

# **Recovery Plan for the Brush-tailed Rock-wallaby *Petrogale penicillata***



**Draft for Public Comment  
August 2005**



**Department of  
Environment and  
Conservation (NSW)**

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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 on Schedule 1 of the *Threatened Species Conservation Act 1995* as Endangered in NSW. This document constitutes the draft formal New South Wales recovery plan for the Brush-tailed Rock-wallaby, and as such considers the conservation requirements of the species.

The Department of Environment and Conservation (NSW) (DEC) believes many interrelated factors contribute to the continued decline of the species. Likely current threats include predation, competition, weeds, disturbance, habitat modification, fire, drought, disease and inbreeding. The DEC is currently seeking to actively control these threats to conserve this species at a number of sites throughout the state.

The long-term major objective of the recovery program is to halt the decline of the species and to recover the species from its status as Endangered. However, this objective is not believed to be achievable within the lifetime of this plan. Therefore the specific objective of this recovery plan is to ensure the sustainability of priority populations and in so doing, prevent the extinction of the Brush-tailed Rock-wallaby in the wild in NSW. The key to achieving this objective will be maintaining representative samples of the regional populations as identified in this plan. It is not within the scope of this recovery plan to actively manage all populations. However, the selected priorities are based on moving toward substantial recovery (which we believe would mean stable or increasing populations at all priority sites in NSW, and no further contraction of the species' range).

Recovery actions will be directed towards the continuation and enhancement of existing predator and introduced herbivore control programs; surveys to enhance our knowledge of the distribution and abundance of the species; the maintenance and enhancement of captive breeding programs for identified regional populations; and the continuation and enhancement of community based conservation programs. Given the broad geographic range of the species, it is likely that there will be a number of overall biodiversity benefits from the implementation of this plan.

The Brush-tailed Rock-wallaby is an iconic species that occurs on both public and private lands. The successful implementation of recovery actions relies on the participation of all sectors of the community. The DEC would welcome opportunities to work with Catchment Management Authorities, community groups and private corporations that may wish to sponsor the implementation of this plan.

I invite you to make a written submission to the DEC regarding this draft recovery plan by Friday October 21, 2005. Please refer to Appendix 2 for details on how to make a submission. The plan will be finalised once all comments have been considered.



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## **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 New South Wales 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.

In addition, sincere thanks are due to the Shoalhaven Area and Warrumbungles National Parks and Wildlife Service staff involved in the BTRW management in those areas, and also to Liz Dovey for providing so much of the initial impetus for the recovery of BTRW in NSW.

The DEC would also like to thank those that have been involved directly with the BTRW recovery team: Deborah Ashworth, Paul Bayne, Dianne Brown, Mike Cavanagh, Peter Christie, Kate Dallimore, Suzanne Dobbie, Mark Eldridge, Andrew Glover, Ernst Holland, Robert Humphries, John Jordan, Brad Law, Geoff Lundie-Jenkins, Graeme Moss, Melinda Norton, Rod Pietsch, Jim Reside, Shane Ruming, Catherine Rummery, John Seebeck, Todd Soderquist, Geoff Underwood, and Vera Wong; and additional working group members: Francesca Andreoni, Shawn Capararo, Rob Close, Leonie Gale, David Goldney, Bronwyn Houlden, Ian Jackett, Michaela Jones, Helen Jordan, Caroline Lees, Dan Lunney, Will Meikle, and Andrew Miller.

The DEC would also like to acknowledge World Wide Fund for Nature, Taronga Zoo, the Foundation for National Parks and Wildlife, and in particular the Kangaroo Valley Friends of the BTRW for their efforts and on-going support for the conservation of this species.

Thank you.

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## 1.0 Introduction

This recovery plan is a key step in conservation of the Brush-tailed Rock-wallaby (*Petrogale penicillata*) in New South Wales. It identifies the actions that will be taken to ensure the long-term viability of this species in nature and the parties responsible for implementing these actions.

The Director-General of the Department of Environment and Conservation may prepare recovery plans for conservation of species listed on Schedules 1, 1A and 2 of the *Threatened Species Conservation Act 1995*.

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.

## 2.0 Legislative Context

### 2.1 Legal Status

The Brush-tailed Rock-wallaby (BTRW) is currently listed as Endangered under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Vulnerable under 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.

Prior to this species being listed as Endangered under the TSC Act, the population of BTRW in the Warrumbungle Ranges in the Coonabarabran District in central northern New South Wales was listed as an Endangered Population under 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 the matters to be addressed by recovery plans and the administrative process for preparing recovery plans and this plan has been prepared to satisfy these requirements. This recovery plan sets the priorities and direction of BTRW conservation and as such sets the focus for BTRW conservation management in NSW.

This draft recovery plan has been prepared with the assistance of a recovery team, a non-statutory group of interested parties with relevant expertise. Components within 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 draft 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 the implementation of this plan is the Department of Environment and Conservation (NSW) (DEC). The DEC will liaise with other government agencies and authorities regarding assistance, and/or approval, for specific implementation measures. Other parties relevant to this plan are the NSW Department of Primary Industries (Forests NSW), and relevant 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*;
- *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*;
- *Total Catchment Management Act 1989*;
- *Wilderness Act 1987*.

The interaction of these Acts with the TSC Act is varied. The most significant implications are described below 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 exercising a decision making function 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.



## 2.6 Critical Habitat

The TSC Act makes provision for the identification and declaration of critical habitat for species, populations and ecological communities listed as Endangered. Once declared, it becomes an offence to damage critical habitat (unless the action is specifically exempted by TSC Act) and 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. Critical habitat is habitat that is critical to the survival of a listed threatened species or listed threatened ecological community. It is an offence under the EPBC Act for a person to knowingly take an action that will significantly damage critical habitat (unless the 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.

## 3.0 Conservation Status

Recent and on-going research on the genetic distinctiveness of individual populations within the species indicates there are three distinctive taxonomic groups of BTRW centred in (i) north-eastern NSW and south-eastern Queensland, (ii) central NSW and (iii) 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 ESU. 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 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.' The three genetic groups within the total BTRW population will be referred to as the Northern ESU, Central ESU and Southern ESU respectively.

Brush-tailed Rock-wallaby sites are recorded in 15 Interim Biogeographic Regionalisation for Australia (IBRA) bioregions. The status of the species in these bioregions is that the species is extinct in six bioregions, in severe decline in four bioregions, and in decline in five bioregions, as indicated in Figure 1 and Table 1. The species is known to occur in seven Catchment Management Authority (CMA) Regions, and thought to be extinct in five others (see Table 2).

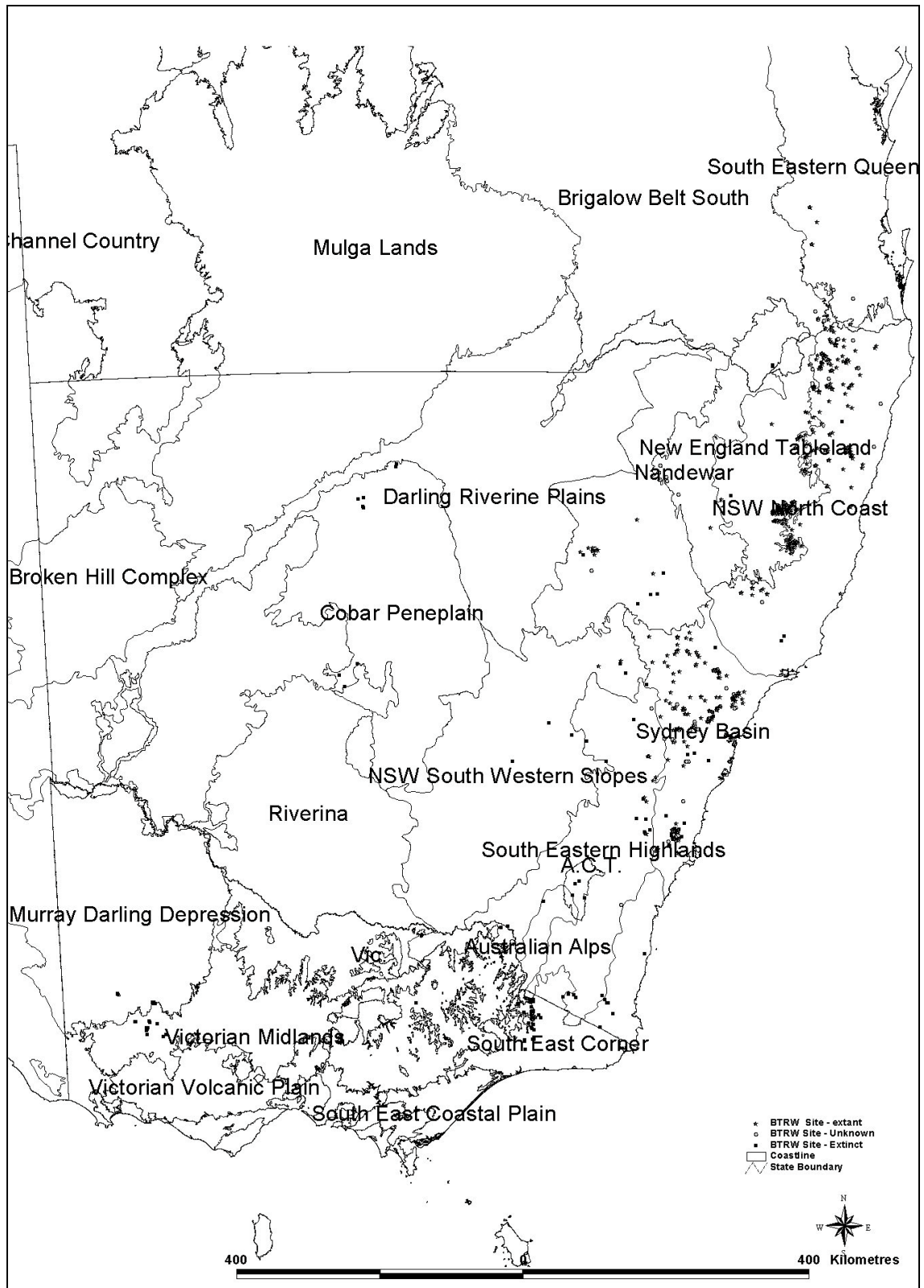


Figure 1. Recorded BTRW and IBRA Bioregions.

**Table 1. Status of BTRW by IBRA Bioregions.**

<b>Bioregion</b>	<b>Status</b>
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 BTRW by CMA Regions.**

<b>Bioregion</b>	<b>Status</b>
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 for these CMA regions, the proximity of known sites would indicate there is a reasonable chance that the species once occurred there.

Of the total 962 nationally recorded sites of BTRW, approximately half are within conservation reserves, as illustrated in Figure 2. The majority 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 – 42 % are in reserves, and 30 % are on freehold lands, as illustrated in Figure 3. The remaining sites are on State Forest, Crown Land or Leasehold lands.

The distribution of extinct and extant sites by tenure 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 sites 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 nature of many records for extinct sites which would lead to an under-recording of extinct sites on private land. Many of the extinct sites on private lands records are old, and what were once suites of colonies have often been recorded only once prior to extinction. This is particularly true of sites where early museum records are the only indication of the existence of a site. In contrast, records within reserves are often multiple sites within complexes of colonies, and often resulting 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 BTRW from a total of 40 DEC managed reserves, comprised of 28 National Parks, nine Nature Reserves and three State Recreation Areas (Table 3). Within these, the BTRW appears to have become extinct in 12 reserves, while remaining in 28 reserves comprised of 20 National Parks, five Nature Reserves and three State Recreation Areas. In addition, there are two timber reserves in northern NSW where extant BTRW have been recorded. The distribution of these reserves is illustrated in Figure 6.

Extant sites in the Central ESU are represented in 12 reserves, and sites in the Northern ESU in 16 reserves (plus the two timber reserves). Ten of the reserves where it would appear that the species has become extinct are in the Central or Southern ESU, and only two 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 of the individual reserves are presented in Table 4.

Table 3. Status of BTRW 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
	28	12	40

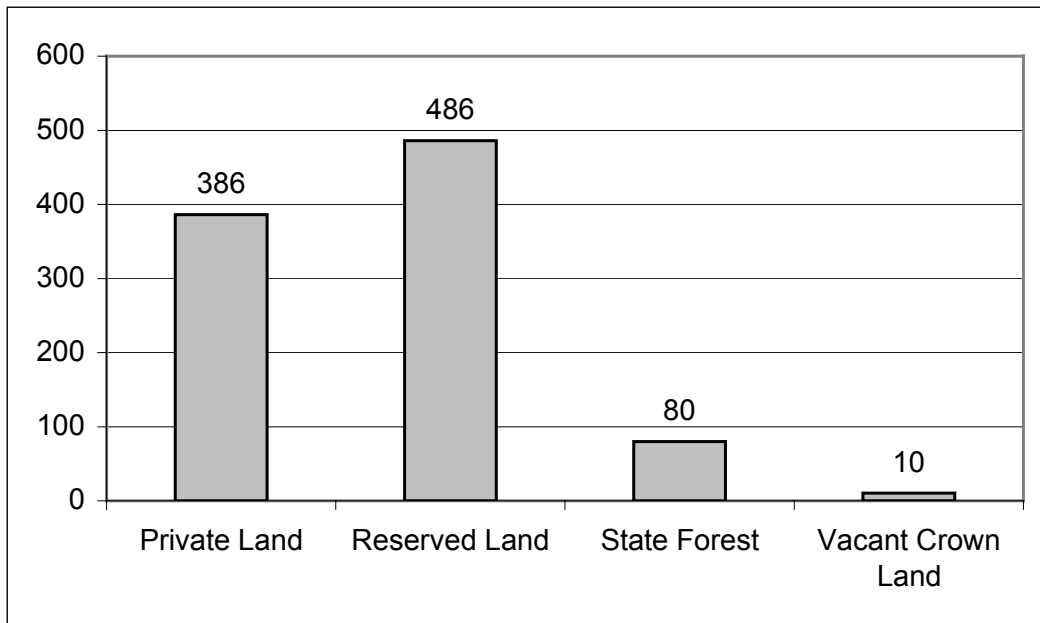


Figure 2. Tenure of recorded BTRW sites across Australia.

