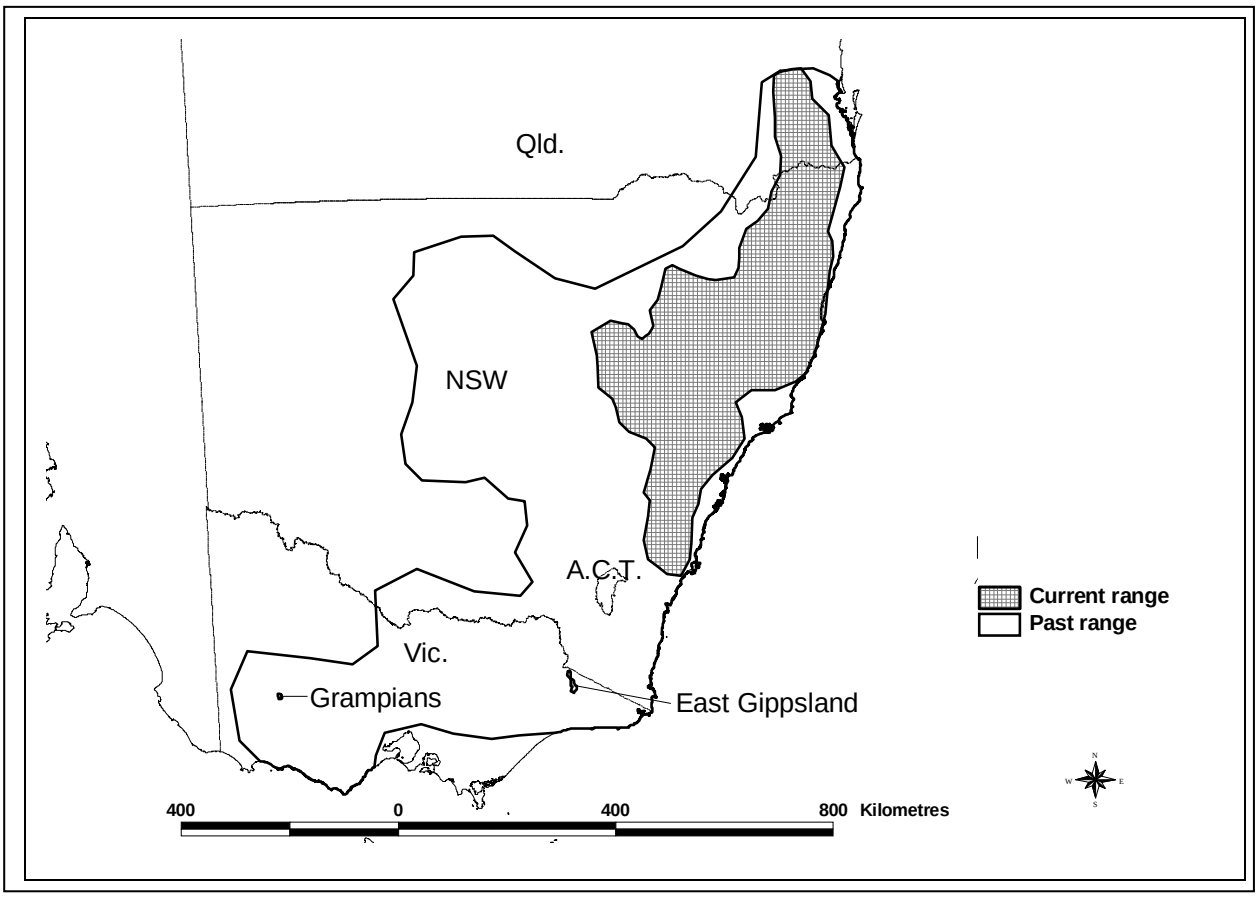

Figure 7. Past and present range of the brush-tailed rock-wallaby

Until recently, the small population in the Grampians in Victoria was the most westerly population, some 550 km away from the nearest population in East Gippsland. The population in the Grampians is now thought to be extinct (Seebeck pers. comm.). In NSW, the populations in the Shoalhaven and the Warrumbungle Ranges are the most southerly and westerly known populations, respectively. Although still fragmented, BTRW occurrence in the north is more continuous along a number of the major river system gorges such as the Apsley-Macleay and Clarence river gorges.

A major survey of the species' distribution was carried out in 1990 (Short and Milkovits 1990). This survey found 37 sites where the species had occurred within the previous 20 years and 30 sites where it was presumed extinct. In 1993, a more comprehensive survey identified 47

colonies existing in 18 sites in central, southern and western NSW and more than 100 colonies in 15 sites in northern NSW (Dovey et al 1997). The survey found a further 14 sites where the animals had become extinct. Since 1993, the BTRW has disappeared from another five sites, meaning it has become extinct at, or vacated, 49 sites since 1990. A National Parks and Wildlife Service survey in 1995 located 15 colonies of BTRWs in Yengo National Park and Parr State Recreation Area and surrounding areas (Rummery et al 1995).

Past variations in rock-wallaby distributions and genetic variation are thought to be due to bioclimatic variables (Eldridge and Browning unpub., Cavanagh unpub.). In particular, modelled shifts in the climate of the ranges of the BTRW and Herbert's rock-wallaby (*Petrogale herberti*) indicate that oscillations and overlaps in the two species' ranges over time may be factors in the development of hybrids between the species. Climate modelling also indicates that the presence of the BTRW in the Grampians region may have occurred only within the last 20,000 to 10,000 years (Cavanagh unpub.).

5.2 Abundance

During the late 1880s, BTRWs were abundant and widespread across the rocky country of south-eastern Australia from southern Queensland to Victoria. From 1900 until about 1920, hundreds of thousands were shot as agricultural pests and hunted for fur (Lunney et al 1997). Their numbers have continued to fall in most localities and it is now estimated that there are between 15,000 and 30,000 animals left. Gaining a more precise estimate of numbers is difficult due to the inaccessibility of the species' habitats, particularly in the north where numbers are greater.

Approximately 17% of BTRWs occur in south-eastern Queensland, 82% in NSW, and fewer than 1% in Victoria. In NSW, as many as 98 % of BTRWs are found north of the Hunter River, and up to 80 % of the total number of BTRWs in Australia are found in north-eastern NSW (see Figure 8). Most northern NSW populations are in the Macleay River and Clarence River gorges (Bayne pers. comm., Dovey et al 1997).

While it is possible that numbers in the north of the species' range were always higher than in the south, substantial evidence indicates the relative numbers in the south have been drastically reduced (e.g. Lunney et al 1997, Short and Milkovits 1990). Accurately estimating abundance remains one of the challenges in recovery planning.

A recent study by Piggott et al (2006a) explains a promising new technique for estimating the population size of BTRW colonies. In a study of four BTRW colonies in Wollemi National Park, individual BTRWs were identified by genetic analysis of scats. DNA fingerprinting of genetic material from faeces can distinguish individuals and provides a minimum number of animals alive at the time of sampling. This method can also distinguish between males and females, and can detect birth and recruitment over time. Repeated sampling in colonies can then provide an estimated population size. In the Wolgan Valley, this technique determined that there was one large colony of approximately 67 animals, two smaller colonies of approximately 11–17 animals and a very small colony of 2–4 animals. In the smallest colony, there was evidence of an increase in population size over a two-year period due to the birth of a new individual from a female previously identified in a different sampling time (Piggott et al 2006a).

An added advantage of this method is that the genetic data obtained can also be used to infer dispersal patterns and population structure.

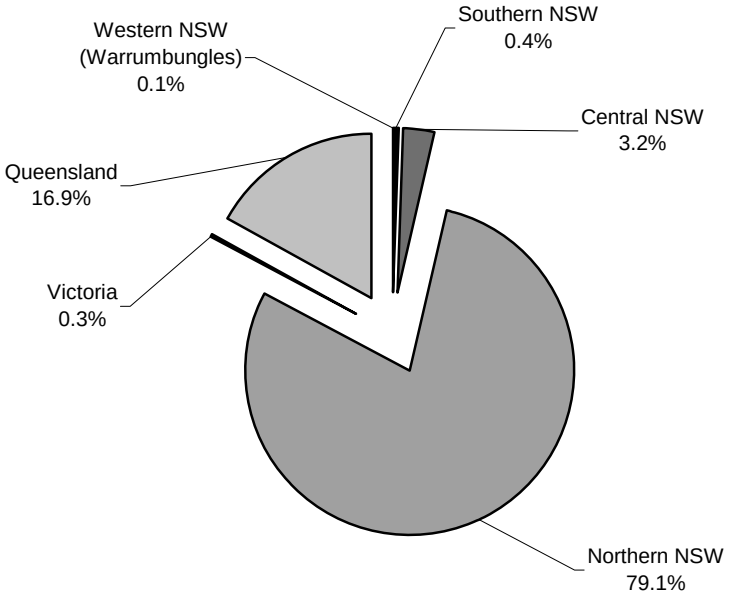

Figure 8. Estimated regional abundance of brush-tailed rock-wallabies

6 Ecology

6.1 Lifecycle

6.1.1 Reproductive biology

Females give birth to one joey at a time, after a gestation period of approximately 30 days (Close 1993). The young remain in the pouch for six months. After the joey first emerges from the pouch, it spends a further 7–20 days in and out of the pouch. As BTRWs are crepuscular (that is, most active at dawn and dusk), young may be left at dawn, dusk or at night in refuges while the mother moves out to feed. Weaning is believed to occur 86 days after leaving the pouch, when the joey is nine months old (Lee and Ward 1989). Sexual maturation of females occurs at 18 months, males at 20–24 months (Lee and Ward 1989, Rob Close pers. comm.). A recent study at Hurdle Creek (Queensland) showed that most males did not begin to father offspring until they reached a weight of 5.2 kilograms and that most breeding males fathered the offspring of multiple females (Goldizen pers. comm.). Life expectancy in the wild is 5–10 years or more (Eldridge et al 1988), and can be longer in captivity.

The minimum time between litters is likely to be 210 days (Lee and Ward 1989). The number of joeys born per year is related to dominance. A study by Joblin (1983) found the dominant female of a group produced 1.09 joeys per year, and the subordinate females produced 0.59 per year. Reproductive success appears to be related to both the dominance rank of breeding females and the habitat the breeding female occupies.

A study of BTRWs on Mototapu Island gave an average age to independence of 230 days, and a mean of 1.35 joeys born per year per female (Bachelor 1980). Breeding seemed to have no particular season and was continuous year-round, probably depending on food availability. Continuous breeding has also been observed in the Shoalhaven Valley where young were seen to vacate the pouch in January, March (twice), April, July, October and November (Susan Robertson pers. obs. cited in NPWS 1999b). In contrast, a study in the Macleay River gorges found that April had the highest birth rate, with most juveniles vacating the pouch during August–November and dispersing during March and May (Joblin 1983). In the same area, Bayne (unpub.) observed some year round breeding with a peak of large pouch young (when they are most easily seen) in late spring, consistent with an autumn peak in birth rates. More recently, a study of breeding patterns of females at Hurdle Creek (Queensland) found that more than 50 % of females in the colony were giving birth to only one joey per year and therefore considered to be breeding below their full potential. This is thought to be related to female condition, although the study did not determine which factors were likely to be affecting their condition. Births in this colony generally peaked in autumn. Young born in autumn or winter left the pouch during spring or summer when food was most abundant, and had a much higher probability of survival through to pouch emergence than those born during spring and summer (Goldizen pers. comm.).

Male BTRWs are thought to be polygynous (i.e. they have more than one partner at a time), with a single male fathering offspring of other males (Goldizen pers. comm.). Female BTRWs are serially monogamous, mating with a single male until he disappears from the colony, then switching to another male (Goldizen pers. comm.). BTRWs often live in family groups of 2–5 adults and usually one or two juvenile and sub-adult individuals (Joblin 1983, Short 1980), but also occur in male–female pairs (Bayne pers. comm.). Mating pairs have highly overlapping home ranges, suggesting that matings occur in local breeding groups that contain a single mating male and one or more breeding females which are close relatives. In the Hurdle Creek survey,

the absence of offspring fathered by roving males suggests this social structure may be the main contributor of maintaining genetic diversity in this species.

6.1.2 Reproductive specificity

Bee and Close (1993) studied the contact zones and the fertility of hybrids produced in captivity of a number of species of the eastern *Petrogale*. Introgression (gene flow from one species into the gene pool of another by backcrossing a hybrid with one of its parents) was identified between the BTRW and Herbert's rock-wallaby (*Petrogale herberti*) and two other *Petrogale* species. Both BTRW and Herbert's rock-wallaby have discrete distributions and only co-occur at the one site where hybridisation occurs (Rob Close pers. comm.). Bee and Close argue the range of morphologically and chromosomally distinct forms of rock-wallabies indicates there is very little to no gene flow between different species of *Petrogale*.

6.1.3 Genetic distinctiveness

The pattern of sequence divergence of BTRW mitochondrial DNA (mtDNA) indicates the presence of three genetically distinct groups or Evolutionary Significant Units (ESUs) (see section 3 and Figure 9). These units consist of:

1. The Northern ESU – a less well defined group of populations in south-eastern Queensland and north-eastern NSW, at least as far south as Woko National Park (Eldridge and Browning 2004). The mtDNA of this group appears most closely related to Herbert's rock-wallaby and may be the result of natural introgression (Eldridge and Close 1992, Bee and Close 1993).
2. The Central ESU – a well-defined central NSW group consisting of closely related populations in the region from the Shoalhaven and Jenolan Caves to Broke and the Warrumbungles.
3. The Southern ESU – a highly divergent lineage consisting of remnant Victorian populations. Representatives of this lineage may have previously occurred in southern NSW.

While the exact level of taxonomic difference remains to be established, it is clear that these three groups exhibit important genetic variations that should be maintained.

The exact boundaries between ESUs are yet to be determined. The boundary between the Northern and Central ESUs lies somewhere between Broke and Woko National Park, and may be centred on the Hunter Valley. Defining the boundary between the Central and Southern ESUs is likely to remain problematic as there are no animals in the Southern ESU living in NSW. Therefore, these boundaries should be considered as **guides only** for management and recovery purposes, and apply mostly to the maintenance of genetic integrity of the three taxonomic groups.

It was previously thought that all sub-adult males and most sub-adult females disperse from their refuges of birth (Joblin 1983). However, recent work examining patterns of inter-colony gene flow, intra-colony gene flow and genetic mating systems has shown significant levels of genetic structure within and among colonies. Studies on the microsatellites and mtDNA of BTRWs indicate that BTRW populations are naturally highly structured and that the amount of gene flow between colonies is limited (Eldridge et al 2001, Eldridge et al 2004, Piggott et al 2006b). For example, restrictions in gene flow can occur over distances of approximately four kilometres or even less (see Piggott et al 2006b). Recent studies on BTRW dispersal indicate that females are more related to females living near them than those further along the same cliff-line, whereas males are more likely to disperse (Hazlitt et al 2004, Piggott et al 2006b).

It is important to note that these studies indicate that gene flow between populations is not completely absent. Instead, it is this low level of gene flow which has maintained the genetic health and cohesion of the BTRW as a species for millennia.

Relatively undisturbed populations of BTRW still contain high levels of genetic diversity (as measured by microsatellites). However, in areas where BTRWs have declined, the remnant populations have lost considerable amounts of genetic diversity and remaining individuals are often highly related. The high genetic differentiation between even neighbouring BTRW colonies (each colony may contain unique alleles) means that the loss of a single colony results in the loss of genetic diversity from a series of colonies (Piggott et al 2006b). Research has shown that even in undisturbed areas, the genetic diversity of any single colony (irrespective of size) represents only a small proportion of the genetic diversity of several colonies. To conserve the genetic diversity of BTRW populations, as many colonies as possible must be protected and ideally, connectivity must be maintained between those colonies. Demographic, environmental and genetic unpredictability severely threaten the survival of these remnant populations.

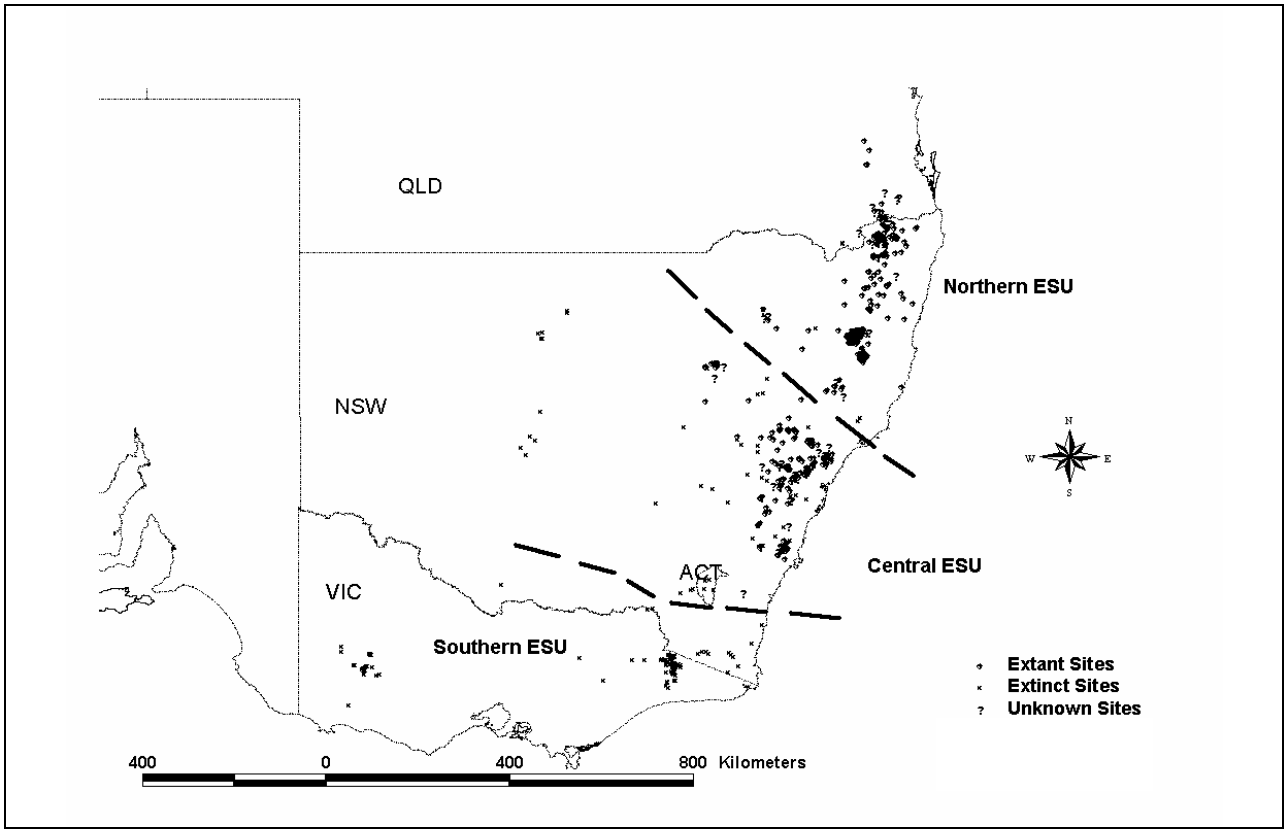

Figure 9. Indicative distribution of brush-tailed rock-wallabies in Evolutionary Significant Units (NB: Boundaries are indicative only)

6.1.4 Recruitment rate

The rate of recruitment and the dynamics of dispersal are little known areas of BTRW ecology. As discussed above, the species appears to have low migration rates between colonies. Low recolonisation rates may be exacerbated by human-induced land use changes and predator pressures. Evidence of dispersal between four BTRW colonies in undisturbed habitat in Wollemi National Park was shown using microsatellites, and the dispersal rate was estimated to be approximately 5%. There was no significant evidence of sex-biased dispersal between these

colonies. Both male and female dispersers were identified, although there were more males than females among the dispersers (Piggott et al 2006b).

Recent human induced BTRW population declines, extinctions and fragmentation have almost certainly severely disrupted the natural process of low level gene flow that has been occurring within this species for thousands of years. As colonies are isolated and restricted to rocky habitats, migrating individuals may be impeded by degraded intervening habitat and more susceptible to predation by foxes using cleared landscapes.

6.2 Diet

Throughout their range, BTRWs feed on a wide variety of grasses and shrubs, and have flexible dietary requirements.

Wakefield (1961) reports finding leaf-fragments of *Clematis microphylla* in the stomach contents of a BTRW, and observed BTRWs feeding on flowers of *Helichrysum conditum, Rhagodia nutans, Rhagodia hastata* and *Microlaena stipoides*, the latter preferred to *Danthonia semiannularis*. A decade later, while investigating colonies in the Grampians in western Victoria, Wakefield (1971) recorded BTRWs feeding on grasses (*Danthonia setata, Stipa semibarbata*) and shrub foliage, browsing additional shrub species for seeds and flowers, and eating the sedge *Lepidosperma filiformes*. Wakefield also noted that species of *Poa* were not eaten.

Jarman and Phillips (1989) analysed one sample of BTRW scats at Wallaby Creek and detected 95% grasses and 5% other plants (dicotyledons).To date, the most detailed research data on the diet of BTRWs was collected at two sites in eastern NSW – Kangaroo Valley and Goulburn River (Short 1989). The results of this work largely substantiate the earlier observational records of the species. Averaged over both sites, the diet of the BTRW consisted of 35–50% grasses, 25–40% forbs and 12–30% shrubs and other plants. However, Short found only minor indications of seasonality in diet, with fruits important in spring at Goulburn River, and grasses forming a greater percentage of food items in summer at Kangaroo Valley.

Ferns, sedges, orchids, roots, bark, flowers, seeds, fruits, lichen, termite mounds, bones, rotten logs and cowpats have all been recorded as part of the diet of different species of rock-wallaby (Short 1980, Copley and Robinson 1983, Short 1989, Horsup and Marsh 1992). These varied food items, and the success of introduced BTRW populations overseas, such as in New Zealand (Batchelor 1980) and Hawaii (Lazell 1984), indicate the BTRW may be an adaptable grazer or browser. Further research is required to determine the preferred diet, how diet is affected by invasion of weeds and how diet affects BTRW condition and reproduction.

6.3 Predators

Predation is thought to have a significant, if not the greatest, impact on BTRW populations, through loss of young wallabies that have just left the pouch and of dispersing young wallabies (e.g. Christensen 1983, Banks 1997, Sharpe 2000). Foxes (*Vulpes vulpes*), dogs, cats, wedge-tailed eagles (*Aquilla audax*) and possibly tiger quolls (*Dasyuridae*) (J. Reside pers. comm.) prey on rock-wallabies. Foxes are thought to be the major factor in the decline of the smaller black-footed rock-wallaby (*Petrogale lateralis*) in south-western Australia (Kinnear et al 1988, Saunders et al 1995, Kinnear et al 1998). Bayne (unpub.) reported a fox appearing to systematically search sites at one BTRW colony. A large feral cat has been observed eating

juvenile allied rock-wallabies (*Petrogale assimilis*) in northern Queensland (Spencer 1991). Reported predators of other species of rock-wallaby include pythons, the king brown snake, and the white-bellied sea-eagle (Eldridge pers. comm.).

Adult BTRWs are not in the high risk 'critical weight range' group of native fauna thought to be at most risk of predation by foxes and dogs (Burbidge and McKenzie 1989, Burbidge and Friend 1990). However, juvenile and sub-adult BTRWs do fall into this group and are therefore considered most at risk.

Circumstantial and anecdotal evidence indicates that BTRWs are eaten by introduced foxes and dogs. Foxes are agile climbers known to access refuge areas. Wild dogs are less likely to invade refuge areas but are a threat to BTRWs while they forage. For example, BTRW remains have been found in two dog scats in the Apsley and Macleay national parks (Lunney et al 1996), and in one fox scat at the Warrumbungle National Park in 1995 (A. Miller pers. comm.). It appears that predation by introduced predators is likely to threaten BTRWs throughout much of their range.

Banks (1997) found seasonal increases in the proportion of eastern grey kangaroos (*Macropus giganteus*) in the diet of foxes in an area of the NSW Southern Alps which correlated with the emergence of juvenile kangaroos from the mother's pouch. Banks also detected the remains of juvenile kangaroos at fox dens, and observed foxes harassing female kangaroos with young.

Even though their habitat provides BTRWs with some protection from predation, it may not protect foraging and dispersing young. If the predation rate on young wallabies is equal to or greater than the birth rate of the colony, the colony will die out within the lifetime of the existing adults, that is on average, between five and ten years, unless there is recruitment from outside the colony.

Fox removal experiments were conducted in yellow-footed rock-wallaby (*Petrogale xanthopus*) populations in western NSW from 1992 to 1998 (Sharpe 1999). Results of this work indicated fox predation was a major influence on the yellow-footed rock-wallaby population, and that predation on juveniles and sub-adults was the primary reason for their limited population. However, the population recovery reported in this study has since been followed by a dramatic population crash under drought conditions due to competition for food between introduced and native herbivores, such as goats and kangaroos, and yellow-footed rock-wallabies, and competition for refuges between feral goats and yellow-footed rock wallabies. This suggests that although fox predation is a major limiting factor, drought is also an important factor, and demonstrates the complexity of these natural systems.

6.4 Competitors

The level of competition between rock-wallabies and other herbivores is generally poorly understood. Competition with native animals has been speculated as potentially affecting BTRW ecology and habitat use, especially competition with wallaroos and kangaroos (Ruming and Moss 2000, Bayne unpub., Eldridge pers. comm.), swamp wallabies (Close pers. comm.) and brush-tailed possums (Eldridge pers. comm.).

Competition between BTRWs and feral goats for refuge areas has been noted by Bayne (unpub.) and postulated by Short and Milkovits (1990). Recent declines in yellow-footed rock-wallabies in Mutawintji National Park, where a fox control program is being implemented, have been

attributed to increased competition with goats as a result of drought (see section 6.3). This is consistent with a study by Banks et al (2000) which concluded that control of foxes is likely to lead to an increase in large macropods such as eastern grey kangaroos, which will compete with BTRWs for food.

Short and Milkovits (1990) note BTRW decline has been most pronounced only in those parts of their range where sheep grazing is the common land use. However, they also note these parts are drier, with fewer areas of steep, rugged terrain, and usually higher numbers of goats, rabbits and foxes. Therefore, it is hard to isolate effects, but Short and Milkovits (1990) believe competition with goats and predation by foxes are the most important factors in BTRW decline.

6.5 Behaviour

BTRWs are nocturnal to crepuscular and spend most of their daylight hours sheltering or sunning themselves on steep rocks sheltered by a cave, overhang or vegetation. They leave shelter to feed (Maynes and Sharman 1983). The use of these refuge areas supply some protection from predators and climatic extremes (Wilson et al 1976, Short 1982, Freeland et al 1988, Burbidge and McKenzie 1989).

This reliance on refuges means the BTRW lives in small groups or colonies, with overlapping individual home ranges of about 15 hectares each (Archer et al 1985). In a study at Goulburn River, Short (1980) found that home ranges were roughly rectangular around the cliffline, ranging from 6–30 hectares in size (with an average of 15 hectares in size) and 400–900 metres along the cliff (with an average of 700 metres along the cliff). Daytime home ranges were much smaller than at night (Short 1980).

Males appear to have larger home ranges than females, and radio-tracking studies indicate that animals usually move no more than two kilometres from their refuges (Lim et al 981). This movement usually occurs at night when the animals go into the surrounding terrain to feed. Batchelor (1980) found the greatest activity occurred three hours before and three hours after sunrise and sunset, with more movement in the middle of the night than in the middle of the day.

Within colonies, both sexes establish territories that may be defended vigorously (Bayne 1994). Within their territories, each BTRW will build a pattern of behaviour that favours the same refuges, sunning spots, feeding areas and pathways (Joblin 1983, Bayne 1994). BTRW rest sites on Motutapu Island in New Zealand were exclusive 95.4 % of the time according to 2368 records, and were never shared by adult males (Grigg et al 1989). However, one male's territory will overlap one or more female territories (Joblin 1983). In a large colony studied by Bayne (1994), there were persistent close associations between one male and one female sharing the same refuges and territory, and resident females were passed from one male to another when one male displaced the other from its territory.

It appears that BTRW colonies do not generally move. Bayne (pers. comm. and 1994) has observed that individuals in the Macleay River Gorge, in northern NSW, are very loyal to their territories, with some individuals seen on the same rock year after year. Similar observations have been made at a colony at Taralga in southern NSW, although both groups in this colony moved or died during the summer of 1997–98 (NPWS 1999). BTRWs may move in response to disturbances (Close pers. comm.). A local landholder at Mt. Wallerawang in Watagan State Forest reported that BTRWs moved in response to a fire, and then returned several years later.

Norris and Belcher (1986) suggest there was once a nomadic group of BTRWs moving along the Snowy River Gorge.

6.6 Population structure

6.6.1 Total population number

The total population of BTRWs in Australia is thought to be between 15,000 and 30,000 animals. This is a significant reduction from previous numbers, as during the period BTRWs were hunted, more than 50,000 animals were shot in one region alone. It is estimated that 10,000 to 25,000 or more BTRWs in the Northern ESU, 500 to 1000 BTRWs in the Central ESU, and less than 10 BTRWs in the Southern ESU remain in the wild.

6.6.2 Natural and human induced fluctuations

Climatic modelling has been used to investigate possible past changes in the distribution of BTRWs (Cavanagh unpub.). This work suggests that under past climatic extremes, a retraction in the southern part of the species' range may have occurred, and that the extension of BTRWs into the south-west of their range, that is, into the Grampians in Victoria, may have occurred within the last 10,000 years. This work also suggests that past climatic extremes may have helped to determine the development and distribution of the ESUs, and resulted in changes in relative abundance across the species' range.

A climate and terrain modelling program was used to investigate correlations between extinct and extant sites (Bugg 1994). This study concluded there are fundamental bioclimatic differences between sites formerly and currently occupied by BTRWs in south-eastern Australia, and therefore a bioclimatic basis for the decline of BTRWs in recent years.

7 Disturbance

7.1 Fire

The impact of fire on BTRW populations is uncertain. BTRWs have been variously reported to disappear, move from, and remain in their habitat during fire. For example, there have been many fires in Kangaroo Valley which have not apparently affected BTRWs (NPWS 1999). Conversely, Wong (1997) reports colonies that have appeared to move after fire. In the Watagan State Forest/National Park, many small fires over the years do not appear to have affected the BTRW. However, at Ingles Road, a site that has been monitored since 1996–97, there appears to have been a recent decrease in BTRW abundance following a more extensive wildfire in October 2000 (C. Rummery pers. comm.). In addition, a study of BTRW colonies and habitats conducted in the Grampians area determined that the absence of recent fire meant colonies stayed where they were. It is probable that the response of colonies to fire depends on the amount of protection afforded by the colony site (e.g. caves for sheltering), and the intensity of the fire.

Fire alters the structure and floristics of vegetation, and possibly the suitability of the vegetation as habitat or food (Bugg 1995). The intensity of single fires, and changing fire regimes, will affect the availability of food resources in and around BTRW sites. Fire will probably have greater impacts in terms of loss of food when fires occur during drought, due to low sustained regrowth after fire in prolonged low soil moisture conditions.

7.2 Floods

Flooding in northern NSW in the 1990s raised concerns about the long-term stability of northern populations of the BTRW (Bayne unpub.). An absence of BTRWs was observed following extensive loss of vegetation along the lower levels of the Macleay and Clarence river catchments. It seems animals in these areas rely heavily on the structure of mesic vegetation (vegetation adapted to a moderately moist habitat) for refuge. Once this vegetation is removed, it creates an unfavourable habitat for the animals (Bayne pers. comm.). While it was expected that BTRWs would return as the vegetation regrows, this has not been investigated. These events highlight the need to avoid complacency with regard to numbers in the north.

7.3 Weeds

While there is little real evidence regarding the effect of weeds, Capararo and Beynon (1996) and Wong (1997) consider that invasion of grassy feeding areas by weeds such as lantana (*Lantana camara)* reduces habitat quality for BTRWs. Weed infestation of particularly woody or shrubby weeds, such as lantana, may both provide and exclude refuge areas, depending on the extent and intensity of the infestation.

7.4 Human disturbances

The impact of human habitation and associated disturbances on BTRW colonies varies and to some extent depends on individual landholders' understanding of, and attitude to, BTRW protection. In some areas, BTRWs have survived and bred on properties where there has been intensive human use and intrusion of core habitat for many years. However, in other localities, indiscriminate or deliberate habitat damage may have severely disrupted and fragmented colonies.

Hunting is no longer a significant factor in continuing BTRW decline. However, shooting probably played a part in earlier reduction of numbers, especially around the turn of the last

century in south-east NSW (Lunney et al 1997). Kangaroos and wallabies were declared as vermin and agricultural pests in NSW in 1880. For 30 years from 1884, Pasture Protection Boards paid bounties on rock-wallabies and many hundreds of thousands were destroyed. The exact number is unknown because the type of wallaby was often not recorded and many records are missing. In 1900, 50,820 rock-wallabies were destroyed in the Tenterfield area alone, and in 1902 there were 37,521 killed around Armidale (Short et al 1990).

Many more rock-wallabies were killed for their skins, with 92,590 sold through just one Sydney wool-broking firm in 1908 (Lucas and Le Souef 1909 in Short et al 1990). Shooting for fur and skins continued until at least the 1920s and illegal shooting was reported at least until the 1960s (Lunney et al 1997). Commercially driven hunting led to the early and steep decline of BTRWs in NSW. Intensive and prolonged hunting from at least 1880–1927 caused local extinctions, as well as widespread reductions in the size of BTRW populations (Lunney et al 1997). BTRWs were also killed for sport (Lim et al 1987). BTRWs may still be killed for food in some local Aboriginal communities (Bayne unpub.).