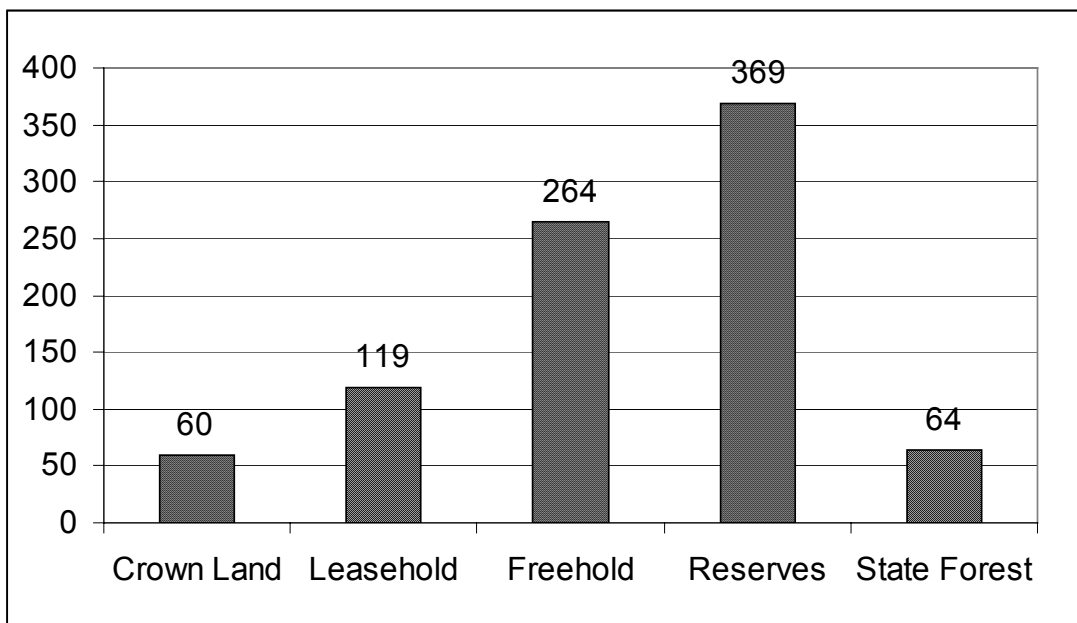


Figure 3. Tenure of BTRW sites in NSW.

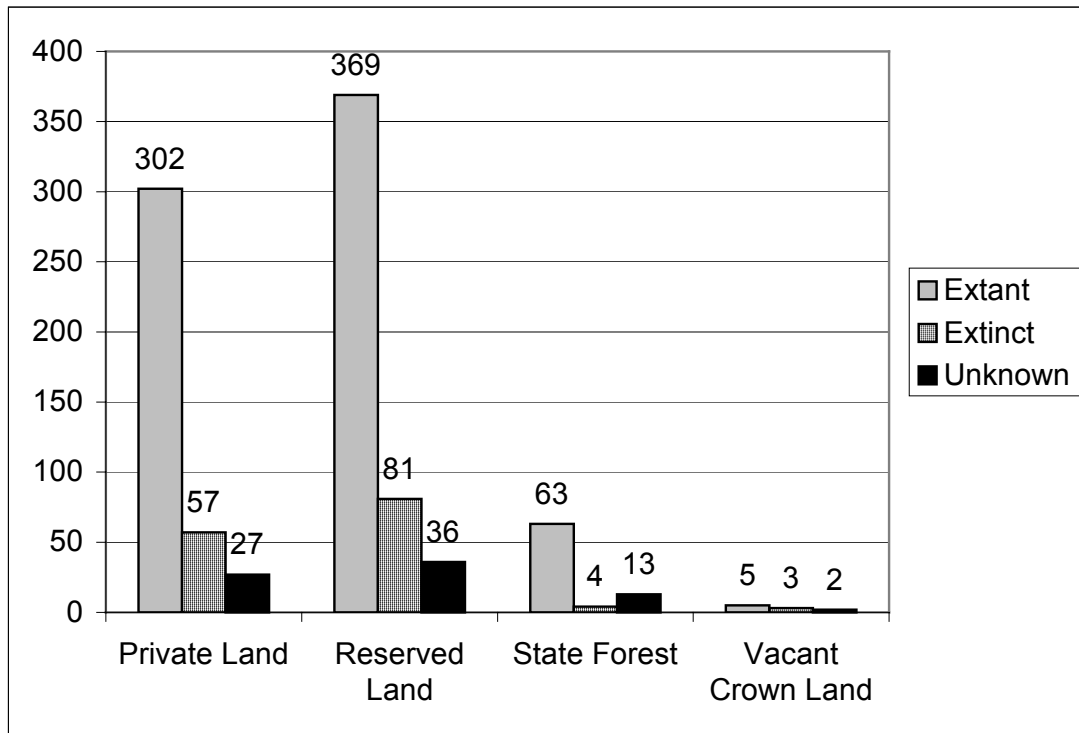


Figure 4. BTRW recorded sites: Tenure by status.

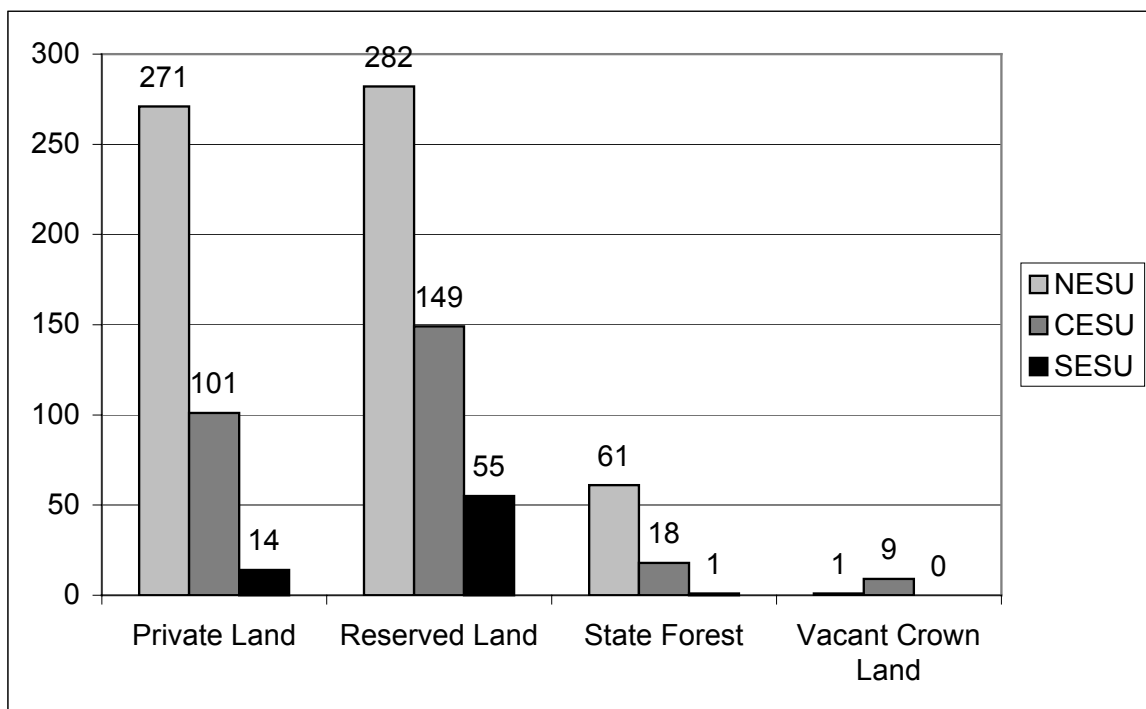


Figure 5. BTRW recorded sites: Tenure by ESU.

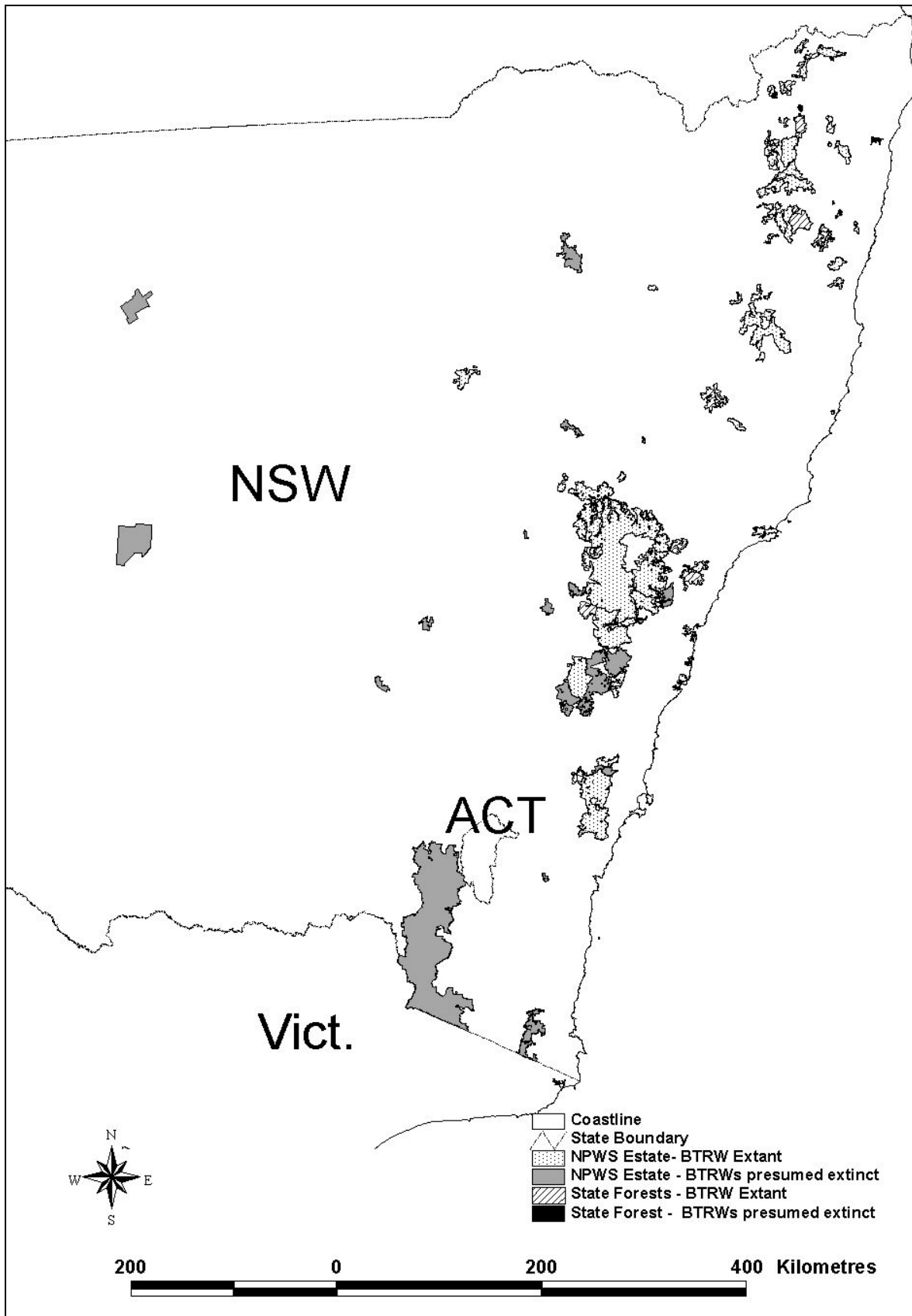


Figure 6. BTRW conservation status in NSW reserves.

**Table 4. Reservation Status of BTRW in NSW National Parks Estate  
(NP – National Park, NR – Nature Reserve, SRA – State Recreation Area).**

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
Burraborang 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
Toooloom 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

\*ESU boundary indeterminate



## 4.0 Description

The BTRW is a distinctively marked medium-sized wallaby and one of the larger species of the genus *Petrogale*. Individuals average 510-586 mm in head to tail length and 500-700 mm 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 kg and for females from 4.9 to 8.2 kg (Strahan 1995).

Brush-tailed Rock-wallabies 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.). Although little colour variation generally occurs between the sexes, the rufous coloration of the male may be more emphatic (Jarman 1989). However, there is considerable variation in colouring and patterning between different populations and between individual wallabies within a population, often allowing individual identification. Variability in the extent and shape of white chest blazes are particularly useful for this (Bayne 1994). The head is marked by a light coloured cheek stripe and a black dorsal stripe from the eyes to behind the head. The flanks are more or less distinctly striped pale-grey over black, and there may be a white blaze, which varies in size and shape, on the chest (Bayne 1994; Eldridge pers. comm.). 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 in some individuals (Eldridge pers. comm.). Colours tend to be lighter and tails less bushy in the north of the 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 compared with other wallabies (Close pers. comm.).

Rock-wallabies are highly agile animals able to move swiftly and confidently, by means of 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).

## 5.0 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 it is now mostly found as small isolated populations dotted across the former range.

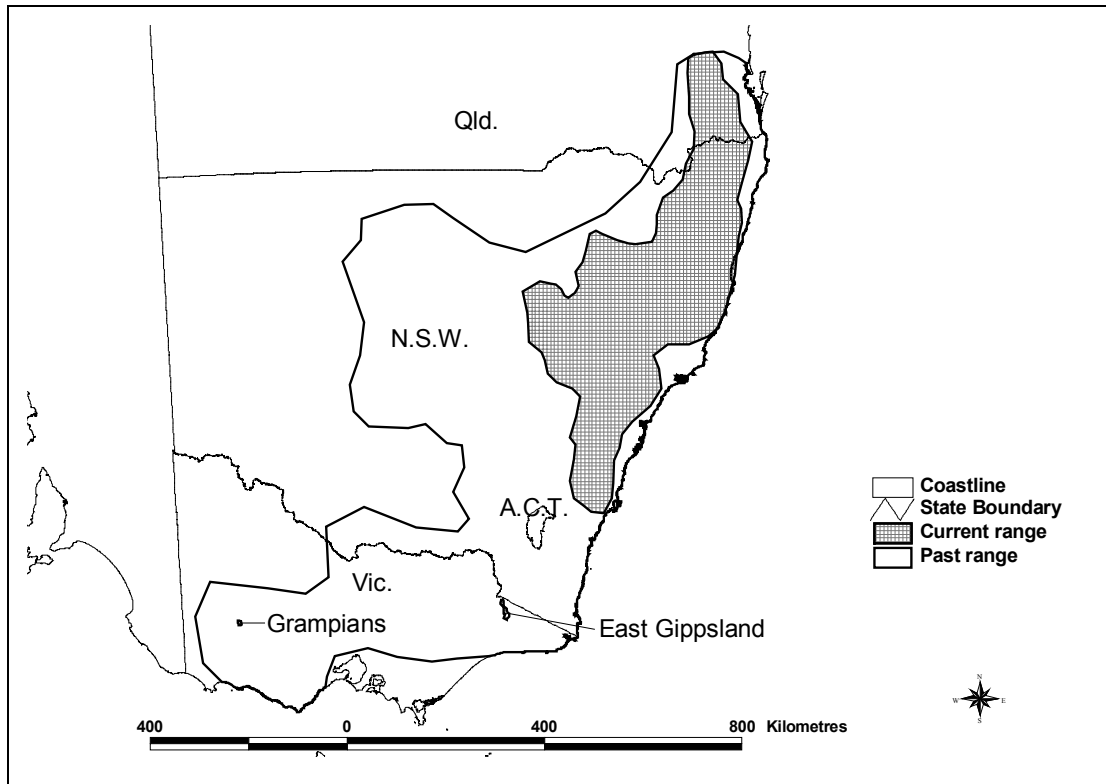


Figure 7. Past and present range of BTRW.

Until recently, the very 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, for example, the Apsley-Macleay and Clarence Rivers.

A major survey of the species' distribution was carried out in 1990 (Short and Milkovits 1990). They found 37 sites where the species had occurred within the previous 20 years and 30 sites where they were presumed extinct. In 1993, a more comprehensive survey identified 47 colonies existing in 18 localities in central, southern and western NSW and more than 100 colonies in 15 localities in northern NSW (Dovey *et al.* 1997). The survey found a further 14 sites where the animals had become extinct. Since 1993 BTRW at five of these localities have disappeared, making a total number of 49 sites known to have become extinct, or vacated, since 1990. A National Parks and Wildlife Service (NPWS) survey in 1995 located 15 colonies of BTRW in Yengo National Park and Parr State Recreation Area and surrounding areas (Rummery *et al.* 1995).

Bioclimatic variables have been postulated to be factors in the past variations in rock-wallaby distributions and genetic variation (Eldridge unpub.; Cavanagh in prep.). In particular, modelled past shifts in the climatic envelopes 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 the hybrid zone between

the species. Past climate modelling also indicates that the presence of BTRW in the Grampians region may have occurred only within the last 20,000 to 10,000 years (Cavanagh in prep.).

## 5.2 Abundance

During the late 1880s, BTRW 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 of BTRW were shot as agricultural pests and hunted for fur (Lunney *et al.* 1997). Subsequently, their numbers appear to have continued to fall in most localities and it is now estimated that there are between 15,000 and 30,000 animals left in total. Gaining a more precise estimate of numbers is difficult due to the inaccessibility of the species' habitats, particularly in the north of its range where numbers are known to be greater.

Based on current records, approximately 17 % BTRW occur in south-eastern Queensland, 82 % in NSW (including ACT), and fewer than 1 % in Victoria. In NSW, as many as 98 % BTRW are found north of the Hunter River, and up to 80 % the total number of BTRW in Australia are found in north-eastern NSW alone (see Figure 8). Moreover, the majority of the northern NSW populations are in the Macleay River and Clarence River gorge complexes (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, there is a substantial amount of evidence which indicates the relative numbers in the south have not only been reduced, but drastically so (eg. Lunney *et al.* 1997; Short and Milkovits 1990). Accurately estimating abundance remains one of the challenges for recovery planning.

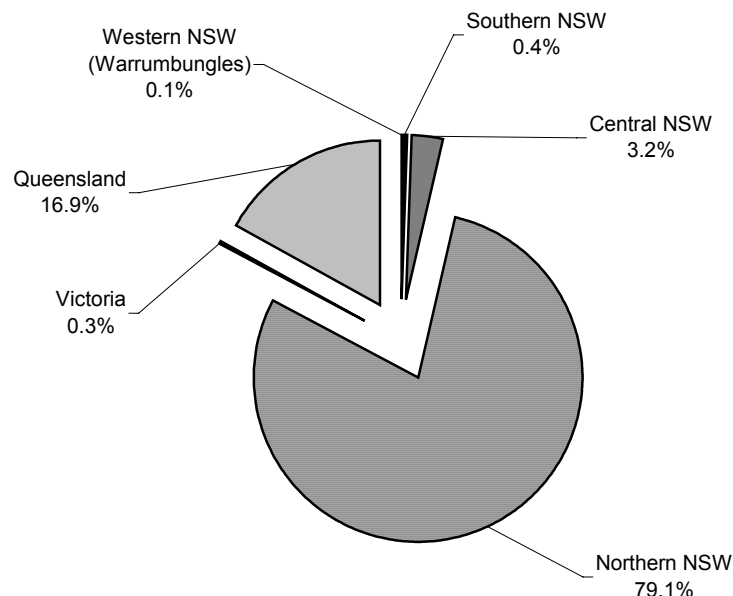


Figure 8. Estimated regional abundance of BTRW.

## 6.0 Ecology

### 6.1 Life Cycle

#### *Reproductive biology*

A study of BTRW on Mototapu Island, gave an average age to independence of 230 days, and a mean of 1.35 pouch young born per year per female (Bachelor 1980). Breeding seemed to have no particular season and was continuous year-round, probably depending mainly 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 1999). 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.) has 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.

Females give birth to a single pouch young at a time, after a gestation period of approximately 30 days (Close 1993). The young remain in the pouch for 6 months. After they first emerge from the pouch, the joey spends a further 7-20 days in and out of the pouch. As BTRW are crepuscular, 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 9 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.). All sub-adult males and most sub-adult females disperse from their refuges of birth (Joblin 1983). Life expectancy in the wild is 5-10+ years (Eldridge *et al.* 1988) but can be longer in captivity.

The minimum time between litters is likely to be 210 days (Lee and Ward 1990). The number of young born per year is related to dominance. A study by Joblin (1983) found the dominant female of a group produced 1.09 young 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 unit occupies.

Brush-tailed Rock-wallabies are polygynous, and a dominant male will be found with up to four females. They appear to live in family groups of 2-5 adults and usually one or two juvenile and sub-adult individuals (Joblin 1983; Short 1980), but are also known to occur in male-female pairs (Bayne pers. comm.).

#### *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 was identified between BTRW and Herbert's Rock-wallaby (*Petrogale herberti*) (and also 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*.

#### *Genetic distinctiveness*

Research to date on the genetic typing of BTRW indicates BTRW populations are naturally highly structured and the level of geneflow between colonies is typically limited (Eldridge and Browning unpub.). For example, restrictions in geneflow can occur over distances of approximately 4 km. Recent studies on BTRW dispersal indicates the females demonstrate strong philopatry within colonies, i.e. they are more related to females in close proximity than those further along the same cliff-line, whereas males are more likely to disperse (Hazlitt *et al.* 2004).

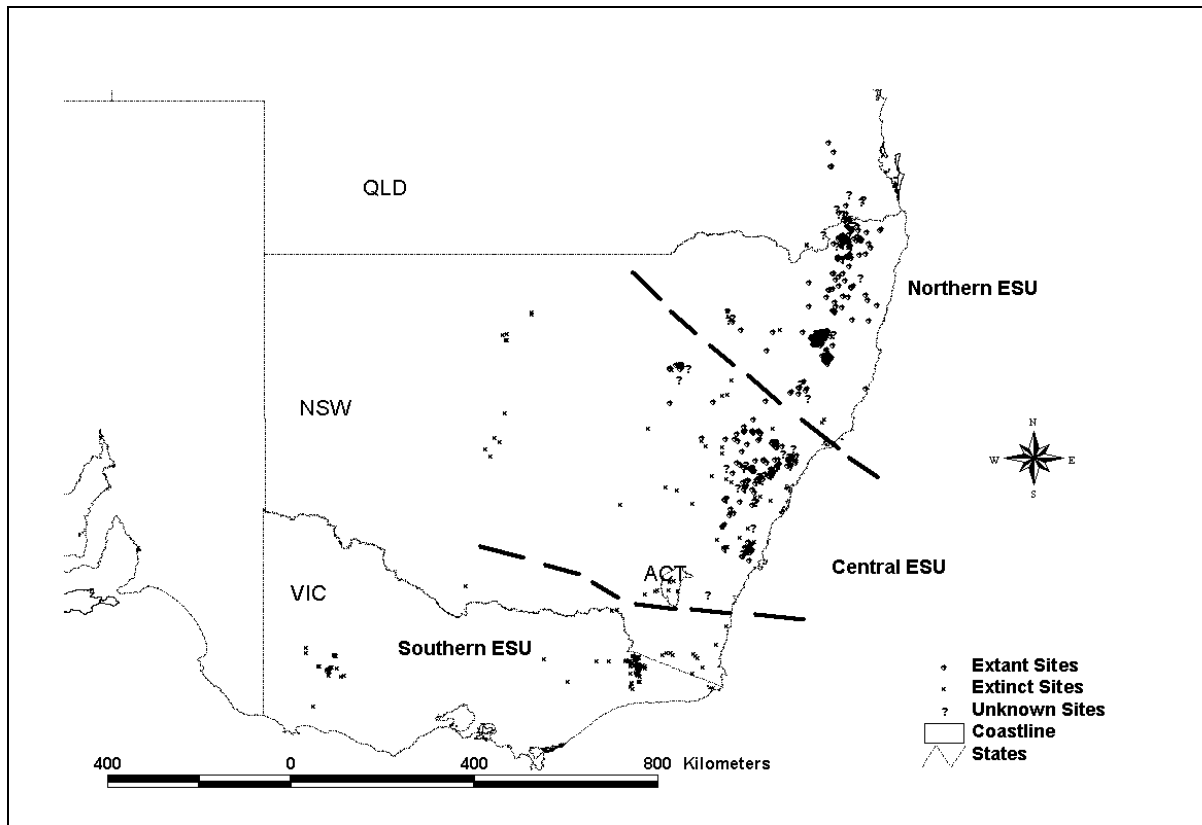
Relatively undisturbed populations of BTRW still contain high levels of genetic diversity (as measured by microsatellites). However, in areas where BTRW have declined, the remnant populations have lost considerable amounts of genetic diversity and remaining individuals are often highly related. Demographic, environmental and genetic stochasticity severely threaten the survival of these remnant populations.

The pattern of sequence divergence of BTRW mitochondrial DNA (mtDNA) indicates the presence of three genetically distinct groups or ESU (see Section 3.0 Conservation Status for the definition of ESU and illustrated in Figure 9):

- (i) A highly divergent lineage currently consisting of the remnant Victorian populations. Representatives of this lineage may have previously occurred in southern NSW.
- (ii) 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.
- (iii) 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. At the northern most extent, a narrow hybrid zone has formed between BTRW and Herbert's Rock-wallaby (Eldridge and Close 1992; Bee and Close 1993).

While the exact level of taxonomic difference remains to be established, it is clear that these three groups exhibit important genetic variation that should be maintained. In this regard, as indicated in Section 3.0, they have been determined to be Evolutionary Significant Units (ESU) (*sensu* Moritz 1994).

The exact boundaries between these ESU are yet to be determined. The boundary between the northern and central ESU lies somewhere between Broke and Woko National Park, and may be centred on the Hunter Valley. Defining the boundary between the central and southern ESU is likely to remain problematic as there are no animals now known from this area. Therefore, these boundaries should be considered as **guides only** for management and recovery purposes, and have most applicability to the maintenance of genetic integrity of the three taxonomic groups.