In many areas around the gorges in north-eastern NSW, kangaroos are culled and a small number of BTRWs may occasionally be shot through misidentification (Bayne unpub.). Although adjoining landholders are usually aware of BTRWs and actively exclude them from culling, this level of awareness is likely to vary between landowners. An education program and information kit for landholders in BTRW areas would be useful to highlight the plight of this species and help gain community support.

7.5 Drought

Bayne (unpub.) found that during a period of drought, numbers at some long-known BTRW colonies were noticeably lower than in pre-drought conditions 18 months earlier. Bayne also found many goats and cattle in areas where BTRWs occurred in Oxley Wild Rivers National Park, noted that many areas were grazed in the Macleay area, and reported that in many places along the valley floor, all vegetation except for the trees was grazed to ground level.

Short (1982) reported that BTRWs retained body condition and continued to breed successfully during a season of 50% below-average rainfall. In contrast, Kinnear et al (1988) reported a significant decline in adult survival of black-footed rock-wallabies (*Petrogale lateralis*) during a period of drought. Spencer (1991) reported a substantial drop in population size of unadorned rock-wallabies (*P. assimilis*) during a period of prolonged drought and high cat predation. The survival rate of pouch young during this time was also reported as being very low (Delaney 1997).

Drought has also been implicated in the decline of the yellow-footed rock-wallaby in western NSW (Lim et al 1992, Sharpe 1999).

7.6 Other disturbances

Little is known of the species' response to other disturbances or what happens to the animals when they disperse. They probably become more vulnerable to predation when forced to travel through open landscapes.

8 Habitat

BTRWs are widely distributed, but populations are isolated even in areas of continuous rocky habitat, particularly in the southern part of their range. A possible explanation for this pattern is that this species has specialised habitat requirements that are met only in localised and patchily distributed locations (Short 1982).

BTRW behaviour and use of habitat has probably changed in many ways in the last 200 years. The introduction of the fox, along with other human-induced changes, is likely to have modified the wallabies' rocky habitat in ways that have made it less suitable for them, so fewer sites are now occupied (Short 1982). BTRW behaviour reported by Le Souef and Burrel (1926) would seem somewhat unusual now: sheltering in hollow logs, and allowing such close approach as to be taken by hand in their caves. Also, '[w]hen hotly pursued the rock-wallaby will make for a [leaning] tree at top speed, and without hesitation spring as high as possible up the trunk, then finally gain a fork or large limb'.

8.1 Refuge sites

BTRW habitat can be classified into three categories:

- loose piles of large boulders containing subterranean holes and passageways
- cliffs with many ledges and some caves or ledges covered by overhangs – cliffs are usually over 15 metres high
- isolated rock stacks, usually sheer-sided and often containing fallen boulders.

The species' use of rocky habitat, rock stacks and boulder piles may afford greater protection from predation. Steep rocky slopes and rock stacks may provide a buffer against environmental stress (Burbidge and McKenzie 1989). All these habitats are difficult for most exotic herbivores, except goats, to penetrate; they have a patchy distribution of fuel which breaks up fires; they provide effective shelter from most predators; and they provide thermally-buffered shelter. Vegetation near rock surfaces also receives shading, and water seepage and run-off that encourages greater plant diversity, extends periods of growth and allows for occasional flushes during drought.

In one study examining habitat requirements, five key habitat variables were tested to assess their suitability as BTRW habitat (Short 1982). The variables were:

- percentage of sheltered ledges
- number of ledges
- percentage of ledges of restricted accessibility
- length of ledges
- aspect, that is, direction the habitat faced.

This habitat model reflects the current situation for the BTRW which has been influenced by environmental changes wrought by post-1788 settlers. Such changes include the introduction of the fox and other feral predators including human beings, which have raised the threshold of suitability of rocky habitat.

Since the work of Short (1982), BTRWs have been found to use a wider range of rocky habitats. They live on much less complex cliffs and will use vegetation rather than rocks for shelter, for example, in some areas of the Shoalhaven (Wong 1997) and the Macleay River gorges (Bayne

unpub.). Large spreading fig trees are a common shelter plant in the New England area (Bayne 1994).

Of 963 recorded sites, Cavanagh (unpub.) found that approximately 73% of sites had a northerly aspect (west through north to east) and 24% of sites had a southerly aspect (west south-west through south to east south-east). Although many extant BTRW colonies are on north-facing slopes and cliff lines (Short 1982), numerous colonies also occur on south-facing cliffs where parts of the site are exposed to the sun, for example, a freestanding rock pinnacle or prominent spur. Such sites are found in Kangaroo Valley (Kutzner and Dodd 1996, Wong 1997), in the Macleay River Gorge (Bayne 1994), at the Warrumbungles and at Mt Kaputar (Soderquist pers. comm.). This information suggests north-facing habitat may be preferred but is not essential, and that aspect should never be used to discount areas of potential BTRW habitat.

8.2 Vegetation

The vegetation on and below the cliff appears to be of equal importance to BTRWs. It is a source of food and shelter and in some cases may provide some protection from predation (Wong 1993, 1997). The proximity of mesic vegetation, and appropriate vegetation structure and floristics, are important habitat factors for BTRWs in the Shoalhaven (Bugg 1995). This follows similar results of studies on other species of rock-wallaby (Lim and Giles 1987, Pearson 1992). Bugg (1995) also found that core BTRW habitat in the Shoalhaven area and in Kangaroo Valley occurs where mesic vegetation is associated with complex cliffs, boulder piles and rock outcrops.

The invasion of grassy feeding areas by weed species such as lantana is thought to reduce habitat quality for BTRWs (Capararo and Beynon 1996, Wong 1997).

9 Management issues

9.1 Threats and reasons for decline

Many factors contribute to the continued decline of this species. Likely current threats are predation, competition, weeds, habitat modification, fire, drought, disease and inbreeding.

While much management focus has been on reducing predation by foxes and competition from goats, habitat modification by people seems to be the ultimate threatening process (*sensu* Simberloff 1986).

9.1.1 Habitat degradation

Australia's poor record in species extinctions is well known – 50% of all mammal species worldwide that have become extinct in the last 200 years occurred in Australia (Short and Smith 1994). Of the 258 currently identified species of non-marine mammal in Australia, 18 are now extinct and a further 35 species have declined to 50% or less of their former range (Burbidge and McKenzie 1989). In addition, a further eight species have become extinct on the mainland and survive only on offshore islands. The prime cause of these extinctions appears to be habitat alteration (Morton 1994) but little is known of the extent and effects of more subtle habitat alterations, particularly in less developed areas.

The BTRW's use of habitat has been affected by many changes. Perhaps the greatest changes are in the structure and extent of vegetation, species assemblages and species proportions. These changes have been caused by clearing, exotic plant invasion, changed fire regimes, exotic herbivore grazing and browsing, land degradation, altered nutrient status, and even altered behaviour and numbers of other native animals. How significant these changes have been on BTRW food and shelter resources is unknown. However, it is notable that most remaining BTRW populations are found in relatively undisturbed areas.

Vegetation clearing and the introduction of new predators have led to the increased isolation of many colonies, with unknown long-term consequences. Research currently being undertaken by Cavanagh (unpub.) indicates there is a positive correlation between habitat fragmentation and broad patterns of extinction in BTRW sites across the species' range.

Habitat modification continues due to rural residential and tourist developments adjacent to some colonies, and the current trend of locating these developments near escarpments and cliff lines to maximise scenic opportunities. Such sites are often core BTRW habitat and development increases the risk of colony fragmentation, permanent changes to potential dispersal corridors, an increase in the numbers of domestic animals and the removal of tree cover. Conversely, development can result in more sensitive land management where conservation measures are undertaken. Education and awareness can reduce natural fire risk, protect BTRW habitat by fencing it to protect it from stock, and result in more intensive feral animal control.

9.1.2 Predation

Foxes

The red fox is generally considered to be a major factor in BTRW decline. Le Souef and Burrel (1926) reported the ease of close approach to BTRWs in their refuges. '[O]wing to this fact, and to the depredations of the fox... the brush-tailed rock-wallaby is now scarce where it was once very numerous'. Rogers (in Wakefield 1954) speaking of Victoria said: 'it is generally thought amongst the locals that shooting reduced the numbers, but that foxes really killed them out'.

Main (1961) and Main and Yadav (1972) investigated the difference in black-footed rock-wallaby (*Petrogale lateralis*) populations on a group of islands off Dampier on the north-western coast of Western Australia. The original population on the fox-free Enderby Island was estimated to be 1500 animals while Dolphin Island (of similar size to Enderby but with foxes and feral cats present), had an estimated population of 50. After fox control on Dolphin Island, there was an almost 30-fold increase in the density of rock-wallabies. Nearby Depuch Island was surveyed in 1962 by the Western Australian Museum, and at that time many black-footed rock-wallabies were present, but there was much evidence of fox predation which had only recently arrived on the island. Twenty years later, there was no trace of rock-wallabies on Depuch Island.

The long history of circumstantial evidence implicating the fox, combined with their own suspicions of fox involvement in black-footed rock-wallaby decline, led Kinnear et al (1988 and 1998) to attempt to gain more evidence. Their work concluded that the fox was a significant factor in the demise and decline of native mammals, but that rock-wallabies can recover even under serious fox predation. The validity of these conclusions has been critiqued (e.g. by Hone 1994 and 1999). Debate over the conclusions drawn from this study shows the importance of testable hypotheses, in this case, the need to monitor predator numbers as well as prey numbers to be able to demonstrate the reasons behind measured population changes.

Hornsby (1982) has reported a juvenile wallaroo (*Macropus robustus*) falling prey to a fox. Studies by Banks (1997) and Banks et al (2000) on foxes and predation on native mammals and rabbits at Namadgi National Park have strongly indicated that juvenile mortality in eastern grey kangaroos (*M. giganteus*) was caused by fox predation. These studies also suggest eastern grey kangaroos alter their behaviour in response to threats from foxes. This is consistent with Kinnear et al's 1998 finding that predation pressure can alter habitat use and foraging behaviour in black-footed rock-wallabies.

Although foxes have been implicated in the decline of macropods in Western Australia, there is limited documented evidence of the impact of foxes on the BTRW. There are differences between the habitat of black-footed rock-wallabies in Western Australia and of the BTRW, which could affect BTRW susceptibility to foxes. Black-footed rock wallabies live on wheat plains and rocky outcrops, whereas BTRWs live in forests, on continuous ridgelines and in precipitous gorges.

Foxes are reputedly more effective predators of rock-wallabies than dingos, actively hunting them on cliffs (Rolls 1969 in Short 1982). Dunn (1984) speaks of the agility and climbing skill of the fox, and its ability to enter into all but the most inaccessible rock-wallaby refuges. Bayne (unpub.) observed foxes flushed into the open when on a BTRW-occupied cliff on three occasions, and twice watched foxes covering every part of a BTRW-occupied cliff and examining each ledge and cave (all these occasions were on gorge–rim cliff colonies). Bayne also noted that on one occasion the fox successfully negotiated a short section of slab.

In contrast, there is no strong evidence for fox predation in northern NSW. Of 144 fox scats collected in the vicinity of BTRW colonies in north-eastern NSW, none contained the remains of a BTRW (Lunney et al 1996). In addition, of 342 scats of dog, dingo and fox examined, BTRW was identified as a prey item in only 1% (Lunney et al 1996), despite the examinations being conducted to coincide with periods of pouch emergence and juvenile dispersal, when predation on the BTRW was expected to be most likely (Lunney et al 1996).

As discussed in section 6.3, results of research undertaken by Sharpe (1999) on populations of the yellow-footed rock-wallaby in western NSW initially suggested that fox predation was the major limiting influence on the population over a six-year period. However, the population subsequently crashed during a period of drought, demonstrating the difficulty in identifying and controlling limiting factors when multiple threats operate.

Dingos
Dingos also appear to prey on BTRWs, and a number of the respondents to the National Parks and Wildlife Service 1993 BTRW community survey (Bayne unpub.) reported seeing dingos chasing BTRWs with one reported known kill (Ross pers. comm. in Bayne unpub.). However, most of the remaining areas of high BTRW density are also areas with high dingo populations, indicating dingos are unlikely to be a strong threat. The presence of dingos may actually be assisting the persistence of BTRWs, through their purported exclusion of foxes (Jarman 1986), or through maintaining lower numbers of competing herbivores, especially goats (Bayne unpub.).

Feral cats
Feral cats are possible rock-wallaby predators. Spencer (1991) records the sharp reduction in the population of an isolated Queensland colony of the allied rock-wallaby (*Petrogale assimilis*) when preyed on by a single feral cat. Between July 1986 and June 1990, the adult population fell from at least 83 to about 26 individuals. Evidence was found of the cat eating two of forty-three adults (4.6%); one of seven sub-adults (14.2%); and five of eleven known young at foot (45.5%). Spencer concluded the cat had a significant effect on this population, and that the decline was largely a result of reduced recruitment. While the allied rock-wallaby is slightly smaller than the BTRW, these results have clear implications for the BTRW, especially young animals. The yellow-footed rock-wallaby, a considerably larger rock-wallaby than the BTRW, has also been recorded as falling prey to feral cats (Sheppard 1990).

Eagles
Eagle predation occurs (Reside pers. comm.), and is possibly more significant in areas where eagle numbers have increased in response to rabbit availability (Lim et al 1987). Bayne (1994) reports observing six wedge-tailed eagles (*Aquila audax*) patrol a single large rock-wallaby colony for three days during a period of drought. Bayne also reported observing a white-breasted sea-eagle (*Haliaeetus leucogaster*) dive towards a BTRW which escaped by rapidly jumping into a cave.

Recent studies on yellow-footed rock-wallabies in western NSW (Sharpe 2000; Sharpe et al in prep.) have identified it as a minor dietary component of wedge-tailed eagles in the study area (0.6 % of the total prey). Sharpe (2000) calculated that eagles killed about four yellow-footed rock wallabies each year, equating to between 2% and 4% of the population.

9.1.3 Disease

Little is known about disease in wild populations of BTRWs, although this species is probably susceptible to the same diseases found in other macropods. As BTRW colonies are naturally separate from one another, the species may be able to survive genetic ‘bottlenecks’ and recover from very low numbers (Close pers. comm.). Inbreeding may be present in some colonies, for example, the Jenolan Caves colony, resulting in suppressed reproduction.

A study which found massive infestations of hydatid cysts in the thoracic cavities of BTRWs suggests a relationship between hydatidosis in BTRWs and sheep (Close 1984 in Lobert 1988). Lobert (1988) also raised the possibility that BTRWs are susceptible to toxoplasmosis infection, carried by cats. A BTRW in Kangaroo Valley was reported to have died from toxoplasmosis in addition to liver fluke infestation (Eldridge pers. comm.).

Lumpy jaw was present in the captive colony at Jenolan Caves before 1988 (Buchan 1995). This disease is more prevalent in populations of macropods which are exposed to human contact and fed soft processed foods.

9.1.4 Competition with introduced and native herbivores

In general, the level of competition between BTRWs and other herbivores is poorly understood. The study outlined in section 6.4 (Short and Milkovits 1990) noted that BTRW decline was most pronounced in parts of their range where sheep grazing areas were occupied by goats, rabbits and foxes. Although the study admitted it was hard to isolate threats, it concluded that competition with goats and predation by foxes were the most important factors in BTRW decline.

Competition with goats is considered partly responsible for the decline of the BTRW on rocky habitat west of the Great Divide as shelter sites there are now occupied by goats (Short and Milkovits 1990). Rabbits also could compete with the BTRW, particularly when food is scarce.

Although direct competition is hard to measure, Lim et al (1987) noted the presence of goats significantly affected the recovery of yellow-footed rock-wallaby populations after drought. Goats can compete for shelter, and Copley (1983) reported goats evicting yellow-footed rock-wallabies from caves.

Bayne (unpub.) has also observed BTRWs being flushed from sites by goats, and refuge sites disturbed or destroyed. In its 1997 *Final determination on the Warrumbungles population of brush-tailed rock-wallabies*, the NSW Scientific Committee stated that competition from goats for shelter sites and food constituted a major threat to the Warrumbungles BTRW population, and that competition was likely to increase during periods of drought (NSW Scientific Committee 1997).

Goat control was undertaken in areas around yellow-footed rock-wallaby colonies in western NSW (Sharpe 1999). Although the population was not directly monitored, numbers slowly declined during this period. Sharpe concluded that either the goat control program had little impact on the goat population, or competition with goats was not the major limiting factor for the yellow-footed rock-wallaby population.

The removal of refuge vegetation may be one of the more important impacts of feral herbivores. Many BTRW refuges, particularly in the northern rivers gorges in north-eastern NSW, consist mainly of vegetation, and agile browsers like goats could totally destroy them (Bayne unpub.). It is likely that the low number of suitable refuge sites is a limiting factor in the distribution of the BTRW.

While competition with herbivores other than goats is difficult to demonstrate, the impact of habitat alteration may be significant. For example, Pearson (1992) considered rabbits were a major factor in altering the habitat of black-footed rock-wallabies. The effect of rabbits may be

spasmodic, and may only be significant during a drought. It is likely that rabbits had major effects during the rabbit plagues of early last century (Lobert 1988).