**Figure 9. Indicative Distribution of Evolutionary Significant Units of BTRW.**  
(NB: Boundaries are indicative only.)

### *Recruitment rate*

The rate of recruitment and the dynamics of dispersal are little known areas of BTRW ecology. However, the species appears to have low migration rates between colonies and low recolonisation rates that may be exacerbated by human induced land use changes and predator pressures.

Recent studies on the microsatellites and mtDNA of BTRW indicate that BTRW populations are naturally highly structured and that the amount of geneflow between colonies is typically limited (Eldridge *et al.* 2001; Eldridge *et al.* 2004). However, it is important to note that both techniques also indicate that geneflow between populations is not completely absent. Instead it is this low level of geneflow which has maintained the genetic health and cohesion of the BTRW as a species for millennia.

Recent human induced BTRW population declines, extinctions and fragmentation have almost certainly severely disrupted the natural process of low level geneflow that has been occurring within this species for thousands of years. As colonies are isolated and restricted to rocky habitats, migration is likely to be impeded by cleared or degraded intervening habitat. Without active and on-going management the long-term future of any population that is now completely isolated is questionable (Eldridge and Browning unpub.).

## 6.2 Diet

Throughout their range, BTRW feed on a wide variety of grasses and shrub browse, and appear to have flexible dietary requirements.

Wakefield (1961) reports an opportunistic stomach content recognition of leaf-fragments of *Clematis microphylla*, and observations of BTRW 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 additional feeding observations of the species. Again grasses (*Danthonia setata*, *Stipa semibarbata*) and shrub foliage were prominent, with additional shrub species browsed for seeds and flowers, and 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 collected specifically on the diet of BTRW was undertaken at two sites in eastern New South Wales – Kangaroo Valley and Goulburn River (Short 1989). The results of this work largely substantiate the earlier observational records on the species. Averaged over both sites, the diet of the BTRW consisted of 35-50 % grasses, 25-40 % forbs and 12-30 % browse. 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, and even termite mound, bone, rotten log and cowpat 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). This, 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/browser.

## 6.3 Predators

Predation is thought to have a particularly significant, if not the greatest impact on macropod populations, (including BTRW) through loss of dispersing young or young at foot (eg. Christensen 1983; Banks 1997; Sharpe 2000). Foxes (*Vulpes vulpes*), dogs, cats, Wedge-tailed Eagles (*Aquila audax*) and possibly Tiger Quolls (*Dasyuridae*) (J. Reside pers. comm.) prey on rock-wallabies. Foxes are thought to have been 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 through a series of refuge sites at one BTRW colony. A large feral cat has been observed eating juvenile Allied Rock-wallabies (*Petrogale assimilis*) in northern Queensland (Spencer 1990). Reported predators of other species of rock-wallabies include pythons, King Brown Snake, and White-bellied Sea-eagle (Eldridge pers. comm.).

Adults of this species 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 BTRW do fall into the critical weight range of fauna and are therefore considered most at risk.

Banks (1997) found seasonal increases in the proportion of Eastern Grey Kangaroo (*Macropus giganteus*) in the diet of foxes in an area of the NSW Southern Alps which was correlated to the emergence of juvenile kangaroos from the mother's pouch. Banks also detected the presence of the remains of juvenile kangaroos at fox dens, and observed foxes harassing female kangaroos with young. Even though their habitat provides BTRW with some degree of protection from predation, it cannot always protect dispersing young. If juvenile predation rate is equal to or greater than the birth rate of the colony, it can be assumed the colony will die out within the lifetime of the existing adults 5-10+ years unless recruitment from outside the colony occurs.

There is much circumstantial and anecdotal evidence that BTRW are eaten by introduced canids. 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.). Although it is likely that predation by introduced predators is likely to be a major limiting factor for BTRW throughout much of their range, there remains limited documented evidence of this.

Sharp (1999) investigating populations of Yellow-footed Rock-wallaby (YFRW) (*Petrogale xanthopus*) in western NSW, conducted fox removal experiments from 1992 to 1998. Results of this work indicate fox predation was a major limiting influence on the YFRW population over this period. Of particular interest, this study demonstrated that predation on juvenile and sub-adult YFRW was the primary causal agent behind the limitation of the total YFRW population.

#### 6.4 Competitors

The level of competition between rock-wallabies and other herbivores is generally poorly understood. Competition between BTRW and feral goats for refuge areas has been noted by Bayne (unpub.) and postulated by Short and Milkovits (1990). Recent declines in YFRW in Mutawintji, where a fox control program is being implemented, have been attributed to increased competition with goats as a result of drought conditions.

Short and Milkovits (1990) note BTRW decline has been most pronounced 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.

Competition with native animals has also been speculated as potentially affecting BTRW ecology and habitat use, eg. Wallaroos and kangaroos (Ruming and Moss 2000; Bayne unpub.; Eldridge pers. comm.), Swamp Wallabies (Close pers. comm.) and Brush-tailed Possums (Eldridge pers. comm.).



## 6.5 Behaviour

Brush-tailed Rock-wallabies live in loose colonies limited by the availability of refuge sites in core habitat. Colonies are often fragmented due to the nature of the terrain and by human development. Consequently, dispersal of young animals between colonies is likely to be constrained in these situations.

Brush-tailed Rock-wallabies are nocturnal to crepuscular and spend most of their daylight hours sheltering or sunning themselves in steep, rocky, complex terrain in some sort of shelter (cave, overhang or vegetation), and ranging out into surrounding terrain at night to feed (Maynes and Sharman 1983). The use of these refuge areas by BTRW are assumed to supply protection from predators and amelioration of climatic extremes (Wilson *et al.* 1976; Short 1982; Freeland *et al.* 1988; Burbidge and McKenzie 1989).

This reliance on refuges leads to the BTRW living 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 to 30 ha in size (400-900 m along the cliff), with an average of 15 ha (700 m along the cliff). Daytime home ranges were much smaller than those 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 2 km from their refuges (Lim *et al.* 1981). This movement is usually at night when the animals go into the surrounding terrain to feed. Batchelor (1980) found the greatest activity occurred three hours before and 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, BTRW habituate the same refuges, sunning spots, feeding areas and pathways (Joblin 1983; Bayne 1994). Brush-tailed Rock-wallaby rest sites on Motutapu Island in New Zealand were exclusive 95.4 % of the time (of 2,368 records) and 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), a number of persistent close associations between one male and one female sharing the same refuges and territory were observed, as was the transfer of resident females 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 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 of this colony moved or died during the summer of 1997/98 (NPWS 1999). Brush-tailed Rock-wallabies may move in response to disturbances (Close pers. comm.). A local landholder at Mt. Wallerawang in Watagan State Forest reported that BTRW moved in response to a fire (and then returned several years later). Norris and Belcher (1986) suggest there was once a nomadic group of BTRW moving along the Snowy Gorge.

## 6.6 Population Structure

### *Total population number*

The total population of BTRW is thought to be between 15,000 and 30,000 animals. This is a significant reduction from previous numbers, as it is known that during the period BTRW were hunted, in excess of 50,000 animals were shot in one region alone. It is estimated that 10,000 to 25,000+ Northern ESU, 500 to 1,000 Central ESU and less than 10 Southern ESU BTRW remain in the wild.

### *Natural and human induced fluctuations*

Climatic modelling has been used to investigate possible past changes in distribution of BTRW (Cavanagh in prep.). This work suggests that under past climate extremes, a retraction in the southern part of the species range may have occurred, and that the extension of BTRW into the south-west of their range, i.e. Grampians in Victoria, may have occurred within the last 10,000 years. This work also suggests that past climate extremes may have played some part in determining the development and distribution of the individual ESU. These variations are also likely to have resulted in changes in relative abundance across the species range within the overall patterns of distribution.

A climate and terrain modelling program has been 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 BTRW in south-eastern Australia and that therefore, there is a bioclimatic basis for the decline of BTRW in recent years.

## 7.0 Disturbance

### 7.1 Fire

The impact of fire on BTRW populations is uncertain. Brush-tailed Rock-wallabies 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 BTRW (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 1996/7, there appears to have been a recent decrease in BTRW abundance following a more extensive wildfire (668 ha burnt in October 2000, C. Rummery pers. comm.). In addition, a study of BTRW colonies and habitats conducted in the Grampians area determined the absence of recent fire was a significant variable in the distribution of colonies (ABRG 1988).

Fire alters the structure, floristics and possibly the suitability of the vegetation (Bugg 1995). It is probable that the response of colonies to fire is dependent on both the amount of protection afforded by the colony site (eg. caves for sheltering), and the intensity of the fire. In addition, intensity of single fire events, and changing fire regimes, will affect the availability of food resources in and around BTRW sites, with probable greater impacts in

terms of loss of food resources when fires occur during drought conditions (due to low sustained regrowth after fire in prolonged low soil moisture conditions).

## 7.2 Floods

Recent flooding in northern NSW has been a cause for concern with regard to the long-term stability with which the northern populations are often regarded (Bayne unpub.). An absence of BTRW has been noted following extensive loss of vegetation along the lower levels of the Macleay and Clarence River catchments. It would appear that animals in these areas are relying heavily on the structure of mesic vegetation as refuge sites, which, once removed, creates an unfavourable habitat for the animals (Bayne pers. comm.). While it is expected that BTRW will return as the vegetation grows back, 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 weed species such as Lantana (*Lantana camara*) reduces habitat quality for BTRW. It is possible that weed infestation, 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, BTRW 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 likely to be a significant factor in continuing BTRW decline. However, shooting probably played a part in earlier reduction of numbers, especially around the turn of the century in the south-east of the state (Lunney *et al.* 1997). New South Wales declared kangaroos and wallabies vermin and agricultural pests 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 the year 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 alone (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). Further historical research identified the extent and relevance of commercially driven hunting pressure to the early and steep decline of BTRW in NSW. Intensive and prolonged hunting from at least 1880 to 1927 caused local extinctions, as well as widespread reductions in the size of BTRW populations (Lunney *et al.* 1997). Brush-tailed Rock-wallabies were also shot for sport

(Lim *et al.* 1987). Brush-tailed Rock-wallabies may be killed for food in some local aboriginal communities (Bayne unpub.).

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

## 7.5 Drought

The effects of drought on colonies of BTRW has been reported by Bayne (unpub.), who found that during a period of drought, numbers at some long-known colonies were noticeably lower than in pre-drought condition some 18 months previous. Bayne also noted that many areas are grazed in the Macleay area, and even within the Oxley Wild Rivers National Park many goats and cattle were seen in areas where BTRW occur, and in many places along the valley floor all vegetation bar the trees was grazed to ground level.

Short (1982) reported that BTRW 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 very low (Delaney 1997).

Drought, as an additive factor, has also been implicated in the decline of the YFRW in western NSW (Lim *et al.* 1992; Sharpe 1999).

## 7.6 Other Disturbance Regimes

Little is known of the species' response to other disturbances or what happens to the animals if they move. When BTRW are forced to leave their refuge habitat, it is probable they become more vulnerable to predation when forced to travel through more open landscapes.

## 8.0 Habitat

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

This study classified occupied BTRW habitat into three categories:

- Loose piles of large boulders containing a maze of subterranean holes and passageways.

- Cliffs with many mid-level ledges and with some caves and/or ledges covered by overhangs. Cliff height is usually over 15 m.
- Isolated rock stacks, usually sheer-sided and often girdled with fallen boulders.

Habitat requirements of the BTRW were examined, and 15 refuge/habitat variables were tested as potential discriminators. Short (1982) developed a predictive equation to assess refuge/habitat suitability, which used 5 variables: percentage of sheltered ledges, number of ledges, aspect of cliff, percentage of ledges of restricted accessibility, and length of ledges.

Importantly though, Short (1982) also points out that this present habitat picture may have developed after environmental changes wrought by European man, including fox and other feral introductions, raising the threshold of suitability of rocky habitat.

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). These habitats are difficult for most exotic herbivores to penetrate (except goats); they have a patchy distribution of fuel which breaks up fires; they provide effective shelter from most cursorial predators and provide energy cheap, thermally buffered shelter. Vegetation near rock surfaces also receives shading, seepage and run-off that encourages greater plant diversity and extends periods of growth and occasional flushes during drought (Johnson *et al.* 1989).

Since the work of Short (1982), BTRW have been found to use a wider range of rocky habitats. Brush-tailed Rock-wallabies have been found living on much less complex cliffs, using vegetation rather than rocks for shelter, eg. 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). Brush-tailed Rock-wallabies have also been found on aspects other than northerly.

While it appears that most BTRW colonies are on north-facing slopes and cliff lines (Short, 1982), colonies have been found on south-facing cliffs 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.), although usually in lower densities. Although the habitat of these colonies is south-facing, there are still areas which are exposed to the sun, eg. a free standing rock pinnacle or prominent spur. Of 963 recorded sites, Cavanagh (in prep.) found that while approximately 73 % faced in a northerly direction (west through north to east), 24 % sites faced in a southerly direction (WSW through south to ESE), as illustrated in Figure 10.

The vegetation on and below the cliff appears to be of equal importance to BTRW. 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, vegetation structure and floristics are important habitat factors for BTRW 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 occurs where mesic vegetation is associated with complex cliffs, boulder piles and rock outcrops. In Kangaroo Valley, BTRW occur in areas where the rainforest vegetation is associated with topographic complexity (Bugg 1995). The invasion of grassy feeding areas by weed species such as Lantana is thought to reduce habitat quality for BTRW (Capararo and Beynon 1996; Wong 1997).