After comparison of the diets of yellow-footed rock wallabies and other herbivores in western NSW, Dawson and Ellis (1979) concluded that even in good conditions there was considerable overlap in the species eaten by the rock-wallabies and by goats and rabbits, and that this increased when vegetation conditions deteriorated, when dietary competition, especially from goats, became severe. Bayne (unpub.) has also observed a rock-wallaby to be flushed away from a small outcrop on a steep grassy slope when cattle grazed to within about 10 metres of the rock-wallaby.

Increased competition with native herbivores could also contribute to BTRW decline. Competition with wallaroos (*Macropus robustus*) and eastern grey kangaroos (*Macropus giganteus*) has been reported. For example, in many parts of the Macleay River gorges, reliable stock water supplies and improved pasture along the gorge rims has resulted in very high numbers of wallaroos and kangaroos inhabiting some rim areas (Bayne pers. obs.). In parts, the densities of these larger macropods along the gorge rims are so high that their tracks into the gorge, where most shelter during the day, are considerably eroded. These densities are often many times higher than in areas where fences prevent the movement of large macropods between gorge and pasture. These artificially high large macropod numbers, especially where maintained by protection in national parks and annual dingo/dog aerial baiting programs, could degrade BTRW habitat in the gorge country (Bayne unpub.).

Swamp wallabies (*Wallabia bicolor*) may compete with the BTRW for food and shelter (Close pers. comm.) although they co-exist naturally. Brush-tailed possums may also be competitors (Eldridge pers. comm.; Moss pers. comm.). Therefore, where these species co-exist with BTRWs, the impact of competition should not be discounted.

As foxes prey on a range of native and introduced herbivores, the impacts of likely increased competition between herbivores including the BTRW must be considered at sites where foxes have been controlled.

9.1.5 Weed invasion

Lantana invasion may reduce the amount of suitable habitat. In low densities or clumps, it can provide shelter for BTRWs (Maynes and Sharman 1983; Wong 1997), and possibly some protection from predators (Wong 1993 and 1997), while dense lantana is likely to be detrimental. Capararo and Beynon (1996) reported that lantana had overgrown feeding areas below the cliff at Kangaroo River, and that it may have contributed to the extinction of the Upper Kangaroo River colony.

The relationship between disturbance leading to the loss of native vegetation cover and the introduction of weeds is little understood in relation to the BTRW. Further research is needed on how changes in management regimes, such as removing cattle, affect weed invasion and ultimately the suitability of habitat for the BTRW.

9.1.6 Fire

Fire may harm or benefit BTRWs, depending on its intensity. A very hot, widespread fire in 1983 in south-eastern NSW burnt from Bundanoon to nearly Hampden Bridge in Kangaroo

Valley (NPWS 1999), and could potentially have adversely affected the BTRW colony in the area by preventing their escape. Bugg (1995) speculates the Kangaroo River colony has persisted because much of its habitat remains unburnt. Major fires erupt in the area on a 10–15 year cycle and remain a constant threat to BTRW colonies. DECC and local bushfire services conduct hazard reduction works in strategic locations in the area to minimise the risk of major fires, but acknowledge the potential of worst case situations (NPWS 1999).

There is anecdotal evidence of easterly movement of the Kangaroo River colony after the 1983 fire. Lobert and Waters (1988) and Pearson (1992) consider that fire may reduce food availability for the BTRW, but Capararo and Beynon (1996) consider fires adjacent to rock-wallaby colonies may favour grass growth for feeding.

Over many years, fires may change the vegetation structure and floristics. For example, frequent burning is likely to be responsible for the loss or contraction of rainforest. Bugg (1995) believes that vegetation change may partially explain the local decrease in BTRW abundance at Kangaroo Valley. The impact of fire regimes on this species requires research.

The ultimate impact of fire is probably determined by the combination of fire intensity and regime, which are determined by land management practices, topography and climatic factors. Further research in this area is required. In assessing the appropriate management response to fire, both the effects on vegetation structure (e.g. promotion of grasses, opening of canopy, loss of mesic vegetation), and other factors (e.g. fox and goat invasions), will need to be considered.

9.1.7 Bioclimatic factors

The influence of bioclimatic changes on BTRW distribution remains unknown. Some argue that bioclimatic changes, resulting in lower rainfall and a decline in rainforest vegetation, have contributed to the contraction in BTRW distribution (Bugg 1994). In contrast, Short and Milkovits (1990) consider climatic variables relatively unimportant compared to micro-habitat variables. The great habitat flexibility demonstrated by BTRWs suggests that, given a slow transition in climate that alters rather than changes habitat, the species may be able to adapt locally to future climate changes.

Preliminary research indicates that some climatic variables correlate with extinction patterns in the species across its range. However, it is likely that these correlations are not causative, but rather reflect the patterns of other extinction factors, for example, land clearing and fox numbers (Cavanagh unpub.).

Cavanagh (unpub.) has investigated the potential impacts of future climate change on BTRW distribution. The preliminary results of this work indicate that under the most likely climate change scenarios (after Bennet et al 1991), there will be most implications for BTRW populations in East Gippsland, the central and western Blue Mountains and the central gorges of the New England Tableland. This would indicate further stressing of the East Gippsland population, and potential stressing of around 30% of the BTRW's total population in the Macleay River gorges. In the central regions, the northern Blue Mountains populations may have better future options for survival, owing to loss of the suitable bioclimatic conditions in other areas.

9.1.8 Management actions

Threatening processes operating across the landscape, such as clearing and changing land use, are key factors for management to address, and are perhaps the most challenging for recovery planning.

While some threatening processes are significant in some areas, there does not seem to be a single cause for decline across the entire range. In some respects, this should not be surprising, given the geographic range and the variability of habitat that this species occupies. However, as fox predation has most often been cited as the primary or critical threatening process, limited resources have most often been allocated to fox control programs.

Two critical components of threat abatement are:
1. to identify the main local and widespread threats and the interactions between these
2. to monitor the effectiveness of management responses.

Both identification and monitoring will need to be undertaken across the species' range to achieve long-term recovery of the BTRW. For example, large colonies may be able to generally survive fox predation, meaning fox control would only be necessary during drought or after widespread fire. Captive breeding and translocation may provide an opportunity to create self-sustaining populations.

There is a need to ensure regional-scale threatening processes are considered when determining appropriate responses. For example, fox predation does not appear to be as significant a threat in the north as it is in the south. This may be because fox numbers in forests in the north appear to be less than in the south (Catling and Burt 1995). However, there is some evidence that there are more foxes when there are more private or cleared lands in an area (e.g. Catling and Burt 1995, Cavanagh unpub., Ormay pers. comm.). It may be that variation in the degree and pattern of habitat fragmentation in southern NSW compared to northern NSW is the major threatening process, and fox predation a result of such clearing (after Simberloff 1986).

Although DECC has a good understanding of the threatening processes affecting the BTRW, control of threatening processes at some sites will continue to be problematic.

9.2 Site effects

The threatening processes affecting BTRWs are little understood, multi-level and usually interrelated. The interrelationships are often complex. Similar outcomes may be observed at sites that are caused by different threats or different relationships between similar threats. The effects of these threats on sites in terms of habitat and resources are summarised in Table 5 overleaf:

Table 5. Damage to brush-tailed rock-wallaby sites from threats

Outcome	Cause of outcome	Agents contributing to cause
Loss of diurnal refuge sites	Loss of and damage to vegetation	• the clearing of native vegetation • grazing by probably mostly feral goats but potentially other herbivores • fire • floods
	Replacement of vegetation	• invasion by exotic weeds such as lantana
Loss of, or damage to, food resources	Removal of food sources	• vegetation changes caused by other herbivores (feral, stock and native) • vegetation clearing and agriculture • changed fire regimes • exotic weed invasion
	Reduction in diversity, persistence and temporal availability of food resources	• vegetation changes caused by other herbivores (feral, stock and native) • vegetation clearing and agriculture • changed fire regimes • exotic weed invasion
	Reduced access to food resources	• pressure from predators leading to behavioural change • vegetation changes caused by other herbivores (feral, stock and native) • vegetation clearing and agriculture • changed fire regimes • exotic weed invasion
Loss of sheltering vegetation away from diurnal refuge sites	Reduced shelter in feeding areas	• vegetation clearing and agriculture • vegetation changes caused by other herbivores (feral, stock and native) • changed fire regimes
	Reduced shelter and refuge in dispersal areas	• vegetation clearing and agriculture • vegetation changes caused by other herbivores (feral, stock and native) • changed fire regimes
Habitat fragmentation and barriers to dispersal	Vegetation clearing	• subdivision and intensification of land use with its associated changes in disturbance rates, associated animals (stock, dogs, cats, foxes) and construction of roads • it is not known what level or extent of clearing will deter BTRW travel

Management programs which address just one threat or effect as a separate entity will ultimately be unsuccessful. Only an integrated threat management approach can provide for the long-term recovery of the species.

9.3 Social and economic issues

9.3.1 Social issues

DECC recognises that actions in this plan may have impacts on the public authorities and private individuals who own or manage land on which the species occurs. Some public and private landholders are reluctant to conserve habitat, and view recovery actions as an intrusion on their rights to manage their land. While these opinions are in the minority, they constitute a challenge for the recovery effort. Personal and regular contact with landholders is a key strategy in encouraging awareness and involvement.

Most BTRW colonies are remote, with few to no interactions with humans. Nevertheless, it may be necessary to restrict visitor access to some sites on public lands where the BTRW population is sensitive to human disturbance. This would not occur without public consultation, and any negative social consequences of restricted access should be minimised.

Positive impacts of recovery include increased preservation of habitats, which will improve the land's aesthetic, recreational and educational value. In Kangaroo Valley, the formation of a BTRW support group has brought added social benefits to the community.

The cultural and historical significance of the BTRW, particularly to the indigenous community, is largely unknown. Improving understanding of BTRW significance in the community will help DECC to manage the species.

Additional positive social consequences of recovery actions include (after NPWS 1999):

- more sophisticated and responsible use of 1080 poison (which is used to control foxes) in the rural community
- landholders working together to control introduced feral animals
- government and research institutions improving ways of communicating current research and technology to the community, and more informed community responses to the government
- the community demonstrating that it can effectively protect threatened species given the necessary training, information and resources
- the government demonstrating that consultation with the community followed by clear direction and ongoing support can achieve success in meeting objectives
- an increased knowledge and appreciation of threatened fauna and biodiversity in general.

9.3.2 Economic issues

The implementation of actions in this recovery plan will result in some degree of economic impact. However, in general, BTRW habitat is largely unsuitable for economic development and there are few land-use proposals completely incompatible with BTRW conservation.

This proposed recovery strategy also seeks to minimise economic impacts through the prioritisation and targeting of recovery efforts. Without a strategic approach to managing this species, and with the continuation of current practices, it is likely that local extinctions will continue, particularly in the southern part of the BTRW's range, given the current rates of loss and degradation of habitat.

The economic consequences of the recovery of the BTRW are the costs associated with implementing this plan. It difficult to estimate the exact costs, as the BTRW occurs on so many sites. However, efforts will be concentrated on conserving the BTRW on publicly-owned land.

Actions involving on-ground management programs and the long-term monitoring of sites will also have economic consequences for land managers. However, these programs will involve activities which are normally required to effectively manage land, such as weed control and feral animal removal. Costs for land managers can be minimised by seeking funding from external sources and by adopting a cooperative approach to management involving DECC, Catchment Management Authorities, other relevant landholders and the community.

In addition to areas managed by DECC, additional areas will need to be managed to conserve the species outside national parks and reserves.

There are at least three options for conserving the BTRW on lands that are not managed by DECC:

1. DECC can negotiate with relevant stakeholders and implement joint conservation management programs.
2. DECC can acquire land in high priority areas that is otherwise poorly represented in national parks and reserves.
3. DECC can encourage landowners or leaseholders to enter into voluntary agreements to conserve the BTRW.

These options should be evaluated in terms of their effectiveness in assisting the recovery of the BTRW, and their economic impact on land managers. Sympathetic management of lands adjacent to BTRW colonies may benefit landowners and land managers by leading to a reduction in goat and fox numbers. Such a reduction may outweigh potential negative impacts such as diminished economic returns from the conserved area. Landowners entering into conservation agreements may also benefit from tax relief.

It is considered that there will be other positive economic consequences from implementing the plan, including:

- for government, overall cost savings by investing in community training and resourcing to minimise public labour expenditure in feral animal control, and more efficient resource use, as management of the species will be more coordinated and strategic
- for the rural community, reduced predation on, and spread of disease to, livestock, and an improvement in long-term agricultural productivity through better land management practices for wildlife
- for landholders negotiating conservation agreements, positive financial outcomes such as tax relief.

9.4 Scientific and taxonomic value

Macropods comprise almost 40% of Australian marsupials and are one of the continent's most successful faunal groups. Rock-wallabies form the largest group of macropods, representing 31% of extant species, and are an internationally recognised model for the study of chromosome evolution and speciation (Eldridge pers. comm.).

The great variation within the rock-wallaby genus *Petrogale* has been attributed to the highly discontinuous distribution of species populations (Poole 1978, Maynes 1989). In all, 28 different rock-wallabies were described between 1827 and 1992, of which 25 were assigned to the genus *Petrogale*, and three to the genus *Peradorcas* (Briscoe et al 1982). There are currently 16 species of rock-wallaby in the *Petrogale* genus, with the genus *Peradorcas* now recategorised as *Petrogale* (Calaby and Richardson 1988).

Much of the work on the taxonomy of *Petrogale* through the late 1980s to early 1990s has been based on identifying characteristic chromosome and genetic markers, involving cytogenetics and G-banding techniques (Eldridge and Close 1992). Phylogenies (evolutionary developments) derived from these techniques have revealed inadequacies in the present taxonomy, indicating a need for a general revision of the genus, and of the eastern taxa in particular (Eldridge and Close 1992).

9.5 Role and interests of indigenous people

To contribute to the preparation of this plan, DECC has assisted in developing a community-based research project across the four Local Aboriginal Land Council areas which cover much of the core habitat of the BTRW in northern NSW. Elders and relevant individuals are being asked to contribute their knowledge of the BTRW, and are being consulted about their issues and concerns. The project enables each community to express their views about ways in which the Aboriginal community should be involved in threatened species management generally. The following Local Aboriginal Land Councils, national parks and state forest areas are covered by this consultation:

- Armidale (Oxley Wild Rivers National Park, Guy Fawkes River National Park, Styx River State Forest)
- Amaroo, Walcha area (Oxley Wild Rivers National Park)
- Guyra (Guy Fawkes River National Park and Guy Fawkes River State Conservation Area)
- Purfleet (Nowendoc National Park, Woko National Park, Tuggolo State Forest and Mernot State Forest).

9.6 Biodiversity benefits

Given the broad geographic range of the BTRW, there will be overall biodiversity benefits from implementing this recovery plan. The mesic vegetation, sandstone escarpments and outcrops that form much of the species' habitat include a broad range of habitats including rainforest, closed woodland, open woodland, wetland and heath. These areas are home to a range of fauna which are listed under the TSC Act.

As identified in the NSW fox threat abatement plan (NPWS 2001), a broad range of native animals are threatened by the fox. Several of these, such as the rufous bettong, share habitat used by the BTRW. Control of predators, introduced herbivores and weeds, and habitat conservation and increased public awareness as a result of this recovery plan, will benefit other native fauna.

9.7 Overview of Evolutionary Significant Units (ESUs)

The following information will assist managers who are responsible for BTRW recovery to manage consistently within and between ESUs. Boundaries between ESUs are indicative, both in terms of their location and their effect, and should be seen as guides only (see Figure 10).