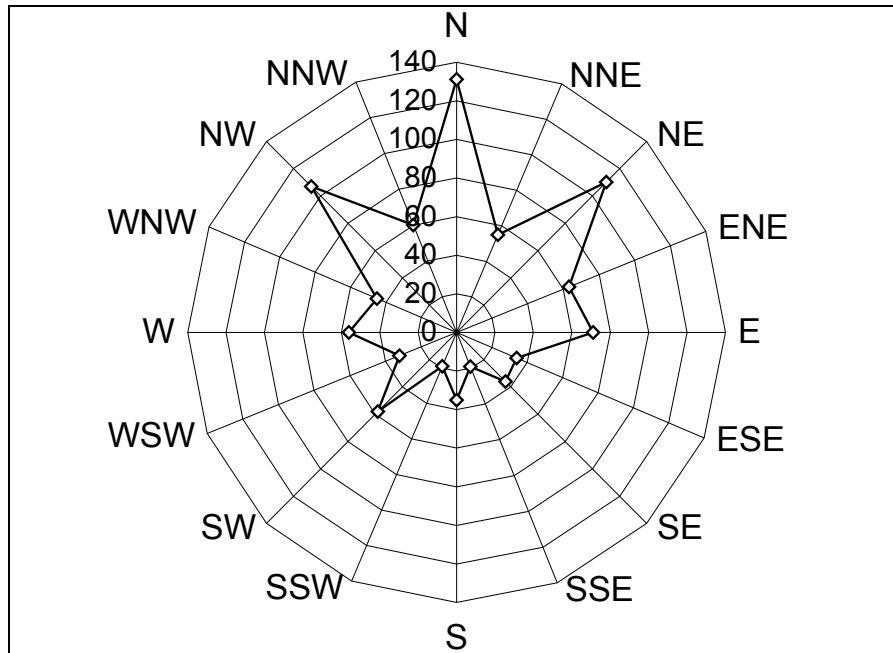


Figure 10. Graph of aspect of recorded BTRW sites.

It is possible that BTRW behaviour and use of habitat has changed in many ways in the last 200 years. The introduction of the fox, along with other human-induced changes, is likely to have raised the suitability threshold of the wallabies' rocky habitat so that fewer sites are now occupied (Short 1982). Behaviour of BTRW reported as typical by Le Souef and Burrell (1926) would seem somewhat unusual in current literature: sheltering in hollow logs, allowing such close approach as to be taken by hand in their caves, and "[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."

## 9.0 Management Issues

### 9.1 Threats and Reasons for Decline

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

While much of the focus has been understandably on the abatement of the proximate threatening processes, that is, predation by foxes and competition from goats, habitat modification at the landscape scale appears to be the potent ultimate threatening process (*sensu* Simberloff, 1986) (Cavanagh in prep.; Bayne pers. comm.).

The following summarises some of the key threatening processes:

### *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 mammals 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 continental (off shore) 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.

Habitat usage by BTRW has been affected by many changes. Perhaps the greatest change is in vegetation: the structure, extent, species assemblages and species proportions. These changes have been caused by a combination of clearing, exotic plant invasions, changed fire regimes, exotic herbivore grazing and browsing behaviour, land degradation, altered nutrient status, and even altered behaviour and numbers of other native animals. How significant these changes have been on the BTRW food and shelter resources is unknown. However, it is notable that the majority of 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 (in prep.) indicates there is a positive correlation between habitat fragmentation at a landscape scale and broad patterns of extinction in BTRW sites across the species' range.

Habitat modification continues due to rural residential and tourist developments adjacent to the some colonies, and there is an apparent trend to locate these developments near escarpments and cliff lines to maximise scenic opportunities. These 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 specific measures are undertaken to produce conservation outcomes. Education and awareness can reduce the natural fire risk, improve the physical protection given to core habitat through fencing against stock and result in more intensive feral animal control.

### *Predation*

The Red Fox is generally considered to be a major factor in BTRW decline, and many authors have suggested this link. Le Souef and Burrell (1926) reported the ease of close approach to BTRW 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 the 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 at 1,500 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 index for rock-wallaby density. Nearby Depuch Island was surveyed in 1962 by the Western Australian Museum, and at that time Black-footed Rock-wallabies were present in large numbers but there was much evidence of fox predation which had then 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) to attempt to gain more positive evidence. In their study, fox control through poisoning and shooting increased Black-footed Rock-wallaby numbers by 138 % and 223 %, whilst two populations where there was no fox control decreased further by 14 % and 85 %. Based on these results, Kinnear *et al.* (1988) concluded the fox was a significant factor in the demise and decline of native mammals and that rock-wallabies have the ability to recover even under serious fox predation.

A response by Hone (1994) questioned the validity of the conclusions of Kinnear *et al.* (1988) on the basis of statistical analysis on a subset of their data. Subsequently, further statistical analyses were conducted on the full set of data provided by Kinnear *et al.* (1988) and including an extra four years of data by Kinnear *et al.* (1998). This analysis confirmed the earlier general conclusions of Kinnear *et al.* (1988). This later report also highlighted the expansion and shift in habitat utilisation and foraging range of the populations where fox control was undertaken.

A further critique by Hone (1999) confirmed the reassessment by Kinnear *et al.* (1998). However, Hone (1999) also stressed the importance in monitoring predator numbers as well as prey numbers, to clarify the mechanism causing the population response that was measured, and not just to leave it as an assumption, that is, to broaden the knowledge base beyond patterns and numbers.

The Black-footed Rock-wallaby is a similar animal to the BTRW, and the implications of this work are likely to apply to BTRW. Hornsby (1982) has also reported a juvenile Wallaroo (*Macropus robustus*) falling prey to a fox, and 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 juvenile mortality in a population of Eastern Grey Kangaroos (*M. giganteus*) caused by fox predation. These studies also suggest Eastern Grey Kangaroos alter their behaviour in response to predation threats from foxes. This is in line 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 Black-footed Rock-wallaby in Western Australia, there is limited documented evidence (although circumstantial and anecdotal evidence) of an impact of foxes on BTRW. Differences exist between the habitat of the Black-footed Rock-wallabies in Western Australia (wheat plains and rocky outcrops) and that of BTRW (forests, continuous ridge lines and precipitous gorges) which potentially affects the BTRW susceptibility to foxes.



As indicated earlier (Section 6.2 Predators), results of research undertaken by Sharp (1999) on populations of the YFRW in western NSW, indicate fox predation was a major limiting influence on the YFRW population over a six year period.

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.) has reported observing on three occasions foxes flushed into the open when on a BTRW occupied cliff, and twice watched foxes actively hunting a BTRW cliff, covering every part and examining each ledge and cave (all of these occasions were on gorge-rim cliff colonies). Bayne also noted that on one of these occasions the route taken by the fox included a short section of slab which it successfully negotiated despite the slab appearing too difficult for a fox to negotiate.

In contrast, strong evidence for fox predation in northern NSW is lacking. Of 144 fox scats collected in the vicinity of BTRW colonies in north-eastern NSW, none contained the remains of BTRW (Lunney *et al.* 1996). In addition, of a total of 342 canid scats (dog, dingo and/or fox), BTRW was identified as a prey item in only 1 % (Lunney *et al.* 1996). This low occurrence is in spite of the fact that the surveys were conducted to coincide with periods of pouch emergence and juvenile dispersal when predation on BTRW was expected to be most likely (Lunney *et al.* 1996).

Dingos also appear to prey on BTRW, and a number of the respondents to the NPWS 1993 BTRW community survey (Bayne unpub.) reported seeing dingos chasing BTRW with one reported known kill (Ross pers. comm. in Bayne unpub.). However, it is notable that most of the remaining areas of high BTRW density are also generally areas with high dingo populations, indicating dingos are unlikely to be causing a strong negative impact. In fact, it has been postulated that the presence of dingos may be assisting the persistence of BTRW, whether through their purported exclusion of foxes (Jarman 1986), or through the maintenance of lower densities of other competing herbivores, whether native or feral, especially goats (Bayne unpub.).

Feral cats have also been suggested as possible predators of rock-wallabies. Spencer (1990) records the sharp reduction in the population of an isolated Queensland colony of the Allied Rock-wallaby (*Petrogale assimilis*) under predation of a single feral cat. Between July 1986 and June 1990, the adult population fell from at least 83 individuals to about 26 individuals. Evidence was found of the cat eating two of 43 adults (4.6 %); one of seven sub-adults (14.2 %); and five of eleven known young at foot (45.5 %). Spencer concluded this 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 BTRW, especially smaller juvenile animals. The YFRW, a considerably larger rock-wallaby than the BTRW, has also been recorded as falling prey to feral cats (Sheppard 1990).

Eagle predation also occurs (Reside pers. comm.), and it is possible that eagle predation has become more significant in some 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 over a single large rock-wallaby colony constantly 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 YFRW in western NSW (Sharp 2000; Sharpe *et al.* in prep.) have identified it as a minor dietary component of Wedge-tailed Eagles within the study area (0.6 % of the total prey items identified). Sharp (2000) calculated that eagle predation accounted for approximately four YFRW each year, equating to between 2 % and 4 % of the total population.

#### *Disease*

Little is known about disease in wild populations of BTRW, although it is likely that this species is susceptible to diseases found in other macropods. Owing to the naturally disjunct nature of BTRW colonies, the species may be capable of surviving genetic ‘bottlenecks’ and recovering from very low numbers (Close pers. comm.). Inbreeding depression 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 BTRW suggests a relationship between hydatidosis in BTRW and sheep (Close 1984 in Lobert 1988). Lobert (1988) also raised the possibility that BTRW 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 apparently present in the captive colony at Jenolan Caves prior to the large scale release in 1988 (Buchan 1995). This disease is more prevalent in populations of macropods which are exposed to human contact and, specifically, fed ‘soft’ (processed) foods.

#### *Competition with introduced and native herbivores*

In general, the level of competition between BTRW and other herbivores is poorly understood. Short and Milkovits (1990) noted that BTRW decline has been most pronounced in those parts of their range where sheep grazing is the common land use. However, they also note that these parts are drier, with fewer areas of steep, rugged terrain, and are usually associated with higher numbers of goats, rabbits and foxes. Therefore it is hard to isolate effects, but this study 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 BTRW on rocky habitat west of the Divide as shelter sites at those locations are now occupied by goats (Short and Milkovits 1990). Rabbits also have the potential to compete with BTRW, particularly in dry times when food may be scarce.

Although direct competition is hard to measure, Lim *et al.* (1987) noted the presence of goats significantly affected the recovery of YFRW populations after drought. Goats can compete for shelter, and Copley (1983) reported goats evicting YFRW from caves. Bayne (unpub.) has also observed BTRW being flushed from sites by goats, and refuge sites disturbed or destroyed. In its 1997 Final Determination on the Warrumbungles’ population of BTRW, the NSW Scientific Committee stated that competition from goats for shelter

sites and food constitutes a major threat to this BTRW population, and that competition is likely to increase during periods of drought (NSW Scientific Committee 1997).

Goat control was undertaken in areas around YFRW colonies in western NSW (Sharp 1999b). Although direct monitoring of the YFRW population was not undertaken, it was noted that YFRW numbers underwent a slow decline during this period. Sharp 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 YFRW populations.

The removal of refuge vegetation may be one of the more important impacts of feral herbivores. A significant proportion of the occupied BTRW refuges, particularly in the northern rivers gorges in north-eastern NSW, are vegetative structures and agile browsers like goats have the potential to totally destroy and remove these refuges (Bayne unpub.). It is likely that the number of suitable refuge sites is a limiting factor in the distribution of BTRW.

While competition with other herbivores is even more difficult to demonstrate, the impact of habitat alteration may be significant. For example, Pearson (1992) considered rabbits as a major factor in the alteration of habitat for Black-footed Rock-wallabies. The effect of rabbits may be spasmodic, and may be significant during times of drought only. It is likely that rabbits had major effects during the rabbit plagues of early this century (Lobert 1988). After comparison of the diets of YFRW and sympatric 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 m.

Increased competition with native herbivores is also potentially a factor in BTRW decline. For example, in many parts of the Macleay Gorge system, 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 areas of considerable erosion. These densities are often many times (perhaps an order of magnitude) 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, have the potential to degrade BTRW habitat in the gorge country (Bayne unpub.).

Swamp Wallabies (*Wallabia bicolor*) may compete with BTRW for food and shelter (Close pers. comm.) although they are known to co-exist naturally. Competition with Wallaroos (*Macropus robustus*) and Eastern Grey Kangaroos (*Macropus rufogiseus*) has been reported, as has the possibility that Brush-tailed Possums may be competitors (Eldridge pers. comm.; Moss pers. comm.). Therefore, where these species co-exist with BTRW, the impact of competition should not be discounted.

#### *Weed invasion*

Lantana invasion may reduce the amount of suitable habitat. In low densities or clumps it can provide shelter for BTRW (Maynes and Sharman 1983; Wong 1997), and possibly some protection from predation (Wong 1993; 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 extinction of the Upper Kangaroo River colony.

The relationship between disturbance regimes leading to loss of native vegetation cover, and the introduction of weeds is little understood in relation to BTRW.

### *Fire*

Fire may act to advantage or disadvantage BTRW, depending on fire intensity. Very hot, widespread fires (e.g. the 1983 wildfire in Kangaroo Valley) may adversely affect the species by preventing their escape. An extensive fire in 1983 in south-eastern NSW burnt from Bundanoon over a widespread area nearly to Hampden Bridge in Kangaroo Valley (NPWS, 1999). Bugg (1995) speculates the Kangaroo River colony has persisted because much of its habitat remained unburnt. Major fires erupt in the area on a 10-15 year cycle and fire remains a constant threat to BTRW colonies in a number of areas across the species' range. The DEC and local Bushfire Brigades conduct hazard reduction works in strategic locations in this 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 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.

It is likely that the ultimate impact of fire is determined by the combination of fire intensity and regime, which are determined by land management practices and topography as well as climatic factors. In assessing the appropriate management response to fire, both the more direct effects on vegetation structure (eg. promotion of grasses, opening of canopy, loss of mesic vegetation), and indirect effects on other factors (eg. fox and goat invasions), will need to be considered as relevant for each site.

### *Bioclimatic factors*

The influence of bioclimatic changes on BTRW distribution remains in dispute. On one hand it has been argued 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 the species 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.

Research currently being undertaken (Cavanagh in prep.) indicates that there are a number of climatic variables correlated to 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, fox numbers.

Cavanagh (in prep.) has also investigated the potential impacts of future climate change on BTRW distribution. The preliminary results of this work indicate that under the most likely Greenhouse scenarios (after Bennet *et al.* 1991), the predicted climatic envelope will largely shift away from the core of the Great Dividing Range, with most implications for those 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 loss of the security of high numbers in the Macleay Gorges, which currently contain a large component (c. 30 %) of the species total population. In the central regions, the northern Blue Mountains populations appear to provide better future options for survival owing to loss of the suitable bioclimatic conditions in other areas.

### **Conclusion**

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 it is clear that some threatening processes are significant in some areas, there does not seem to be a single cause for declines 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. As noted above, fox predation has most often been cited as the primary or critical threatening process, and on this basis, limited resources have most often been allocated to fox control programs.

Two critical components of threat abatement are (i) identification of critical threats (and their interactions) at both the local and landscape scale, and (ii) monitoring the effectiveness of management responses. Both identification and monitoring will need to be effectively implemented across the species' range if long-term recovery of the BTRW is to be achieved.

Also important for those populations or colonies that are most at risk, is a better understanding of factors at work in comparison to colonies or populations which are regionally robust, for example, Macleay Gorges.

There is a need to ensure regional-scale threatening processes are used to determine appropriate responses. For example, fox predation does not appear to be as significant a threat in the north of the BTRW range as it is in the south. Fox numbers in forests in the north appear to be less than in the south (Catling and Burt 1995), which, on face value, may be the reason for the differential impacts. However, there is some evidence to suggest fox numbers are negatively correlated to distance from private or cleared lands (eg. Catling and Burt 1995; Cavanagh in prep.; 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 causative or 'ultimate' threatening process, and fox predation the major resultant or 'proximate' threatening process (after Simberloff 1986).

Until a better understanding of the threatening processes of the BTRW is gained, the control of threatening processes will continue to be problematic.

## 9.2 Site Effects

The threatening processes affecting BTRW are little understood, multi-level, usually inter-related and the inter-relationships are often complex. Similar outcomes may be observed at sites although caused by different threatening processes, or different relationships between similar threatening processes. The end effects on habitat and resources of these processes can be summarised as follows:

### Loss of diurnal refuge sites

- 1 Loss and damage to refuge vegetation:
  - Agents:
    - Clearing native vegetation
    - Probably predominantly feral goats but potentially all other herbivores
    - Fire
    - Floods
- 2 Replacement of refuge vegetation
  - Agents:
    - Exotic plant invasions, weeds eg. Lantana

### Loss of, or damage to, food resources

- 1 Removal of food sources
  - Agents:
    - Vegetation changes caused by other herbivores (feral, stock and native),
    - Clearing and agriculture
    - Changed fire regimes
    - Exotic weed invasion
- 2 Reduction in diversity, persistence and temporal availability of food resources
  - Agents:
    - Vegetation changes caused by other herbivores (feral, stock and native),
    - Clearing and agriculture
    - Changed fire regimes
    - Exotic weed invasion
- 3 Reduced access to food resources
  - Agents:
    - Pressure from predators – behavioural changes

Vegetation changes caused by other herbivores (feral, stock and native),  
 Clearing and agriculture  
 Changed fire regimes  
 Exotic weed invasion

Loss of shelter vegetation away from diurnal refuge sites

- 1 Reduced shelter at feeding areas  
 Agents:  
 Clearing and agriculture  
 Vegetation changes caused by other herbivores (feral, stock and native)  
 Changed fire regimes
- 2 Reduced shelter and refuge potential in dispersal areas  
 Agents:  
 Clearing and agriculture  
 Vegetation changes caused by other herbivores (feral, stock and native),  
 Changed fire regimes

Habitat fragmentation and barriers to dispersal

- 1 Clearing: it is not known what level or extent of clearing will deter BTRW travel
- 2 Subdivision and intensification of land use: associated changes in disturbance rates, associated animals (stock, dogs, cats, foxes), roads

It is likely that the success of management programs which address any one threat or any one effect as a separate entity will ultimately prove to be unsuccessful. Only an integrated threat management approach is likely to provide for the long-term recovery of the species.

## 9.3 Social and Economic Issues

### 9.3.1 Social Issues

The DEC recognises that actions within this plan may have impacts on the public authorities and private individuals who own or manage land on which the species occurs. Some landholders (both public and private) are reluctant to conserve habitat and view the recovery effort 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 in the recovery effort.

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

Positive impacts of implementation of the plan on sections of the community include increased preservation of habitats, which will improve the aesthetic value and recreational and educational potential for residents in areas where BTRW occur. The experience in Kangaroo Valley in particular has also shown that the formation of support groups can bring added social benefits to the community.

The cultural and historical significance of the BTRW, particularly to the indigenous community, is largely unknown. Improving our understanding of BTRW significance in the community will assist the management of the species and has been identified as a priority under Research Priority Action 12.3.12 (see also section 9.5).

Expected positive social consequences include (after NPWS 1999):

- More sophisticated and responsible use of 1080 poison in the rural community;
- Landholders working in an integrated manner to control introduced feral animals;
- Improved means of communicating current research and technology from government and research institutions to the community and community responses to government;
- Demonstration by the community that it can effectively protect threatened species given the necessary training, information and resources;
- Demonstration by government that consultation with the community followed by clear direction and on-going 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 the actions of this recovery plan will result in some degree of economic impact. However, in general, BTRW habitat is largely unsuitable for economic development and currently there are few land-use proposals completely incompatible with BTRW conservation.

The 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 the species will be reduced to a level where local extinctions continue, particularly in the southern part of its range, given the current rates of loss and degradation of habitat.

The economic consequences of the recovery of the BTRW are those costs associated with the implementation of this plan. The exact value of the costs associated with implementing this plan are difficult to estimate, due to the number of sites where the species occurs. However, an attempt has been made to minimise any direct impacts by concentrating efforts on conservation of the species on land in public ownership.

Actions involving on-ground management programs and the long-term monitoring of sites will also have economic consequences for land managers. However, it is considered that these management programs involve recurrent activities which are required for the normal management of the land, such as weed control and feral animal removal. Costs can be minimised by seeking funding from external sources and by adopting a co-operative approach to management, which involves the DEC, Catchment Management Authorities, other relevant landholders and the community.

In addition to areas currently managed by the DEC, additional areas will need to be managed to conserve the species off-park.

There are at least three options to deal with the issue of off-reserve conservation:



- Negotiate and implement joint conservation management programs;
- Negotiate land acquisitions in high priority areas that are otherwise poorly represented by the reserve system;
- Negotiate and encourage voluntary management codes with the relevant land owners or leaseholders.

These options should be evaluated in terms of their effectiveness in assisting the recovery of the species and their economic impact on the management of holdings. Sympathetic management of lands adjacent to BTRW colonies may potentially impact on the carrying capacity of, and economic returns from, these areas. However, the benefits to these adjacent landowners and managers through reduction in goat and fox numbers may outweigh this impact.

It is considered that other positive economic consequences will also result from the implementation of the plan.

Expected positive economic consequences include:

- For government, overall cost savings by investing in community training and resourcing to minimise public labour expenditure in feral animal control work;
- For the rural community, reduced predation on, and spread of disease to livestock;
- An improvement in long-term agricultural productivity through better land management practices for wildlife;
- More efficient resource use, as management of the species will be more coordinated and strategic;
- Positive financial outcomes where land use changes for BTRW management are proposed for landholders negotiating conservation agreements.

#### 9.4 Scientific and Taxonomic Value

Macropods comprise almost 40 % of the Australian marsupial fauna 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 genus *Petrogale* has been attributed by a number of authors (eg. Poole 1978; Maynes 1989) to the highly discontinuous distribution of species populations. In all, 28 forms of rock-wallaby 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-wallabies in the *Petrogale* genus, with the genus *Peradorcas* now categorised 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 the identification of characteristic chromosome and genic markers, involving cytogenetics and G-banding techniques (Eldridge and Close 1992). Phylogenies derived from these techniques have revealed inadequacies in the present taxonomy, indicating a need for a general revision of the genus, and the eastern taxa in particular (Eldridge and Close 1992).

## 9.5 Role and Interests of Indigenous People

To contribute to the preparation of the BTRW Recovery Plan, DEC has assisted in developing a community-based research project across the four Local Aboriginal Land Council (LALC) areas which cover much of the core habitat/refuge areas for the BTRW in northern NSW. Elders and relevant individuals in these areas are being consulted about their knowledge, issues and concerns about the BTRW. The project also gives the opportunity for each community to provide their views about how the Aboriginal Community should be involved in threatened species management generally. The following LALCs, national parks and state forest areas are covered by this consultation:

- Armidale (Oxley Wild Rivers NP, Guy Fawkes River NP, Styx River SF);
- Amaroo, Walcha area (Oxley Wild Rivers NP);
- Guyra (Guy Fawkes River NP & SCA); and
- Purfleet (Nowendoc NP, Woko NP, Tuggolo SF and Mernot SF).

The knowledge, issues and concerns identified through this consultation will be incorporated into the recovery program for the BTRW, and applied to other areas across NSW.

## 9.6 Biodiversity Benefits

Given the broad geographic range of the BTRW, it is likely that there will be a number of overall biodiversity benefits from the implementation of this recovery plan. The mesic vegetation, sandstone escarpments and outcrops that form a large portion of the species habitats, include a broad range of habitats such as rainforest, closed woodland, open woodland, wetland and heath. These habitats are home to a range of fauna which are listed under the TSC Act.

Through the NSW Fox Threat Abatement Planning process, a broad range of native animals have been identified as threatened by the fox. A number of these are known or can be assumed to share some of habitats used by BTRW, eg. Rufous Bettong. Control of predators, introduced herbivores and weeds, together with habitat conservation and increased public awareness as a result of this recovery plan will benefit a wide range of other native fauna.

## 9.7 Overview of Evolutionary Significant Units

The following information is provided to assist managers responsible for BTRW recovery manage consistently within and between the ESU. Boundaries between ESU are indicative only, both in terms of their location and their effect and *should be seen as guides only* (see Figure 11).

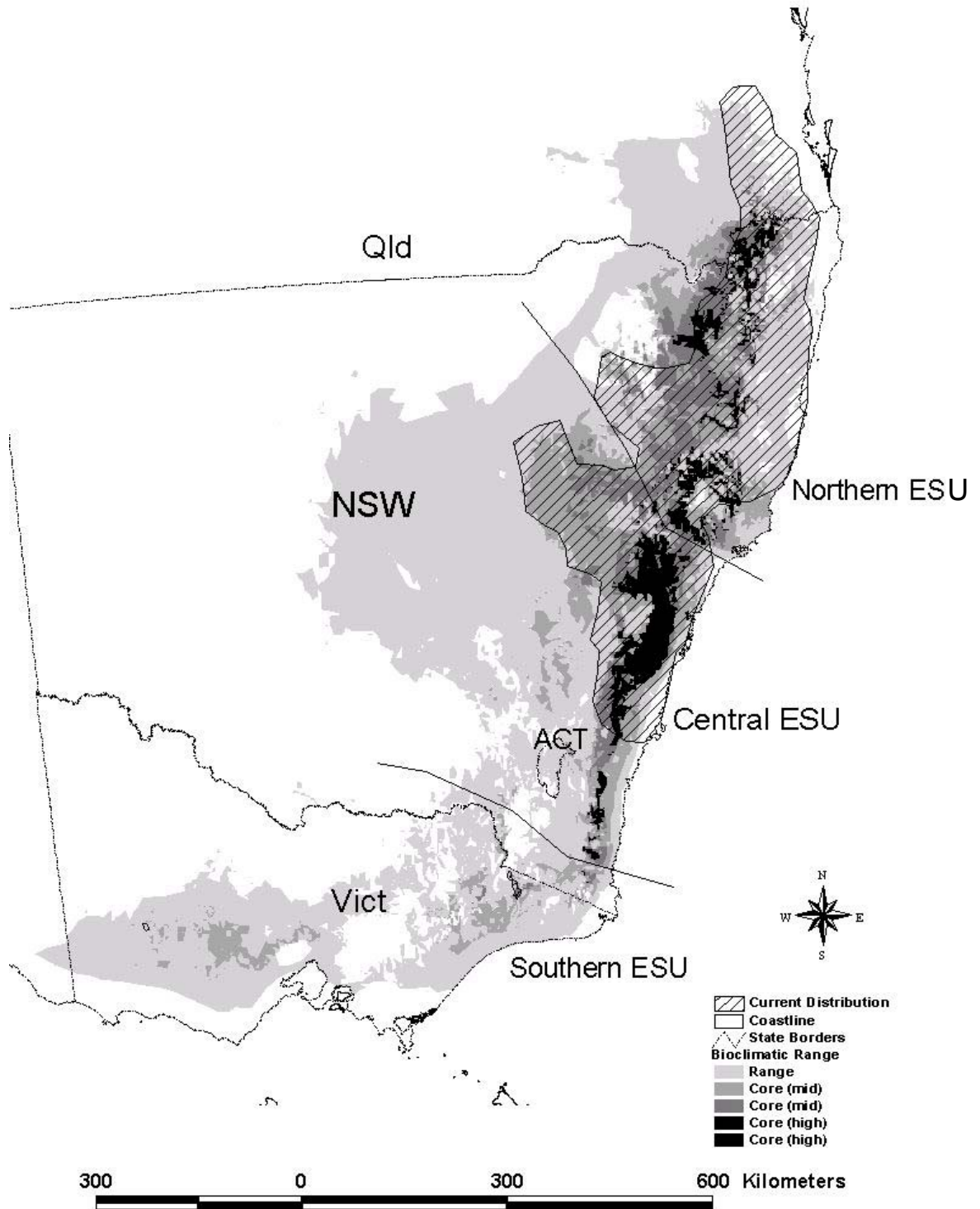


Figure 11. ESU and bioclimatic range of BTRW (NB. ESU boundaries are indicative only).