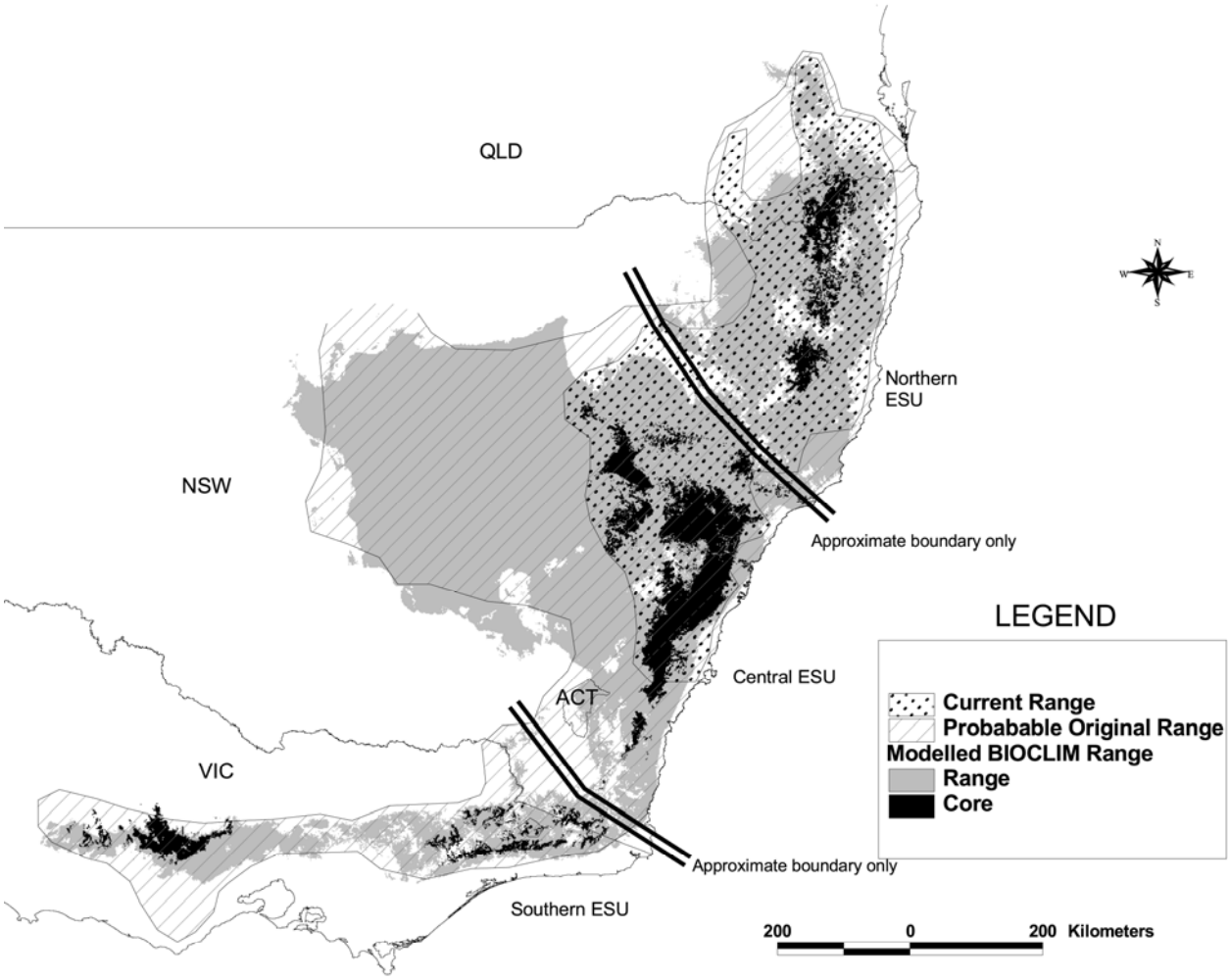

Figure 10. ESUs and the bioclimatic range of BTRW
(NB. ESU boundaries are indicative only.)

9.7.1 Northern ESU

There are many BTRW colonies in the Northern ESU and it is estimated that over 90% of BTRWs belong to this group. While there is the possibility of local, short-term extinctions, the Northern ESU populations should be secure in the long-term. There are large tracts of suitable habitat, much of which is in national parks and reserves, particularly in the region from northern Washpool National Park to southern Oxley Wild Rivers National Park. Potential habitat is more fragmented north of Washpool National Park (up to and beyond the NSW–Queensland border), and in the southern part of the ESU towards the Hunter Valley. While there is varying potential for animals to move through the ESU, colonies north of Toowoomba appear to be separated from populations in south-eastern Queensland (Lundie-Jenkins pers. comm.).

In a biogeographic context, populations in the Northern ESU occur mainly in the New England Tableland, NSW north coast and south-east Queensland Interim Biogeographic Regionalisation for Australia (IBRA) bioregions. There are also sites in the Nandewar IBRA bioregion**.** While modelling indicates the bioclimatic core in this northern region occurs north of the Hunter Valley around the Upper Manning River, there is a strong bioclimatic envelope following the ranges as far north as Noosa in south-eastern Queensland (Cavanagh unpub.).

The reasons for the persistence of large populations in this ESU compared to the Southern and Central ESUs is not known, although as noted earlier, lower fox densities and variations in habitat fragmentation may be major factors. However, the highest non-urban fox densities measured to date in Australia were recorded by Thompson and Fleming (1994) in the Northern Tablelands of NSW, who measured 4.6–7.2 foxes/km^2. The next highest published measurement is for Central Victoria of 3.9 foxes/km^2 by Coman et al (1991).

Research into the Northern ESU contingent of BTRWs can provide knowledge about robust populations which can in turn provide important information about recovering the species. However, the robustness of these populations is still in question, as recent work has indicated Northern ESU populations are also in decline. Further surveys and monitoring programs are needed to provide firmer estimates of abundance and connectivity between populations.

9.7.2 Central ESU

Most BTRW colonies in the Central ESU appear to be in the northern Blue Mountains national parks (Wollemi and Yengo national parks). The severe decline in the wild colonies around Jenolan Caves, while possibly a local phenomena, indicates that the populations in the southern Blue Mountains are in decline and may be more threatened than those in the north. Knowledge of the occurrence and abundance of BTRWs in the central, less accessible areas of the Greater Blue Mountains national parks is poor, and current estimates may be wrong. However, it is highly unlikely that numbers are greater than 2000, even allowing for error. There are also some sites on which BTRWs have become extinct and one small extant colony between the southern Blue Mountains and Shoalhaven populations, but these are separated by large areas of agricultural land.

Populations in the Warrumbungles and Shoalhaven regions now appear to be isolated from the Blue Mountains populations, and the long-term survival of these populations cannot be assured unless active management is undertaken. Suitable BTRW habitat exists south of the Shoalhaven populations, and it is possible that some isolated colonies exist in some of the more remote areas, for example in Deua and Wadbillaga national parks. The small numbers and isolated nature of the Warrumbungles and Shoalhaven populations places them at some risk from inbreeding. This may be a factor in the long-term survival of these populations. On the basis of present knowledge, the Shoalhaven and Warrumbungles populations represent the edges of the range of BTRWs in the Central ESU and are separate from other populations. In this context, conservation of these colonies on-site must be a priority for management.

Extant Central ESU populations occur largely in the Sydney Basin. BTRWs are extinct in the South Eastern Highlands and South East Corner IBRA bioregions. The Warrumbungles population is in the Brigalow Belt South IBRA bioregion. The largest bioclimatic core area for the species is in the Greater Blue Mountains, with smaller core areas in the Upper Hunter area, which is separated from the Greater Blue Mountains by the Hunter Valley. There is a general tendency for the core of the bioclimatic range to rise in elevation from south to north, with the greatest topographic range centred on the northern Blue Mountains (Wollemi) (Cavanagh unpub.). Of the two outlying western populations, the Warrumbungles population is in the bioclimatic range associated with the Greater Blue Mountains area, while the Mount Kaputar site is on the edge of the species' bioclimatic range.

Given the proximity of many of the sites in the Central ESU to urban areas, and tourism and recreational sites, community involvement in managing the more accessible BTRW populations will be vital in ensuring long-term conservation of the colonies in these areas.

9.7.3 Southern ESU (Victoria)

There are no known extant populations in the Southern ESU in NSW. As it is highly likely that the population in the Grampians in Victoria is also extinct (Seebeck pers. comm.), the small population in East Gippsland in Victoria is all that remains in the wild. This population appears to be unable to sustain itself in the long-term, and no source populations are available in the region or state. The long-term genetic robustness of these populations is threatened by inbreeding.

The Grampians population, which now appears to be extinct, occurred in the Murray Darling Depression IBRA bioregion. The East Gippsland population, and historically recorded sites, occur in the Australian Alps and the south-east corner IBRA bioregions. The Grampians site appears to be relatively bioclimatically isolated from the East Gippsland sites, and modelling of past climate changes indicates that the migration of animals to the Grampians may have taken place within the last 10,000 years (Cavanagh unpub.). There have been other historic records and sub-fossil remains from both regions, but there are no known extant colonies.

Recovery planning and conservation management in this ESU is directed through the Victorian *Flora and Fauna Guarantee Act 1988* and ensuing Victorian BTRW Action Plan under the guidance of the Victorian BTRW recovery team. The Victorian BTRW recovery team has initiated a captive breeding and translocation program.

10 Previous actions undertaken

10.1 Surveys

The NSW National Parks and Wildlife Service introduced a program to arrest the continuing decline of the BTRW in NSW in 1993. This program consisted of:

- a survey to locate all extant sites
- a community awareness and involvement campaign
- the development of population management plans for priority extant sites
- ongoing research into threats and impacts
- historical research into the timetable and causes of the decline of the BTRW in NSW.

A report on the results of the surveys has been produced for the southern part of the species' range (Wong 1993), and summarised in Bayne (unpub.) for the northern populations. More recently, surveys were undertaken in Morton National Park.

Historical research into the timetable and causes of decline in the BTRW in NSW extended the historical range of the species and indicated greater continuity in its distribution than previously recorded (Lunney et al 1997). It also identified the extent and relevance of commercially driven hunting to the early and steep decline of the BTRW (Lunney et al 1997).

10.2 Captive populations

Captive populations of BTRW are held in Australia and have been used as a focus of behavioural, management and genetic research. Two separate populations are managed in zoos through the Australian Species Management Program (the species management arm of the Australasian Regional Association of Zoological Parks and Aquaria).

Animals taken from the wild in East Gippsland, Victoria, form the basis of one of these populations. Healesville Wildlife Sanctuary manages this population in close cooperation with the Victorian BTRW recovery team. Tidbinbilla Nature Reserve (ACT) and Adelaide Zoo (SA) have also been involved in this program.

Tidbinbilla Nature Reserve, in close cooperation with the NSW BTRW recovery team, manages a second population. These animals were sourced from Kawau Island in New Zealand, and have been held in Tidbinbilla Nature Reserve, Taronga Zoo (NSW) and Gorge Wildlife Park (SA).

To date, these regionally managed populations have been used to develop husbandry protocols and to establish and refine techniques for rapid population expansion through cross-fostering, using tammar wallabies and yellow-footed rock-wallabies as surrogates (Bell and Close 1994, Taggart et al in prep, J. Reside pers. comm.).

10.3 Predator control

Fox control programs to protect the BTRW are being undertaken on a number of sites, including sites in Kangaroo Valley, Warrumbungles National Park, western Wollemi National Park (Wolgan River, Bulga to Durie, Kandos to Capertee), northern Wollemi National Park (Baerami and Widden Valley), northern Yengo National Park (Growee Gulph, Nulla Mountain), Goulburn River National Park and near Attunga in the New England area.

The NSW National Parks and Wildlife Service (NPWS) (now DECC) researched the effectiveness of NPWS and community fox baiting programs around BTRW colonies. In Kangaroo Valley, a community baiting program was implemented with NPWS in 1994. NPWS implemented a monthly 1080 baiting and monitoring program from March 1997 to 2001 around four BTRW colonies in Broke and Milbrodale in the Hunter Valley. Three unbaited sites in the Hunter and Hawkesbury area were also monitored. Continual systematic monitoring of five colonies (three baited and two unbaited) has been conducted since 1998 (Rummery et al 1997). Only limited analyses could be run on the combined data of Hunter Valley and Kangaroo Valley because monitoring in Kangaroo Valley began after monitoring in the Hunter Valley, and four years after the commencement of baiting in Kangaroo Valley. There was no significant difference in abundance over time between baited and unbaited colonies when data for both the Hunter and Kangaroo valleys was combined. However, analysis of the Kangaroo Valley data indicated that baited colonies were declining at a much slowly rate than unbaited colonies (Norton et al 2002). However, as the sample size was very small, the significance should be treated with caution.

There was a variable response in the baited and unbaited colonies in the Hunter Valley study, which led to difficulties in interpreting data. Some unbaited sites experienced less of a decline than the baited areas, suggesting there may have been differences in predation pressure between the colonies before the baiting programs were implemented (Rummery et al 2000).

Predation by the red fox was listed as a key threatening process under the Threatened Species Conservation Act in March 1998. The listing was based on the potential impact of foxes on nine threatened species listed under the Act, including the BTRW. A threat abatement plan (TAP) for predation by the red fox was prepared by the NPWS in 2001. The TAP proposes actions to reduce the impacts of fox predation on threatened species, and conserve biodiversity. The BTRW has been identified as a priority species for investigation and action under the fox TAP and a number of priority areas have been identified (see Table 6).

The objectives of the Fox TAP (NPWS 2001) are to:

1. Ensure that fox control programs undertaken for conservation purposes in NSW focus on threatened species which are most likely to be affected by fox predation.
2. Ensure that fox control programs minimise the impacts of fox predation on targeted threatened species.
3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programs.
4. Provide support for the implementation of the TAP.

Table 6. Brush-tailed rock-wallaby sites identified or monitored for fox control in the fox TAP.

DECC region	Site	Status*
Hunter	Barnard River	M
Central Coast/Hunter	Nth Yengo National Park/Broke	FM
	Nth Wollemi – Martindale	M
	Watagans	FM
	St Albans	M
Blue Mountains	Wolgan	FM
	Jenolan Caves	F
South Coast	Kangaroo Valley	FM
	Taralga	F
Northern Plains	Warrumbungles	M

* M = monitoring only; F = fox control only; FM = fox control and monitoring

10.4 Competitor control

In its final determination to list 'competition and habitat degradation by feral goats, *Capra hircus'* as a key threatening process under the TSC Act, the NSW Scientific Committee recognised the BTRW as one threatened species affected by feral goats (NSW Scientific Committee 2004). The BTRW should be considered a priority species for any threat abatement program targeting goat control.

In Warrumbungles National Park, goats are being controlled in areas where BTRWs are found. Goat control is also occurring in the core BTRW habitat of Oxley Wild Rivers National Park. Goats have not yet invaded all this area but may be expanding their range. Continuing goat control and preventing goat populations from expanding are priorities for the protection of this largest-known BTRW population. BTRWs should benefit from these goat control programs.

11 Species' ability to recover

The long-term objective of the recovery program is to halt the decline of the BTRW and to recover the species from its status as endangered. However, this objective is not believed to be achievable within the five-year timeframe of this plan. 'Recovery' through this plan will therefore focus on increasing recruitment at priority sites, and halting or decreasing the rate of decline of BTRW populations regionally and within each ESU. It will not be possible to recover the species' former distribution and abundance, given the degree of habitat modification and the fragmented nature of the species' distribution. In fact, unless actions are taken to reduce threats, the BTRW will continue to decline in its current locations and the species will become locally extinct in some areas. Given the large percentage of small and fragmented sites, and the number of threats on sites, the continued local extinction of this species is likely unless adequate resources are directed towards abating threats.

The species could recover if the actions listed in section 12 are implemented. This assessment is based on:

- the ability of BTRWs to breed rapidly under favourable conditions
- the extent of suitable habitat in their extant range, particularly in the north
- community support for protecting the BTRW in the state and nationally.

Large populations have been successfully bred from a few animals, for example, in Hawaii where a colony grew from just two animals. The development of a strategic captive breeding and translocation program to supplement small colonies has been identified as a priority for this species once predators and competitors have been controlled in such colonies.

A focus of this recovery plan is the control of predation by foxes, undertaken in conjunction with the fox threat abatement plan (see section 10.3). Actions will be undertaken to gain more information on fox predation and the effectiveness of control measures, and to implement control measures more effectively. Fox removal is likely to increase competition among herbivores, including other macropods. Therefore, in areas where fox removal can be demonstrated, herbivore monitoring and control are recommended.

BTRWs have coped with close settlement and a degree of human disturbance, for example, in the Shoalhaven (Short and Milkovits 1990). However, the type, intensity and location of the disturbance probably determine the degree of threat. The attitudes, understanding and awareness of people are critical factors in the long-term recovery of the species in settled areas. The involvement of local communities is a vital component in this species' recovery.

12 Recovery objectives and performance criteria

The following section details the specific objectives and priority actions of this recovery plan. The hierarchy of priorities reflects the relationships between the objectives and actions, rather than their importance. For example, it is necessary to better understand threatening processes and current programs before being able to improve techniques and programs. While these objectives have been developed specifically to address the recovery of the species in NSW, they are also consistent with the national recovery actions detailed in the 1996 *Action plan for Australian marsupials and monotremes* (ANPWS 1996).

12.1 Overall objectives

Program objective: The long-term major objective of the recovery program is to halt the decline of the species and to recover it from its status as threatened. However, this objective is not believed to be achievable within the timeframe of this plan.

Recovery plan objectives: The specific objectives of this recovery plan are to:

1. Increase recruitment at priority sites
2. Decrease the rate of decline in range and abundance
3. Prevent the decline of the species to a level at which it would risk becoming extinct in the wild
4. Increase knowledge to enable more effective management of the species.

The key to achieving these objectives will be to maintain and increase regional populations in each ESU. As the protection of all BTRW sites is not possible through this plan, the plan does not aim to necessarily conserve all populations.

This plan acknowledges that in the short- to mid-term there will continue to be losses in abundance and some extinction of local populations, and that some contraction of the species' range may occur regionally due to these losses. This plan seeks to offset these impacts by controlling predators and competitors at priority sites and establishing captive breeding programs to support on-site management where required.