### 9.7.1 Northern ESU

There are a large number of colonies in the Northern ESU and it is estimated that over 90 % BTRW belong to this group. While the possibility of local, short-term extinctions exists, the populations in Northern ESU to be in a robust situation in the long-term. Substantial tracts of suitable habitat occur and much of this is reserved, particularly in the region from northern Washpool NP to southern Oxley Rivers NP. The potential habitat is more fragmented north of Washpool NP (up to and beyond the NSW/Queensland border), and in the southern extent of the ESU towards the Hunter Valley. While there is varying potential for animals to move throughout the ESU, colonies north of Toowoomba appear to be separated from the populations in south-eastern Queensland (Lundie-Jenkins pers. comm.).

In a biogeographic context, the populations in the Northern ESU occur mainly in the New England Tableland and NSW North Coast and South East Queensland IBRA bioregions. Sites are also known from the Nandewar IBRA bioregion. While modelling indicates the bioclimatic core in this northern region occurs north of the Hunter Valley in the area around the Upper Manning River, there is a strong bioclimatic envelope following the ranges as far north as Noosa in south-eastern Queensland (Cavanagh in prep.).

The reasons for the persistence of large populations in this ESU compared to the Southern and Central ESU is not known, although as noted earlier, lower relative fox densities and variations in habitat fragmentation patterns 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/ha. The next highest published measurement is for Central Victoria of 3.9 foxes/ha by Coman *et al.* (1991).

The apparent robustness of the Northern ESU populations provides opportunities for gaining knowledge about robust populations which can provide important information for recovery of the species overall. However, the actual robustness of these populations is yet to be demonstrated, and recent work has indicated Northern ESU populations are also in decline. Further surveys and monitoring programs are required to provide firmer estimates of abundance and connectivity between populations.

### 9.7.2 Central ESU

The major areas of BTRW colonies in the Central ESU appear to be in the northern Blue Mountains national parks (Wollemi and Yengo NPs). 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 BTRW in the central, less accessible areas of the Greater Blue Mountains national parks is poor, and current estimates of only some hundreds of animals may be in error by an order of magnitude. However, it is highly unlikely, that numbers are in excess of 2,000 even allowing for this degree of error. There are also a number of extinct sites 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 region now appear to be isolated from the Blue Mountains populations, and the long-term survival of these populations can not 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 NP. The small numbers and isolated nature of the Warrumbungles and Shoalhaven populations, places them at some risk from genetic drift caused by in-breeding. This may be a factor in the long-term survival of these populations.

Extant Central ESU populations occur largely in the Sydney Basin IBRA bioregion, but extinct sites are also known from the South Eastern Highlands and South East Corner IBRA bioregions. The Warrumbungles population is within the Brigalow Belt South IBRA bioregion. The largest bioclimatic core area for the species centres on the Greater Blue Mountains area, with smaller core areas the Upper Hunter area in the northern New South Wales region which is separated by the Hunter River valley itself. This would appear to be the bioclimatic core of the species range. 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 in prep.). Of the two outlying western populations, the Warrumbungles population is within 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 management of the more accessible BTRW populations will be vital in ensuring long-term conservation of the colonies in these areas. On the basis of present knowledge, the Shoalhaven and Warrumbungles populations represent the edges of the range of the Central ESU and are disjunct from other populations. In this context, conservation of these colonies on site must be a priority for management.

### 9.7.3 Southern ESU (Victoria)

There are no known extant populations within the Southern ESU in NSW. As it is highly likely that the population in the Grampians is also extinct (Seebeck pers. comm.), the small population (fewer than 10 animals) in East Gippsland is all that remains of this ESU in the wild. The 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 the risk of depression through in-breeding.

The Grampians population, which now appears to be extinct, occurred in the Murray Darling Depression IBRA bioregion and the East Gippsland population (and historically recorded sites) occur in the Australian Alps IBRA bioregion and the South East Corner IBRA bioregion. 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 in prep.). 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 of this ESU is directly met through the Victorian *Flora and Fauna Guarantee Act 1988* and ensuing Victorian BTRW Action Plan under the guidance of the Victorian BTRW recovery team.

## 10.0 Previous Actions Undertaken

### 10.1 Surveys and Research

A program to arrest the continuing decline of the BTRW in NSW was instigated by the NPWS 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;
- Implementation of the Population Management Plans;
- On-going research into threats and impacts; and
- Historical research into the timetable and causes of the decline in abundance of 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 NP.

Research into the genetics of BTRW has been undertaken by a number of researchers, including Close (1988), Close *et al.* (1988), Close *et al.* (1994), Eldridge and Close (1992), Eldridge *et al.* (1988) and (1994), and Eldridge *et al.* (2004).

Historical research into the timetable and causes of decline in BTRW in NSW extend 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 BTRW (Lunney *et al.* 1997).

Research and studies on the behaviour and ecology of BTRW have also been undertaken, and publications on this work include Jarman and Bayne (1997), and Bayne (1994).

### 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 have been managed in zoos through the Australian Species Management Program (the species management arm of the Australasian Regional Association of Zoological Parks and Aquaria, ARAZPA).

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

A second population has been coordinated through Tidbinbilla Nature Reserve, in close cooperation with the NSW BTRW recovery team. Animals in the population 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 and YFRW as surrogates (Bell and Close, 1994; (Taggart *et al.* in prep.; J. Reside pers. comm.).

In addition, locally derived animals are held at Jenolan Caves, and Macquarie University (NSW) holds a range of *Petrogale* species.

### 10.3 Predator Control

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

Research was undertaken by NPWS into the effectiveness of NPWS and community fox baiting programs around BTRW colonies. A 1080 baiting and monitoring program was implemented on a monthly basis 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. In Kangaroo Valley, a community baiting program was implemented in conjunction with NPWS in 1994. 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 set of Hunter Valley and Kangaroo Valley because monitoring in Kangaroo Valley began after the Hunter, 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 for the available combined Kangaroo Valley and Hunter Valley data set.

Analysis of the Kangaroo Valley data set indicated an effect of baiting, with the baited colonies declining at a significantly slower rate than the unbaited colonies (Norton *et al.*, 2002). However, the sample size was very small and hence the significance should be treated with caution. There was a variable response in the different colonies in the baited and unbaited areas in the Hunter Valley study, which lead to difficulties in interpreting data. In addition, results indicated that the non-baited sites in the Hunter Valley experienced less of a decline than the baited areas, suggesting there may have been differences in predation pressure between the colonies prior to the implementation of baiting programs (Rummery *et al.* 2000).

Predation by the red fox was listed as a *key threatening process* under the TSC Act in March 1998. The listing was based on the potential impact of foxes on nine threatened species listed under the Act, including BTRW and the YFRW. A threat abatement plan (TAP) for predation by the red fox was prepared by the NPWS in 2001. The purpose of the plan is to propose actions to reduce the impacts of fox predation on threatened species, and

**Table 5. BTRW sites identified and/or monitored for fox control in the Fox TAP.**

DEC Region	Site	Status <sup>1</sup>
Hunter	Barnard River	M
Central Coast/ Hunter	Nth Yengo NP/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

<sup>1</sup>M = monitoring only; F = fox control only; FM = fox control and monitoring

to help conserve biodiversity more generally. 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 5).

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

- 1 Ensure that fox control programs undertaken for conservation purposes in NSW focus on those threatened species which are most likely to be impacted by fox predation.
- 2 Ensure that fox control programs are effective in minimising 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 plan.

#### 10.4 Competitor Control

Goat control specific to BTRW is currently being undertaken at Warrumbungles NP. Goat control is also occurring in the core BTRW habitat of Oxley Wild Rivers NP. Goats have not yet invaded all of this area but may be expanding their range. The continuation of goat control and the prevention of the expansion of these goat populations is a priority for the protection of this, the largest known BTRW population. Brush-tailed Rock-wallabies are also likely to benefit from goat control programs undertaken by the DEC. 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 of the threatened species known to be impacted by feral goats (NSW Scientific Committee 2004). The BTRW should be considered a priority species for any future threat abatement program targeting goat control.

#### 10.5 Recovery Planning

To date, a recovery plan has been developed for the population of BTRW at the Warrumbungles (NPWS 2003), and a Population Management Plan (PMP) has been developed for the Shoalhaven population in southern NSW. In addition, a draft site management plan has been prepared for the population at Jenolan Caves.



A national research recovery plan has been prepared for the species (Hill 1991). In addition, the 1996 Action Plan for Australian Marsupials and Monotremes (ANPWS 1996) outlines appropriate recovery actions at a national scale.

In 1999, following a workshop convened by the NPWS to address recovery issues for NSW, a recovery team was established to progress the recovery planning for BTRW across its range. This plan has been developed by the BTRW recovery team, and takes into account the previous recovery efforts. A national recovery plan is also in preparation.

## 11.0 Species Ability to Recover

‘Recovery’ in the context of this five-year plan will be targeted towards increasing recruitment at priority sites, decreasing the rate of decline of BTRW populations regionally and within each ESU, and in particular preventing the species from declining to the extent to which it would be at risk of extinction in the wild. It will not be possible to recover the integrity of the species’ former distribution and abundance, given the degree of habitat modification and the now extremely disjunct nature of the species’ distribution. In fact, unless actions are taken to reduce threats, it is likely that reductions will continue to occur in the current number of sites and the species will become locally extinct in some areas. The likelihood of continued local extinctions of this species are quite high given the large percentage of sites that are very small and fragmented, and the number of threats acting on sites.

There is significant potential for the recovery of the species if the actions detailed in Section 12 are implemented. This assessment is based on the ability of this species to breed rapidly under favourable conditions (particularly in the absence or near absence of fox predation), the extent of suitable habitat in the remaining areas of its extant range, particularly in the north, and the community support for protection of the species in the state and nationally.

A focus of this recovery plan is the control of predation by foxes, undertaken in conjunction with the Fox TAP. Specific actions are detailed to gain better information on fox predation and the effectiveness of control measures, and to implement control measures more effectively and efficiently.

Results of a preliminary Population Viability Analysis for BTRW conducted by Hill (1991) suggest small populations have limited chance of long-term survival although how this relates to recovery potential remains unknown. However, large populations have been known to be successfully bred from a very small number of animals, for example, in Hawaii where a large population bred from just two animals. Therefore, the development of strategic captive breeding and translocation programs undertaken in conjunction with appropriate threat abatement programs has been identified as a priority for this species.

Brush-tailed Rock-wallabies have coped with close settlement and a degree of human disturbance in a number of areas, for example, in the Shoalhaven (Short and Milkovits 1990). However, the type, intensity and location of the disturbance probably determines the degree of threat. The attitudes, understanding and awareness of the people involved in the activities are critical factors in the long-term recovery of the species in settled areas. The effective and active involvement of local communities is therefore seen as a vital component in this species’ recovery.

## 12.0 Recovery objectives and performance criteria

The following section details the specific objectives and priority actions for 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 in a position to improve techniques and programs. While these objectives have been developed specifically to address the recovery of the species in NSW, they have also been developed to be consistent with recovery actions at a national scale as 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 the species from its status as threatened. However, this objective is not believed to be achievable within the lifetime of this plan.

**Recovery Plan Objectives:** The specific objectives of this recovery plan are:

1. To increase recruitment at priority sites;
2. To decrease the rate of decline in range and abundance;
3. To prevent the decline of the species to a level at which it would be at risk of becoming extinct in the wild; and
4. To increase knowledge to enable more effective management of the species.

The key to achieving these objectives will be maintaining robust and representative samples of the regional populations within each of the ESU. The protection of all BTRW sites is beyond the constraints of this plan, and therefore it is not an objective of this recovery plan that all populations of BTRW will necessarily be conserved.