A further critical element is to efficiently manage threats, and the first step in that process is to gain a better understanding of threatening processes. Having said that, lack of knowledge should not impede active conservation management, especially when positive results can be achieved without the full extent of knowledge about causes.

Five priority strategies have been identified to achieve the overall objectives of this plan: coordination, research, site management, community involvement, and captive breeding and translocation.

Table 7. Summary of recovery objectives and actions for conservation of the brush-tailed rock-wallaby

Recovery objective	Priority action
Coordination	
Specific objective 1. Ensure that BTRW sites are managed at all levels (at a site and ESU level, regionally, at a state level and nationally)	1: Support the continuation of the NSW BTRW recovery coordinator
Research	
Specific objective 2. Identify and better understand processes affecting BTRW recovery	2: Systematically document existing and potential threatening processes 3: Assess current threat abatement programs 4: Design and trial new alternative threat abatement techniques
Specific objective 3. Improve knowledge of the distribution and abundance of the BTRW	5: Develop a system to provide ongoing information on the distribution of BTRWs in each ESU 6: Develop standardised survey techniques for estimating BTRW presence or absence 7: Compare and develop monitoring techniques for estimating BTRW abundance 8: Establish a network of sites to be monitored for BTRW presence or absence, and abundance, in each ESU
Specific objective 4. Determine the genetic differences between the Central ESU and Northern ESU BTRW populations	9: Determine biogeographic boundaries between the Northern and Central ESUs 10: Research the degree of taxonomic separation between ESUs
Specific objective 5. Gain a better understanding of BTRW ecology	11: Research BTRW ecology
Site management	
Specific objective 6. Ensure that management of BTRW sites and colonies is systematically documented	12: Establish a database to collate information on past and present occupation of BTRW sites and management actions being undertaken at each site, and implement an ongoing review program 13: Develop best practice guidelines for site management 14: Develop site-specific management programs for priority BTRW sites within the framework provided by the best practice guidelines
Specific objective 7. Control introduced predators at sites identified under priority action 14	15: Develop a management network to control predators across the species' range, and implement control programs at priority sites

Recovery objective	**Priority action**
Specific objective 8. Minimise the impact of introduced competitors at sites identified under priority action 14	16: Develop a management network to control feral competitors across the species' range and implement control programs at priority sites.
Specific objective 9. More effectively implement predator and competitor control programs by improving their acceptance and level of implementation in the community	17: Develop broader community support for ongoing predator and competitor control programs
Specific objective 10. Manage BTRW habitat at priority sites to reduce or reverse habitat degradation	18: Identify sites and land management actions to ameliorate significant impacts caused by habitat loss
Captive breeding and translocation	
Specific objective 11. Establish a policy that provides a framework and protocols for captive breeding and translocation of BTRWs	19: Develop a policy paper which clearly articulates the criteria for captive breeding and translocation 20: Develop protocols for evaluating the effectiveness of translocation in terms of animals' survival and breeding potential
Specific objective 12. Maintain and enhance robust captive populations	21: Establish and maintain a genetically healthy captive population
Specific objective 13. Identify priority sites for trial BTRW translocation into the wild	22: Identify priority sites for each ESU using the criteria established in the policy papers developed through priority action 19
Community involvement	
Specific objective 14. Raise level of community awareness and support for the recovery of the BTRW	23: Develop and distribute generic community information and participation kit
Specific objective 15. Raise the level of community involvement in BTRW recovery management	24: Promote opportunities for community involvement in the implementation of the BTRW recovery program 25: Continue to foster the efforts of the Friends of the BTRW in Kangaroo Valley 26: Establish, where feasible, community support groups in each ESU, either regionally or on a site-by-site basis 27: Engage the corporate sector in financing components of the plan such as funding a network of sites, or contributing to the captive breeding program.

12.2 Coordination objectives and actions

Specific objective 1. Ensure that BTRW sites are managed at all levels (at a site and ESU level, regionally, at a state level and nationally)

Priority action 1: Support the continuation of the NSW BTRW recovery coordinator

Aim
To provide effective and efficient delivery of BTRW recovery actions and programs at the site, regional, ESU, state and national levels.

Performance indicator
- The part-time NSW BTRW recovery coordinator position continues to be supported throughout the duration of this plan.

Justification
The BTRW is an iconic species. It occupies a large biogeographic range and occurs across a wide array of administrative, tenure, and land management areas. It is therefore vital that recovery actions are coordinated at site, regional, ESU, state and national levels. Such coordination will require the continuation of current staff resources.

Methods
The implementation of this recovery plan relies on the continuation of the coordinator.

The coordinator's tasks include:
- developing standardised reporting and management guidelines
- monitoring priority BTRW sites, including collating information and data on distribution, abundance and management
- reviewing BTRW fox control programs including the fox threat abatement plan
- developing captive breeding and translocation policies and protocols
- managing a range of programs including site management programs, predator and competitor control programs, and research and habitat protection programs
- developing joint funding applications for research
- reviewing threatening processes, assessing new threat abatement techniques, and researching BTRW ecology
- coordinating community information and involvement
- reporting on the implementation of this plan
- representing DECC on the national BTRW recovery team.

Responsibilities
DECC, BTRW coordinator

12.3 Research objectives and actions

Specific objective 2. Identify and better understand processes threatening BTRW recovery

Priority action 2: Systematically document existing and potential threatening processes

Aim
To provide a centralised, accessible database and information on threatening processes that impede the recovery of the species.

Tasks to achieve this aim include:
- developing and distributing a questionnaire that documents the distribution and intensity of threats to the species at site, ESU, and regional levels
- collating responses, and analysing and producing a report which summarise them
- updating this information as required
- providing copies of the report to DECC regional managers and other land managers (e.g. Forests NSW)
- developing a database to store and retrieve this information.

Performance indicator
- The questionnaire is produced within the first 18 months of this plan.
- The database is developed within the five-year timeframe of this plan.
- The database is reviewed annually and updated as required.

Justification
Identifying and evaluating threatening processes at species, ESU, regional and site levels will indicate the prevalence and importance of threats at all levels. Such an indication will help to direct recovery team efforts and resourcing allocations.

Methods
- Design and send out the questionnaire to regional managers, rangers, field officers and landholders to assess and clarify which threats occur at which sites and at what intensities.
- Collate replies, and record and evaluate the information.
- Prepare and distribute the summary report to regional managers, and update information as required.
- Coordinate this process with tasks undertaken to achieve specific objective 6.

Responsibilities
The BTRW recovery coordinator or a contractor should design the questionnaire and submit it to regional managers, rangers and landholders in each ESU.

Priority action 3: Assess current threat abatement programs

Aims
To assess and improve the management of threatening processes within the context of BTRW recovery.

Tasks to achieve this aim include:

- comparing current threat abatement programs and determine their effectiveness
- identifying knowledge, methodological and field implementation gaps in current threat abatement programs
- providing recommendations for improving threat abatement programs.

Performance indicator
- A report assessing the effectiveness of programs with recommendations for future actions is completed within the first 18 months of this plan.

Justification
Understanding current knowledge and methodological gaps and how these influence the strategic implementation of threat abatement programs will enable managers to understand the reasons for the success or failure of such programs, and develop more effective new and improved programs.

Methods
- Identify sites where management and research teams are generating compatible data. Each team will identify the strengths and weaknesses of their threat abatement processes, permitting knowledge, methodological and implementation gaps to be identified.
- Collate data and identify areas of common ground.
- Conduct a comparative quantitative and qualitative analyses of data.
- Provide results of the analysis to the fox threat abatement plan coordinator and BTRW recovery team coordinator.

Responsibilities
The BTRW recovery team coordinator or a contractor to contact land managers of relevant sites and facilitate identification of appropriate data for analysis.

Priority action 4: Design and trial new alternative threat abatement techniques

Aim
To enhance threat abatement management by implementing new or improved threat abatement techniques, especially with regard to fox and goat control.

Tasks to achieve this aim include:
- developing and evaluating alternative or improved techniques for assessing threatening processes at the species, ESU, regional and site levels
- developing and implementing new or improved threat abatement implementation strategies
- developing and evaluating techniques for determining the effectiveness of threat abatement methods
- writing a report describing the reasons for the success or failure of the threat abatement methods, and indicating directions for future program preparation and planning.

Performance indicators
- A program is developed and implemented within the first three years of this plan.
- An assessment report with recommendations for future actions is completed within the five-year timeframe of this plan.

Justification
The development of both improved and alternative threat abatement programs is required to supplement current programs that are not effectively halting the decline of the BTRW.

Methods
- Develop alternative and improved threat abatement techniques at field sites with a BTRW monitoring program in place, concentrating on alternative fox and goat control techniques.
- With regard to fox threat abatement, coordinate techniques with those of the fox threat abatement plan team.
- Compare new with existing techniques to measure the success of the new or improved techniques.

Responsibilities
BTRW coordinator; relevant land managers; fox threat abatement plan research group.

Specific objective 3. Improve knowledge of the distribution and abundance of the BTRW

Priority action 5: Develop a system to provide ongoing information on the distribution of BTRWs in each ESU

Aim
To improve the baseline information available for research into and management of the BTRW, by providing a regularly updated database on the distribution of the BTRW.

Tasks to achieve this aim include:
- identifying areas where there is poor knowledge of the current distribution
- implementing surveys to improve knowledge of the current distribution, particularly in areas where knowledge is poor and implications for management are greatest, e.g. Wollemi, Yengo, Kanangra, southern Morton and Wadbilliga/Deua national parks and adjacent state forest areas in the Central ESU
- following up the landowner surveys begun by the NPWS in 1993
- developing and maintaining the BTRW survey database
- updating DECC's Wildlife Atlas.

Performance indicator
- Current databases are updated with a minimum field survey effort equivalent to two weeks of each year of the plan.
- A survey database is developed and maintained within the five-year timeframe of this plan.

Justification
An accurate understanding of the distribution of the BTRW will help the recovery team direct its efforts. Without an accurate understanding, it is difficult to prioritise areas requiring further resources and management activities. Current information indicates that information gaps may be most significant in the Central ESU. The absence of BTRW records in some areas in the Central ESU may be due to the lack of surveys in these areas. This is more significant for the Central ESU than the Northern ESU due to the much lower numbers of BTRWs in the Central ESU.

Methods
- Liaise with regional land managers and field staff to update current knowledge on distribution, and undertake tasks outlined in priority action 12.
- Identify significant information gaps in past survey efforts.
- Develop a survey program to update significant known sites and explore new sites, using information gained and available models of potential BTRW distribution to guide search efforts.
- Develop an information pamphlet targeted at recreational users and park visitors for distribution on-site, requesting information to assist in locating new BTRW sites.

Responsibilities
BTRW coordinator; relevant land managers.

Priority action 6: Develop standardised survey techniques for estimating BTRW presence or absence.

Aim
To improve the techniques used to record and determine the status of BTRW sites.

Tasks to achieve this aim include:
- reviewing current techniques and procedures for surveying colonies
- developing a standard set of procedures, techniques and recording methods
- producing a report in the form of guidelines for field staff.

Performance indicator
- Guidelines for standardised techniques are produced within the first 18 months of this plan.

Justification
BTRW presence/absence data forms the basis of the distribution database that is being developed as part of the recovery program (see specific objective 3). A standardised presence/absence methodology will increase the reliability of the categorisation of a site as a BTRW site, and will allow distribution at various sites to be compared within and between ESUs.

Methods
This methodology should be developed at sites known to contain BTRWs, in conjunction with priority action 5, as this will give a measure of the success of the technique. This action will also be coordinated with priority action 12.

Responsibilities
The BTRW coordinator. To be carried out by the teams working on priority action 5, in collaboration with those that will use the technique, i.e. the contractor working on specific objective 3 and the regional staff that will search potential BTRW sites.

Priority action 7: Compare and develop monitoring techniques for estimating BTRW abundance

Aim
To improve information on the abundance of the BTRW.

Tasks to achieve this aim include:
- comparing the accuracy and precision of current monitoring techniques
- developing and evaluating alternative monitoring techniques
- producing guidelines on standardised survey and monitoring techniques.

Performance indicators
- Research to be completed within the first two years of this plan.
- A report evaluating the techniques, listing the pros and cons of each technique, to be produced within six months of completion of research.

Justification
There are currently several methods for estimating macropod abundance which vary considerably in their accuracy and precision. Consequently, the determination of the status of BTRW colonies and populations, and the regions and ESUs in which they occur, is compromised. A standardised method will allow meaningful comparisons to be made at each level. However, it is acknowledged that no one method will apply to all sites.

Methods
- Undertake a desktop review of current techniques.
- Compare survey methods and develop new methods if required, in captive colonies held in large 'natural' enclosures where wallaby abundance can be measured (e.g. Tidbinbilla Nature Reserve, Jenolan Caves). This will permit the different methods to be tested for their effectiveness in maintaining or increasing abundance.
- Compare the different methods in wild populations to investigate how differences in movement patterns and density influence the interpretation of results.
- Trial methods and incorporate successful methods into management at colonies where abundance has been or is being measured (e.g. fox threat abatement plan sites).
- Collect follow-up data (relevant land management agency staff, tertiary students, and volunteers).

Responsibilities
BTRW coordinator; relevant land managers; contractor to set up monitoring trials.

Priority action 8: Establish a network of sites to be monitored for BTRW presence or absence, and abundance, in each ESU

Aim
To improve the effectiveness and efficiency of monitoring BTRW presence and abundance at the species and ESU levels.

Tasks to achieve this aim include:
- developing criteria for determining priority sites for recovery
- identifying and establishing sites for monitoring presence and absence in each ESU
- identifying and prioritising sites for monitoring abundance in each ESU
- comparing and evaluating the abundance of BTRWs in each ESU using the most appropriate techniques.

Performance indicator
- Criteria for determining priority sites to be established within the first 12 months of the plan.

- Priority sites to be identified and monitoring to be initiated for 12 sites within the first four years of this plan.

Justification
Monitoring data from sites in each ESU will provide baseline information against which comparisons of the broad status of the BTRW can be gauged. In addition, the information will assist in assessing the success of threat abatement programs across the species' range (see priority action 4).

Methods
The monitoring protocols established in priority actions 12 and 13 will be applied at representative sites in each ESU. These sites can be existing sites where monitoring programs are already in place or where research is being conducted. New sites may also need to be included to increase the monitoring levels in some regions in the ESU.

Responsibilities
BTRW coordinator; relevant land managers; contractor.

Specific objective 4. Determine the genetic differences between the Central and Northern ESU BTRW populations

Priority action 9: Determine biogeographic boundaries between the Northern and Central ESUs

Aim
To help recover the species by determining the location of the boundary between the Northern and Central ESUs.

Performance indicator
- Boundaries defined to best extent within the first 18 months of this plan.

Justification
Under the recovery plan, the broadscale management of BTRW populations is within the confines of each ESU. The locations of the boundaries between the three identified ESUs are currently unknown. The geographic position of the boundary between the Southern and Central ESUs is now only of academic interest as all intervening BTRW populations are believed to be extinct.

The location of the boundary between the Central and Northern ESUs in the east lies somewhere between Broke and Woko National Park. Extant BTRW populations are known from this zone and need to be assigned to their correct ESU. The Hunter River forms a known biogeographic boundary in south-eastern Australia (Cracraft 1991) and is a likely candidate for the boundary between the ESUs. It is important to know where ESU boundaries lie as this will have consequences for recovery efforts and management actions.

Methods
- Trap and sample BTRWs on either side of the Hunter River.

Conduct mitochondrial DNA (mtDNA) analysis to determine the ESU to which these populations belong. Tasks associated with this action will be coordinated as relevant with priority actions 5 and 8.

Responsibilities
Research will be conducted by Macquarie Research in collaboration with head office and regional DECC staff.

Priority action 10: Research the degree of taxonomic separation between ESUs

Aim
To determine the taxonomic status of BTRWs in the three ESUs.

Performance indicator
- Taxonomic status is determined within the timeframe of this plan.

Justification
The mtDNA divergence in the BTRWs found in the three ESUs is equivalent to that found between other subspecies and species of rock-wallaby. To determine the taxonomic significance of these differences, corroboration must be sought from other independent genetic markers. Microsatellites would be an obvious choice, but currently there are insufficient samples from the northern ESU to assess whether or not microsatellite data shows the same pattern between ESUs as has been observed in the mtDNA. This information will also be required to inform any review of the legislative status of the ESUs.

Methods
- Trap and sample at least 20 animals from at least three populations from the Northern ESU. Animals should be drawn from at least three sites in the northern tablelands gorge systems and one site in south-eastern Queensland.
- Genotype all animals at about 10 microsatellite locations and compare the results with existing data from Central and Southern ESU populations. The feasibility of undertaking morphological analyses will be assessed.

Responsibilities
Microsatellite research will be conducted by Macquarie Research in collaboration with regional DECC staff.

Specific objective 5. Gain a better understanding of BTRW ecology

Priority action 11: Research BTRW ecology

Aim
To significantly improve knowledge of BTRW ecology to assist in the management of BTRW recovery.

Tasks to achieve this aim include:
- using the information in this recovery plan to identify knowledge gaps, and making recommendations about filling priority BTRW ecology information and data gaps
- identifying key areas for BTRW ecology research
- developing research programs that address any intrinsic factors (e.g. reproductive ecology, habitat requirements) or extrinsic factors (e.g. fragmentation, fire, competition, predation) influencing BTRW populations
- promoting research into gaps in three research institutions across Australia.

Performance indicator
- Research programs are developed and implemented within the timeframe of this plan

Justification
A greater understanding of BTRW ecology will improve understanding of ways in which individuals, colonies and populations respond to threatening processes, form the basis of future threat abatement programs, and enable BTRW colonies and populations to be more efficiently managed. The knowledge gaps identified in this recovery plan should be used to assist with the prioritisation, design and implementation of research and management programs. There is much documented and undocumented information available on the ecology and behaviour of BTRWs, which will help to fill these knowledge gaps.

Methods
- Identify key gaps in BTRW ecology information.
- Develop field research programs using standard and new BTRW surveys, habitat assessment and threatening process techniques. These actions may be carried out on the fox threat abatement plan sites.

Responsibilities
DECC and other land management agencies regionally, in conjunction with the fox threat abatement plan research team and research institutes.

12.4 Site management objectives and actions

Specific objective 6. Ensure that management of BTRW sites and colonies is systematically documented

Priority action 12: Establish a database to collate information on past and present occupation of BTRW sites and management actions being undertaken at each site, and implement an ongoing review program

Aim:
To provide an ongoing assessment of BTRW sites, threatening processes and management actions.

Tasks associated with this action include:
- providing survey and data forms and guidelines to all landowners and agency staff at BTRW sites
- liaising with and supporting stakeholders including landowners and land management agency staff, to encourage evaluation of sites
- developing and implementing review and feedback mechanisms for reporting and recording, including entering data into a site management database.

Performance indicators
- Site data sheets are developed and distributed within the first 12 months of adoption of this plan.
- Recipients have completed site inspections and data sheets within the first 18 months of adoption of this plan.

- Baseline database are completed within the first two years of adoption of this plan.

Justification
Site and management information is required to:
- establish a site and management baseline
- allow prioritisation between sites for management actions
- allow ongoing evaluation of sites and management to more effectively allocate resources over time.

Methods
- Design site data sheets in-house.
- Circulate data sheets to DECC regional and area offices for evaluation.
- Distribute collated information to relevant DECC regional and area offices, NSW Forests regions, Rural Lands Protection Boards, researchers, landholders and other experts so they can provide information on the various BTRW sites using the standardised techniques referred to in specific objective 3.
- Update information annually.

Responsibilities
BTRW recovery coordinator, DECC staff, relevant land management agencies.

Priority action 13: Develop best practice guidelines for site management

Aim
To provide a consistent framework to manage recovery of the BTRW across its range.

Tasks associated with this aim include:
- designing a draft manual which includes criteria for determining priority management sites as per priority action 8
- circulating the draft manual to relevant DECC regional and area offices for evaluation
- completing the manual and distributing it to relevant land managers, Catchment Management Authorities, researchers, landholders and experts.

Performance indicator
- Manual produced and circulated within 18 months of adoption of this plan.

Justification
Best management practices must be consistently and repeatedly implemented at BTRW sites and the efficacy of those actions must be measured and compared across sites.

Methods
Recovery team to develop the BTRW site management manual in liaison with relevant land managers. The manual will include the standardised site data sheets developed through priority action 12, projects outlined in priority actions 5 and 8, and priority site management actions.

Responsibility
BTRW recovery plan coordinator.

Priority action 14: Develop site-specific management programs for priority BTRW sites within the framework provided by the best practice guidelines.

Aim

To ensure more effective and efficient management responses to recovery management at priority sites.

Tasks associated with this action include:

- developing methods for determining priority sites for management action
- establishing and implementing a framework for prioritising sites in ESUs and in NSW
- developing site management plans or programs for each identified priority site, or suite of sites.

Performance indicators

- Sites prioritised by second year of adoption of plan.
- Management plans or programs prepared for each site or suite of sites by fourth year of adoption of plan.

Justification

Different management options can be implemented at each site, depending on the nature and degree of threats. This plan has already recognised that intensive management actions are not desirable nor will be feasible for each site. Therefore a means of prioritising which management actions are suitable for which sites is required.

Methods

- An expert panel will develop a framework and decide on priority sites for each ESU. This information will be incorporated into the site database (see priority action 12). The BTRW recovery plan coordinator will liaise with land managers and other stakeholders for their input into the process.
- The BTRW coordinator and BTRW recovery team will develop management programs in liaison with land managers. The programs will be reviewed at two-yearly intervals, coinciding with reviews of priority action 12.
- The programs will be implemented through relevant priority actions. For example, where a site is to be managed for research purposes, the relevant research priority action(s) will be implemented.

Responsibilities

BTRW recovery plan coordinator, recovery team, expert panel, relevant land managers, key stakeholders.

Specific objective 7. Control introduced predators at sites identified under priority action 14

Priority action 15: Develop a management network to control predators across the species' range, and implement control programs at priority sites

Aim

To ensure more effective and efficient management of predators through coordinating feral control efforts in each ESU. The focus will be on fox control in each ESU, in conjunction with the fox threat abatement plan team and other DECC pest control program personnel, and with

other stakeholders, at sites where the need for fox control has been identified under priority action 14.

Tasks to achieve this aim include:

- identifying where fox control is being undertaken
- designing, implementing and reviewing individual fox control programs on sites identified in priority action 14
- supporting the implementation of the fox threat abatement plan as relevant to BTRW recovery objectives
- supporting the implementation of other relevant predator control programs, such as feral cat control
- establishing a schedule for review of programs.

Performance indicator

- Coordinated control programs are established and reviewed as scheduled within the timeframe of this plan.

Justification

The conservation of extant colonies may hinge on the efficacy of predator, primarily fox, control. It is therefore critical that priority fox control sites are managed using the best available knowledge and appropriate monitoring.

Methods

- Collate information from sites where foxes are being controlled (see priority action 12).
- Establish a fox control subcommittee to design individual fox control programs at priority sites identified in priority action 14.
- Develop alternative options for protecting BTRWs from fox predation where relevant. Such options could include fencing, trapping, or provision and protection of refuges.
- Consider the indirect effects of predator control on BTRWs, such as concurrent control of competitors such as goats and rabbits.

Close liaison will occur between the BTRW coordinator and fox threat abatement plan coordinator, regional threatened species recovery coordinators and managers, DECC pest officers, Rural Lands Protection Boards and other stakeholders. When a method for feral cat control has been developed, its application should be considered at BTRW priority sites.

Responsibilities
DECC fox threat abatement plan coordinator, DECC cat threat abatement plan coordinator, DECC pest control officers, BTRW recovery plan coordinator, relevant land managers including Rural Lands Protection Boards.

Specific objective 8. Minimise the impact of introduced competitors at sites identified under priority action 14

Priority action 16: Develop a management network to control feral competitors across the species' range and implement control programs at priority sites.

Aim
To ensure more effective management of introduced competitors by coordinating control efforts in each ESU, and with other stakeholders, at sites where the need for competitor control has been identified in priority action 14.

Tasks to achieve this aim include:
- identifying where competitor control is being undertaken
- designing, implementing and reviewing individual competitor control programs on sites identified in priority action 14
- establishing a schedule for review of programs.

Performance indicator
- Coordinated control programs are established and reviewed as scheduled within the timeframe of this plan.

Justification
The conservation of extant colonies may hinge on the efficacy of competitor control measures, e.g. goat control. It is critical that best management occurs at identified priority competitor control sites, using the best available knowledge, methods and monitoring.

Methods
- Collate information from competitor control sites (see priority action 12).
- Establish a competitor control subcommittee to design individual competitor control programs at sites identified in priority action 14.
- Consider the indirect effects of competitor control on BTRWs, such as lack of introduced prey for foxes, when determining management actions and develop appropriate actions, e.g. concurrent control of foxes.
- Implement competitor control programs at priority sites.

There will be close liaison between the BTRW coordinator, regional threatened species recovery coordinators and managers, and other relevant stakeholders including Rural Lands Protection Boards.

Responsibilities
BTRW recovery plan coordinator, DECC pest control officers, relevant DECC threat abatement plan coordinators, relevant land managers including Forests NSW and Rural Lands Protection Boards.

Specific objective 9. More effectively implement predator and competitor control programs by improving their acceptance and level of implementation in the community

Priority action 17: Develop broader community support for ongoing predator and competitor control programs

Aim

To maintain and enhance support for predator and competitor control programs and the establishment of new programs at priority sites identified in priority action 14, with an emphasis on working with local landholders.

Tasks to achieve this aim include:

- DECC continuing to support community-based control programs in Kangaroo Valley and northern Yengo National Park
- informing, training and instructing other authorities and landholders about 1080 baiting in environmentally sensitive areas
- controlling competitors in areas where fox predation has been reduced
- supplying the necessary funding and materials for predator and competitor control on private lands at priority sites
- identifying linkages with other baiting or species recovery programs.

Performance indicators

- Landowners at priority sites are provided with information, support and, where possible, resources to undertake coordinated control programs throughout the timeframe of this plan.
- The level and breadth of community support increases as indicated by ongoing feedback from landowners and other stakeholders through priority actions 12 and 24.

Justification

The impacts of foxes and goats have been informally identified as key threatening processes across much of the BTRW's range. These impacts need to be controlled across large areas, and are often most effective when there is liaison with neighbouring property owners and land managers. Gaining increased levels of support from these stakeholders will greatly assist the implementation of on-site management actions.

Methods

- Identify priority sites under priority action 14 on private land.
- Initiate site management plans in consultation with landholders and key stakeholders.
- Where possible, coordinate liaison through priority action 24.

All control plans involving private lands will be developed with local landowners, in accordance with the conditions of consent given by relevant landholders, and legal and policy requirements of relevant land management agencies and Rural Lands Protection Boards.

Responsibilities

BTRW coordinator, Forests NSW, relevant Rural Lands Protection Board, relevant land managers.

Specific objective 10. Manage BTRW habitat at priority sites to reduce or reverse habitat degradation

Priority action 18: Identify sites and land management actions to ameliorate significant impacts caused by habitat loss

Aim

To provide support for dealing with habitat loss, both locally and regionally.

Tasks to achieve this aim include:

- identifying areas or regions where habitat loss or degradation is a significant threat to BTRW populations
- developing specific habitat protection guidelines to protect significant BTRW habitats
- at sites in the identified areas, promoting connections between habitat to allow dispersal between sub-populations and allow colonisation of other suitable habitat.

Performance indicator

- Priority sites for habitat protection are identified and habitat conservation actions are initiated within the timeframe of this plan.

Justification

Habitat destruction and degradation affect BTRW populations in many ways, such as increasing the animals' exposure to predators, competitors, fires and weeds. Dealing with both the causes of habitat degradation, such as land clearing, and the impacts of those causes, such as the introduction of foxes and invasion by weeds, will significantly increase the long-term likelihood of successful recovery of BTRWs.

Methods

- Identify sites where habitat degradation is a major threatening process.
- Convene an expert panel to develop habitat protection guidelines.
- Incorporate these guidelines into planning mechanisms affecting habitat on these sites, such as local environmental plans, catchment management plans, regional conservation plans and fire management plans. These guidelines will also be useful when planning timber harvesting operations and weed control programs.
- Protect important habitat by negotiating voluntary conservation agreements with relevant private landholders, developing incentives under property vegetation plans, relocating recreational activities away from identified sites, and voluntarily acquiring lands in high priority areas that are otherwise poorly represented in national parks and reserves.

Responsibilities

BTRW coordinator; relevant land managers including DECC, Catchment Management Authorities, Forests NSW, Rural Lands Protection Boards, and local councils.

12.5 Captive breeding and translocation objectives and actions

Specific objective 11. Establish a policy that provides a framework and protocols for captive breeding and translocation of BTRWs

Priority action 19: Develop a policy paper which clearly articulates the criteria for captive breeding and translocation

Aim

To ensure captive breeding and translocation programs are consistent with best practice management for recovering BTRWs.

Tasks to achieve this aim include:

- preparing a draft translocation and captive breeding strategy
- producing a final policy paper ratified by the BTRW recovery team
- preparing an Australasian Species Management Program Captive Management Plan for the BTRW.

Performance indicator

- Policy paper is developed and endorsed through the recovery planning process by the end of year 1.

Justification

Some BTRW colonies have recently become extinct and there are likely to be regional extinctions within the next 5 to 20 years, particularly in the Central ESU. To preserve this species across its range, some sites will need intensive management of threatening processes as well as supplementation of breeding stock due to low viability and inbreeding. A rigorous and strategic approach is required to reduce unwanted genetic mixing of populations and ensure efficient recovery management.

Methods

- Prepare a draft translocation and captive breeding strategy, for review and endorsement by the BTRW recovery team.
- Seek the support of the Australasian Regional Association of Zoological Parks and Aquaria to prepare and endorse a captive management plan for the BTRW.

Responsibilities

BTRW recovery team.

Priority action 20: Develop protocols for evaluating the effectiveness of translocation in terms of animals' survival and breeding potential

Aim

To ensure translocation programs are effectively achieving their aims for BTRW recovery.

Tasks to achieve this aim include:

- developing criteria for evaluating the effectiveness of programs
- developing evaluation techniques in liaison with relevant experts

- producing a report on evaluation, with recommendations for action
- implementing protocols as per recommendations.

Performance indicators
- Protocols to be endorsed by the recovery team by year 2 of the plan.

Justification
Translocation is an intensive and interventionist management option for maintaining the genetic variation and population range of a species. To ensure translocation efforts are strategically targeted with optimum chances for success, the effectiveness of programs needs to be evaluated and feedback provided to inform future management actions. To date, there have been few systematic attempts to determine the effectiveness of translocations.

Methods
- Produce a definition of 'effectiveness' which defines the desired survival and breeding outcome of translocations.
- Develop proposed evaluation techniques in liaison with experts.
- Produce report on evaluation techniques with recommendations.
- Implement techniques as per recommendations.

Responsibilities
BTRW recovery team.

Specific objective 12. Maintain and enhance robust captive populations

Priority action 21: Establish and maintain a genetically healthy captive population.

Aim
To provide an effective 'back up' for BTRW management through maintaining and enhancing the genetic stock and numbers of BTRW in captivity, and to expand captive populations to levels where re-introductions and enhancements of threatened populations are possible.

Performance indicators
- Programs are identified and resources allocated.
- Captive management plan is completed as per priority action 19.
- Captive husbandry manual is completed by year 2.
- Sourced stock are incorporated into captive population by year 2, and as necessary to maintain genetic diversity in subsequent years.

Justification
BTRW populations in the Central and Southern ESUs are deemed to be most at risk, and are most likely to require artificial maintenance of some populations or colonies. As the numbers of BTRWs in the wild are low, it will be necessary to source animals from captive bred populations for supplementing wild populations. The robustness of the captive stock needs to be enhanced and maintained to improve the success of potential supplementation.

Methods
- Maintain a 'studbook' for the species.
- Develop a captive husbandry manual.
- Implement a captive management plan.
- Identify source populations for establishing, maintaining and enhancing captive breeding stock.
- Identify ways of achieving and maintaining genetically robust breeding stock.

Responsibilities
The captive population will be managed by the zoological industry, in liaison with relevant state conservation government agencies, as part of the current Australasian Species Management Program and Taxon Advisory Group processes. Potential source populations for the maintenance of captive stock should be identified by the BTRW recovery team.

Specific objective 13. Identify priority sites for trial BTRW translocation into the wild

Priority action 22: Identify priority sites for each ESU using the criteria established in the policy papers developed through priority action 19

Aim
To ensure translocation is only undertaken at sites where it is the most effective response for achieving BTRW recovery at local, regional, ESU and national levels.

Tasks to achieve this aim include:
- developing a clearly articulated rationale and need for translocation
- assessing the feasibility of trial release programs
- identifying priority sites for translocation
- developing translocation proposals for trial sites
- undertaking translocation release trials.

Performance indicators
- Feasibility of trial release programs is investigated.
- Sites to be identified by the end of year 1 of the plan.
- Translocation proposal for trial sites to be completed and approved by year 2 of the plan.
- Captive breeding trial translocation program to be established by year 3.

Justification
The release of animals into the wild is resource intensive, and should only be undertaken when no other management actions are likely to be effective and where threat abatement programs are in place. Sites for possible translocation must be rigorously evaluated to ensure the recovery of the species at the local, regional, ESU and national levels.

Methods
- Develop a document prioritising sites for translocation, and a translocation proposal for trial sites, for ratification by the recovery team and relevant land management agencies.
- Compile a list of priority sites for each ESU with supporting documentation detailing requirements, timeframes and management considerations such as genetic match, population

demography, threatening process control, not interfering with current colony research and management, and having an existing monitoring program in place.
- Assess the feasibility of, and implement, trial release programs.
- Implement close post-release monitoring.
- Assess experimental trial release programs on a case-by-case basis, and be consistent with the criteria for translocation and the overall objectives of this plan. (University research projects will be established to investigate the success of translocation trials.)

Responsibilities
Priority sites for translocation to the wild for each ESU should be identified by the BTRW recovery team, in consultation with relevant land managers. DECC and other regional land management agencies will collaborate with universities to develop and undertake research projects.

12.6 Community involvement objectives and actions

Specific objective 14. Raise level of community awareness and support for the recovery of the BTRW

Priority action 23: Develop and distribute generic community information and participation kit

Aim
To increase community understanding of recovery management of the BTRW, highlight the potential impacts of activities on the BTRW, and promote opportunities for community participation in BTRW management.

Tasks to achieve this action include:
- reviewing wildlife management programs, especially rock-wallaby programs, that incorporate community involvement and encourage community participation
- developing and producing a generic community information and participation kit containing information relevant to the community, to raise community awareness and support
- undertaking stakeholder analysis
- developing a list of opportunities for community participation in BTRW recovery management to include in the kit.

Performance indicators
- The community information kit is completed within one year of the commencement of the plan and distributed within the timeframe of the plan.
- Relevant landowners and activities groups at priority BTRW sites are informed within two years of the commencement of the plan.
- A review and update of the kit is undertaken after five years.

Justification
Some colonies occur on private lands, or adjacent to private lands. Information needs to be made available to the public on ways in which the community can help monitor and manage the BTRW. Through raising community awareness, there is likely to be more support for and participation in BTRW recovery programs.

Methods

- Appoint a community information kit manager who will be responsible for developing, producing and initially distributing the kit. The kit will provide information for landholders, recreational community groups and those interested in wildlife, schools, government departments and other interested parties.
- The community kit manager to develop a list of ways in which the community can be involved, following liaison with members of other wildlife programs which include community involvement.
- Distribute the kits in areas identified as priority BTRW sites and any other areas where community support or involvement is encouraged. The kits should be sent to local libraries and included on relevant websites, e.g. the Friends of the BTRW and DECC websites.
- Review and update the kit as required. Coordinate this action through priority action 12.

Responsibilities

BTRW coordinator; Catchment Management Authorities, relevant land managers (primarily DECC Highlands Area and Hunter Valley BTRW staff); Friends of the BTRW, based in Kangaroo Valley.

Specific objective 15. Raise the level of community involvement in BTRW recovery management.

Priority action 24: Promote opportunities for community involvement in the implementation of the BTRW recovery program

Aim

To involve the community in implementing the recovery program at identified BTRW priority sites and in other areas as appropriate.

Tasks to achieve this action include:

- identifying which demographics and BTRW sites are suitable for community involvement
- identifying, and implementing as relevant, appropriate management programs and tasks that the community can be involved in
- liaising with Catchment Management Authorities about opportunities for landholder involvement in the recovery program
- providing Catchment Management Authorities with guidelines on best practice site management as per priority action 13. In the absence of the formal guidelines, DECC will liaise with the Catchment Management Authorities to ensure BTRW community projects are consistent with this recovery plan.

Performance indicators

- Opportunities are identified and promoted within two years of the commencement of the plan.
- Catchment Management Authority specific guidelines are prepared within 12 months of commencement of the plan.
- DECC and Catchment Management Authorities work together to help landholders develop community conservation projects that support the recovery plan.
- Landholders in each Catchment Management Authority area are involved in the implementation of this plan by year 5.

Justification
Some BTRW colonies are on private lands, or adjacent to private lands. Community involvement is an important aspect of conservation both in and outside national parks and reserves, and should be a greater component of conservation projects that benefit BTRW recovery and conservation management generally. Catchment Management Authorities play an important role in expanding community involvement in species management programs, and funding conservation projects. To ensure a best practice approach to BTRW management, community programs must complement existing programs and actions under this recovery plan. For example, if developing a community fox baiting program in a BTRW area, Catchment Management Authorities and landholders must have a comprehensive understanding of BTRW ecology, best practice fox control methods, BTRW and fox monitoring techniques, bait density, buffer zones, and how to protect species such as quolls and domestic dogs.

Methods
- Identify areas where community involvement in BTRW management is suitable (see priority action 23).
- Develop a stakeholder communication plan, and identify and promote appropriate participation opportunities using the community information kit (see priority action 23).
- Compile timetables of works where opportunities exist for volunteer community involvement. These timetables, compiled on a regional or project level, could be incorporated into a newsletter which also contains information on activities being held and the projects being conducted. These newsletters could be mailed out, available at local libraries, sent to local newspapers and placed on the Friends of the BTRW and DECC websites.
- Support and further develop existing community involvement in BTRW management.

Responsibilities
BTRW coordinator, Catchment Management Authorities, relevant land managers.

Priority action 25: Continue to foster the efforts of the Friends of the BTRW in Kangaroo Valley

Aim
To ensure continued community support for and involvement in the Kangaroo Valley program.

Tasks to achieve this aim include:
- providing technical and administrative assistance as relevant
- maintaining and enhancing the liaison between DECC and the Friends of the BTRW.

Performance Indicator
- Friends of the BTRW continues to be active in BTRW recovery in the Shoalhaven Region.

Justification
Community involvement is a major component of the Shoalhaven BTRW project and a desirable component of future BTRW management programs. Through supporting and fostering the efforts of the Friends of the BTRW, community involvement in the program is likely to continue. Much can be learnt from the experiences of the Friends of the BTRW and community involvement in the Shoalhaven.

Methods
The Friends of the BTRW will be supported by DECC through the provision of technical and administrative assistance where required. In conjunction with this group, DECC will continue to inform the public about the BTRW program in Kangaroo Valley. Further community support and participation will be encouraged.

DECC and the Friends of the BTRW will inform the public about the objectives and actions in this plan.

Responsibilities
DECC Highlands Area Office, DECC South Coast Region, Friends of the BTRW, overseen by BTRW coordinator.

Priority action 26: Establish, where feasible, community support groups in each ESU, either regionally or on a site-by-site basis.

Aim
To ensure continued community support and involvement in BTRW management.

Tasks to achieve this aim include:
- assessing the feasibility of establishing support groups
- coordinating work either regionally or on a site-by-site basis
- investigating the feasibility of broadening the role of the Friends of the BTRW to provide regional or statewide networks.

Performance indicators
- The feasibility of establishing support groups that are similar to, or an extension of, the Friends of the BTRW in Kangaroo Valley, is assessed within two years of the adoption of this plan.
- Support groups, if feasible, are established within the timeframe of this plan.

Justification
Community involvement has been a major factor in conserving the Shoalhaven BTRW colonies. The creation or extension of community support groups in other regions will help to conserve BTRWs in those regions. In raising the level of community involvement in BTRW recovery management, there will also be an increased awareness of general conservation issues.

Methods
- Assess the feasibility of establishing support groups in regions other than the Shoalhaven, and provide recommendations for future management actions to set up such groups, including whether they would be best formed at the local, regional or ESU level.
- Enlist the support groups in implementing and promoting community involvement under priority action 24. Input will be sought from the Friends of the BTRW and from other DECC staff already working on projects involving the community.
- Assess the feasibility of the Friends of the BTRW expanding their role and membership to an ESU level. This option will be examined further by DECC and the group.

Responsibilities
BTRW coordinator, relevant land managers, Friends of the BTRW, contractor.

Priority action 27: Engage the corporate sector in financing components of the plan such as funding a network of sites, or contributing to the captive breeding program

Aim
To gain funding to support implementation of the plan and improve opportunities for community involvement.

Performance indicator
- Marketing campaign targeting corporate sponsorship launched within two years.
- Private sponsorship achieved within five years.

Justification
Additional funding will assist with the implementation of the recovery plan and is likely to provide unique opportunities to increase the community's understanding of the plight of the BTRW and other threatened species, and thus expand community involvement. As an iconic species with a broad distribution, developing opportunities for corporate sponsorship of components of the species recovery program is likely to be mutually beneficial.

Methods
- The BTRW recovery coordinator to seek the support of the Foundation for National Parks and Wildlife to develop a marketing strategy to seek corporate sponsorship.
- Undertake a marketing campaign which invites corporate sponsorship.

Responsibilities
BTRW coordinator, BTRW recovery team.

13 Alternative management strategies

There are no known alternative management strategies to those described above that are feasible and likely to achieve recovery of the BTRW across its range.

Unknown alternative management strategies may be found in the future, such as biological control of foxes or feral cats. If any are considered to improve the rate of recovery based on research or scientific opinion, this plan will be amended.

The following alternative actions fall within the context of the captive breeding and translocation objectives in this recovery plan.

13.1 Alternative action 1 – translocation between ESUs

Within NSW, this recovery plan restricts translocation to within an ESU, with no transfers across ESU boundaries. Supplementation of the Southern ESU is currently being undertaken as part of the recovery of the species in Victoria. Broadening the transfer of genetic stock between ESUs may be considered by the recovery team if the priority actions fail to recover the populations in the Central or Southern ESUs in the long-term. This transfer would involve translocating BTRWs from colonies in the Northern ESU to supplement populations in the Central or Southern ESU. Proposals for translocation would need be developed in accordance with the proposed captive breeding and translocation policy for the BTRW and approved by DECC. Translocations would only be implemented with the agreement of landholders at the removal and relocation sites.

13.2. Alternative action 2 – accelerated breeding

This action may be considered more broadly by the recovery team if the priority actions fail to recover the species in the long-term. This action involves captive breeding using the accelerated breeding techniques researched by Bell and Close (1994). The technique has been used successfully in Victoria with Southern ESU BTRW, and involves fostering of young BTRWs by other macropod species such as the tammar wallaby. This approach is more labour intensive than traditional captive breeding strategies, and therefore proposals for accelerated breeding of the Central ESU will only be considered by the recovery team once other priority actions have been undertaken, or should a catastrophic event threaten the Central ESU population with imminent extinction.

14 Implementation

Appendix 1 summarises the costs and responsibilities for the implementation of recovery actions specified in this plan.

15 Preparation details

The preparation of this recovery plan was coordinated by DECC in consultation with the BTRW recovery team.

15.1 Date of last amendment

No amendments have been made.

15.2 Review date

This recovery plan will be reviewed by the recovery team every five years from the date of adoption, or earlier if a radical departure from the implementation schedule is warranted by new information.

16 Acronyms and abbreviations

BTRW – brush-tailed rock-wallaby
DECC – Department of Environment and Climate Change (NSW)
EP&A Act – *Environmental Planning and Assessment Act 1979*
EPBC Act – *Environment Protection and Biodiversity Conservation Act 1999*
ESU – evolutionary significant unit
IBRA – Interim Biogeographic Regionalisation for Australia
mtDNA – mitochondrial Deoxyribose Nucleic Acid
NPW Act – *National Parks and Wildlife Act 1974*
NPWS – National Parks and Wildlife Service
NSW – New South Wales
TAP – threat abatement plan
TSC Act – *Threatened Species Conservation Act 1995*

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Appendix 1. Recovery plan cost schedule

Priority action no.	Action	Priority	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)	Year 5 ($)	Total cost ($)	Responsible agency	In-Kind ($)	Cash ($)	Additional funds required ($)
1	BTRW recovery coordinator	1	45 000*	45 000*	45 000*	45 000*	45 000*	225 000*	DECC	225 000*		
2	Document threatening processes	1	#	1 000				1 000	DECC		1 000	
3	Assess threat abatement programs	1		#	#				DECC			
4	New threat abatement techniques	2		27 000	9 000	9 000	9 000	54 000	DECC			54 000
	Department of Primary Industries costs			3 000	1 000	1 000	1 000	6 000	DPI (Forests)			6 000
5	Information on distribution	2		15 000	15 000	5 000	5 000	40 000	DECC			40 000
	Department of Primary Industries costs			5 000	5 000			10 000	DPI (Forests)			10 000
6	Standardise survey techniques	2		See action 5	See action 5	See action 5	See action 5		DECC			
	Department of Primary Industries costs			See action 5	See action 5	See action 5	See action 5		DPI (Forests)			
7	Standardise monitoring techniques	2		10 000	5 000			15 000	DECC			15 000
8	Monitoring network	2	4 000	500	500	500	500	6 000	DECC	6 000		
	Department of Primary Industries costs		1 000	500	500	500	500	3 000	DPI (Forests)	3 000		
9	Determine geographic genetic boundaries	2	10 000	10 000				20 000	DECC			20 000
10	Determine degree of taxonomic separation	3	10 000	10 000	10 000			30 000	DECC			30 000
11	Ecological field research	2		15 000	15 000	15 000	15 000	60 000	DECC			60 000
12	Collate management information	1	#		#		#		DECC			
13	Best management guidelines	2	2 000					2 000	DECC	2 000		

Priority action no.	Action	Priority	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)	Year 5 ($)	Total cost ($)	Responsible agency	In-Kind ($)	Cash ($)	Additional funds required ($)
14	Develop site plans	1	2 000	500	500			3 000	DECC	2 000	1 000	
15	Develop predator control network	1	15 000**	15 000**	15 000**	15 000**	15 000**	75 000**	DECC	75 000**		
	Department of Primary Industries costs		5 000**	5 000**	5 000**	5 000**	5 000**	25 000**	DPI (Forests)	25 000**		
16	Develop feral competitor control programs	2	7 500	7 500	7 500	7 500	7 500	37 500	DECC	37 500		
	Department of Primary Industries costs		2 500	2 500	2 500	2 500	2 500	12 500	DPI (Forests)	12 500		
17	Community support base for control programs	3	#	#	#	#	#		DECC			
18	Ameliorate habitat degradation	2	2 000	2 000	1 000	1 000	1 000	7 000	DECC			7 000
19	Policy paper	1	#						DECC			
20	Evaluate effectiveness of translocation	1		#					DECC			
21	Enhance captive breeding sites	1	2 500					2 500	DECC	2 500		
22	Identify priority sites	1	#	10 000	10 000	10 000	10 000	40 000	DECC			40 000
23	Community information kit	1	10 000	5 000				15 000	DECC			15 000
24	Community involvement opportunities	2		500	500	500	500	2 000	DECC		2 000	
25	Kangaroo Valley Friends of the BTRW	2	#	#	#	#	#	1 000	DECC		1 000	
26	Support other support groups	2	1 000	1 000	1 000	1 000	1 000	5 000	DECC		5 000	
27	Seek corporate sponsorship	2	#	#	#	#	#		DECC			
	TOTAL							**702 500**		**390 500**	**15 000**	**297 000**

* cost relates to the salary and on-costs of the recovery plan coordinator, based on the position being a Senior Project Officer (EPO 9).
** funded by the NSW Fox Threat Abatement Program
# costs have been incorporated into time of recovery plan coordinator
In-kind funds represent actions that are DECC core duties and are covered by current resources e.g. salary component of funded position
Cash funds are required for those actions that require a capital expense item e.g. printing
Additional funds required include volunteer in-kind time or cash grants.

Appendix 2. Summary of advice provided by the NSW Scientific Committee.

Under section 66A, recovery plans must include a summary of advice given by the NSW Scientific Committee, details of any amendments made to the plan to take account of that advice and reasons for any departure from that advice. The Scientific Committee's comments on the *Draft recovery plan for the Brush-tailed rock-wallaby* Petrogale penicillata and details of the amendments made, are tabled below:

Advice	**Response**
Recovery plan objectives should be more ambitious.	Plan amended.
Advises seek greater justification for maintaining genetic variation in the plan.	Noted, and the plan amended to provide clearer justification based on objects of TSC Act.
Section 6.1 Evidence of land clearing hindering dispersal should be presented.	Relevant section has been amended to improve clarity.
Section 6.3, 7.5, 9.1 Questions conclusions drawn from research on impact of foxes on black-footed rock-wallabies and therefore the BTRW.	Relevant sections have been amended to reflect uncertainties due to interactions of threats.
Section 9.1 Commends outline of threats and limiting factors and recommends further discussion on habitat degradation.	Noted, and plan amended.
Section 7.4 Commends discussion of impacts of hunting. Recommends expanding discussion of interaction of threats to large populations e.g. impact of predation in times of drought, or post-fire.	Noted, and plan amended.
Section 8.0 Overemphasis of presence of BTRW on north-facing sites deflects interpretation of true limiting factors.	Relevant section has been amended to clarify habitat use and preference.
Section 9.6 Suggests expanding impact of predator control on competitor abundance.	Plan amended.
Priority action 7 Suggests survey methods be compared in wild populations rather than captive, and that list of survey methods be included in the plan.	Incorporated into plan to be developed under priority action 7.
Questions action to undertake further literature review given compressive plan.	Priority action 11 amended.
Priority action 11 Suggests research priorities are articulated.	Incorporated into plan to be developed under revised priority action 11.
Section 11.0, 12.5 Suggests further justification of captive breeding and translocation actions.	Captive breeding and translocation program is intended as an experimental trial and will only be initiated if supported by captive facilities and other relevant stakeholders.