This plan acknowledges that in the short- to mid-term there will continue to be losses in abundance and some extinctions of local populations, and that some contraction of the species range may occur at a regional level due to these losses. This plan provides for amelioration of these impacts through the establishment of strategic management at priority sites, and the establishment of robust captive breeding programs to support on-site management where active, interventionist population management is required.

A further critical element in this plan is the management of threatening processes in an effective and efficient way, and the first step in the process is to gain a better understanding of these processes. Having said that, an empirical approach is also supported, in so far as the precautionary principle would dictate, i.e. lack of knowledge should not be an impediment to active conservation management. This is particularly so where positive empirical results can be demonstrated, even if we may not quite know why.

Five broad priority strategies have been identified to achieve the overall objectives of this plan. These strategies address key objectives identified within the plan as requirements to achieve recovery. These five broad components are: coordination; research; site management; community involvement; and captive breeding and translocation. Specific

objectives are detailed in the following section within the context of the overall objectives and priority strategies.

## 12.2 Coordination Objectives and Actions

**Specific Objective 1 (Coordination):** *Ensure that management of BTRW sites is coordinated at all levels – area/region; ESU; state; nationally.*

### Coordination Priority Action 12.2.1

Support continuation of a NSW BTRW recovery coordinator.

#### Aim

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

#### Performance Indicator

- The part-time NSW BTRW recovery coordinator position continues to be supported during the life of this plan.

#### Justification

The BTRW is an iconic species. Brush-tailed Rock-wallabies occupy not only a large biogeographic range, but also occur across a wide array of administrative, tenure, and land management arrangements and conditions. Consequently, it is vital that the implementation of the tasks to achieve these objectives are coordinated at all levels, i.e. site, regional, ESU, state and national. The effective coordination of the recovery effort will require commitment to continuation of current staff resources.

#### Methods

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

Priority tasks include:

- Development of standardised reporting and management guidelines;
- Monitoring of priority BTRW sites including collation of information and data on distribution, abundance and management;
- Review of BTRW fox control programs including NSW Fox TAP;
- Development of captive breeding and translocation policies and protocols;
- A range of programs including site management programs, predator and competitor control programs, research and habitat protection programs;
- Joint funding applications for research;
- Reviews of threatening processes, assessment of new threat abatement techniques, and BTRW ecology;
- Community information and involvement;
- Reporting on the implementation of this plan; and
- Represent DEC on national BTRW recovery team.

#### Responsibilities

DEC Biodiversity Management Unit (BMU); BTRW coordinator

### 12.3 Research Objectives and Actions

**Specific Objective 2 (Research).** *To identify and better understand processes threatening BTRW recovery.*

**Research Priority Action 12.3.1.** Undertake systematic documentation of existing and potential threatening processes.

#### **Aim**

To provide a centralised, accessible database and information resource on threatening processes relevant to the recovery of the species.

Tasks to achieve this aim are:

- Develop and distribute a questionnaire proforma that documents the distribution and intensity of threatening processes at the species, ESU, regional and site levels;
- Collate and analyse the responses and produce a report summarising the responses;
- Maintain (update) this information as required;
- Provide copies of the report to DEC regional managers and other land managers (eg. Forests NSW); and
- Develop a database to store and retrieve this information.

#### **Performance Indicator**

- The summary report is produced within the first 18 months of this plan;
- Database is reviewed annually and updated as required.

#### **Justification**

Identifying and evaluating threatening processes at the species, ESU, regional and site levels will give an indication of their relative prevalence and importance at the various levels. This will help to direct recovery team efforts and resourcing allocations.

#### **Methods**

Design and send out questionnaire to regional managers, rangers, field officers and landholders to assess and clarify which processes occur at which sites and at what intensities. Replies will be collated and information recorded and evaluated. The summary report will then be prepared and distributed to regional managers, and an information update program initiated. This process will be coordinated with tasks undertaken to achieve Specific Objective 6 (Site Management).

#### **Responsibilities**

BTRW recovery coordinator or contractor to carry out design and submit questionnaire proforma to regional managers, rangers, landholders etc. within each ESU.

**Research Priority Action 12.3.2.** Undertake an assessment of 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 are:

- To compare current threat abatement programs and determine their effectiveness;
- To identify knowledge, methodological and field implementation gaps in current threat abatement programs; and
- To provide recommendations for improving threat abatement programs.

**Performance Indicator**

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

**Justification**

An understanding of the current knowledge and methodological gaps and how these influence the strategic implementation of threat abatement programs in the field is fundamental to understanding the reasons for the success or failure of such programs, and hence, to the development of new and improved programs.

**Methods**

Identify sites where management and research teams are generating appropriate and compatible data sets. Each site team will identify the strengths and weaknesses of their threat abatement processes permitting knowledge, methodological and implementation gap identification. Data require collating and areas of common ground need to be identified. Comparative quantitative and qualitative analyses of these cross referenced data sets is then required. Close liaison will be maintained with the Fox TAP Coordinator.

**Responsibilities**

BTRW recovery team coordinator or contractor to contact land managers of relevant sites and facilitate identification of appropriate data sets for analyses.

**Research Priority Action 12.3.3.** Design and trial new alternative threat abatement techniques.

**Aim**

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

Tasks to achieve this aim are:

- Develop and evaluate alternative or improved techniques for assessing threatening processes at the species, ESU, regional and site levels;
- Develop and implement a program to incorporate new or improved threatening process abatement methods and implementation strategies, to minimise the inefficiencies in current threat abatement management; and
- Develop and evaluate alternative techniques for determining the effectiveness of threat abatement methods.

**Performance Indicators**

- An assessment report with recommendations for future actions is completed within the life of this plan;
- A program is developed and implemented within the first 3 years 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 at the population/regional level. A report describing the reasons for the success or failure of various programs is required to indicate directions for future program preparation and planning.

**Methods**

Alternative and improved threat abatement techniques will be developed at field sites that have a BTRW monitoring program in place. Priorities for development of new techniques are for alternative fox and goat control techniques. With regard to fox threat abatement, this criteria will be best met by coordination with the Fox TAP program. A comparison with existing techniques will be undertaken to allow a comparison against which to measure the success of the new or improved techniques.

**Responsibilities**

BTRW coordinator; relevant land managers; Fox TAP research group.

**Specific Objective 3 (Research).** *To improve the knowledge of the distribution and abundance of the BTRW.*

**Research Priority Action 12.3.4.** Develop a system to provide ongoing information on the BTRW distribution within each ESU.

**Aim**

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

Tasks to achieve this aim include:

- Identify areas where there is poor knowledge of the current distribution;
- Implement surveys to improve our knowledge of the current distribution, particularly in areas where current knowledge is poor and implications for management are greatest, e.g., Wollemi, Yengo, Kanangra, southern Morton and Wadbilliga/Deua NPs and adjacent areas of State Forests in the Central ESU;
- Follow-up the landowner surveys begun by NPWS in 1993;
- Develop and maintain BTRW survey database; and
- Update DEC Wildlife Atlas.

**Performance Indicator**

- Current databases are updated with a minimum field survey effort equivalent to two weeks undertaken each year of the plan.
- Survey database developed and maintained.

**Justification**

An accurate understanding of the distribution of the BTRW underpins the direction of the recovery team efforts. The current distribution is uncertain. This makes it difficult to

prioritise areas requiring further resources and management activities. Current information indicates that information gaps may be most significant within the Central ESU distribution. The absence of records in a number of areas in the Central ESU may be apparent absences only 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 BTRW in the Central ESU.

### Methods

- Liaise with regional land managers and field staff to update current knowledge on distribution. This task will be undertaken in conjunction with tasks outlined in Site Management Priority Action 12.4.1.
- Identify significant information gaps in past survey efforts.
- Develop a survey program to update significant known sites and to 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.

**Research Priority Action 12.3.5.** Develop standardised survey techniques for estimating BTRW presence/absence.

### Aim

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

Tasks to achieve this aim include:

- Review current techniques and procedures for surveying colonies for presence/absence;
- Develop a standard set of procedures, techniques and recording methods; and
- Produce a report in the form of guidelines for field staff.

### Performance Indicator

- Guidelines to standardised techniques produced within the first 18 months of this plan.

### Justification

Brush-tailed Rock-wallaby presence/absence data forms the basis of the “distribution database” that is being developed as part of this recovery program (see Specific Objective 3 (Research)). A standardised presence/absence methodology will increase the reliability of the categorisation of a site as a BTRW site, and will also allow comparisons of distribution within and between ESU over time.

### Methods

This methodology should be developed at sites known to contain BTRW, in conjunction with Research Priority Action 12.3.4, as this will give a measure of the success of the technique. This action will also be coordinated with Site Management Priority Action 12.4.1.

**Responsibilities**

BTRW coordinator. To be carried out by the teams working in Research Priority Action 12.3.4, in collaboration with those that will use the technique, i.e. the contractor working on Specific Objective 3 (Research), the regional staff that will search potential BTRW sites.

**Research Priority Action 12.3.6.** Compare and develop monitoring techniques for estimating BTRW abundance.

**Aim**

To improve information on the abundance of BTRW.

Tasks to achieve this aim are:

- Undertake a desktop review to compare the accuracy and precision of current monitoring techniques;
- Develop and evaluate alternative monitoring techniques as required.

**Performance Indicators**

- Research completed within the first two years of this plan;
- A report evaluating techniques with recommendations for future management produced within six months of completion of research.

**Justification**

There are currently several methods for estimating indices of macropod abundance which appear to vary considerably in their accuracy and precision. Consequently, the determination of the status of colonies, populations, regions and ESU is confounded. The standardisation of methods is required so that meaningful comparisons can be made at each of these levels. However, it is acknowledged that not all methods will be as achievable at all sites. It is likely that a “most informative” method will be possible at some sites but not all sites, and it may be appropriate to use such a method where it is possible while endeavouring to find a more generic method.

**Methods**

A desktop review will be undertaken of current techniques. Survey methods will then be compared and developed in captive colonies where wallaby abundance can be measured (eg. Tidbinbilla Nature Reserve, Jenolan Caves). This will permit the calibration of methodologies against actual abundance estimates. These methods may then be trialled and incorporated into management at colonies where abundance has or is being measured (eg. Fox TAP sites). Follow-up data collection to be undertaken by relevant land management agency staff, tertiary students, and volunteers as most appropriate.

**Responsibilities**

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

**Research Priority Action 12.3.7.** Establish a network of sites to be monitored for BTRW presence/absence and abundance within each ESU.

**Aim**

To improve the effectiveness and efficiency in monitoring BTRW presence and abundance at the ESU and species level in recovery planning.



Tasks to achieve this aim are:

- Develop criteria for determining priority sites for recovery effort;
- Identify and establish representative sites for monitoring presence/absence within each ESU;
- Identify and prioritise sites for monitoring abundance within each ESU; and
- Compare and evaluate the status of ESU using the most appropriate techniques.

#### **Performance Indicator**

- Criteria for determining priority sites established within 12 months.
- Priority sites identified and monitoring initiated for 12 sites within the first four years of this plan.

#### **Justification**

The establishment of a set of standardised and representative “indicator” monitoring sites within each ESU will form an absolute minimum data collection network to provide baseline data upon which comparisons of the broad status of BTRW can be gauged. In addition, information from these sites will assist in the assessment of the success of threat abatement programs across the species’ range.

#### **Methods**

The monitoring protocols established in Site Management Priority Actions 12.4.1 and 12.4.2 will be applied at representative sites selected within each ESU. These sites can be existing sites where monitoring programs are already in place and/or where research is being conducted. New sites may also need to be included to increase the monitoring levels within some regions in the ESU.

#### **Responsibilities**

BTRW coordinator; relevant land managers; contractor.

**Specific Objective 4 (Research).** *To determine the genetic differences between the Central ESU and Northern ESU BTRW populations.*

**Research Priority Action 12.3.8.** Determine biogeographic boundaries between the Northern and Central ESU.

#### **Aim**

To assist management for recovery of the species by determining the location of the boundary between the Northern and Central ESU.

#### **Performance Indicator**

- Boundaries are 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 distinct mtDNA group (ESU). The locations of the boundaries between the three identified ESU are currently unknown. The geographic position of the boundary between the Southern and Central ESU is now only of academic interest as all intervening BTRW populations are believed extinct.

The location of the boundary between the Central and Northern ESU in the east lies somewhere between Broke and Woko NP. 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 ESU. It is important to know where ESU boundaries lie as this will have consequences for recovery efforts and management actions.

### **Methods**

Brush-tailed Rock-wallabies will be trapped and sampled on either side of the Hunter River. Mitochondrial DNA (mtDNA) analysis will be conducted to determine the ESU to which these populations belong. Tasks associated with this action will be coordinated as relevant with Research Priority Actions 12.3.4 and 12.3.7.

### **Responsibilities**

Research will be conducted by Macquarie Research in collaboration with Head Office and Regional DEC staff.

**Research Priority Action 12.3.9.** Conduct research to determine the degree of taxonomic separation between ESU.

### **Aim**

- To determine the taxonomic status of the three ESU identified within BTRW.

### **Performance Indicator**

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

### **Justification**

The mtDNA divergence amongst the three ESU is equivalent to that found between other subspecies and species of rock-wallaby. In order 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 disjunct pattern between ESU as has been observed in the mtDNA. This information will also be required to inform any review of the legislative status of the ESU.

### **Methods**

Trap and sample at least 20 animals from at least three populations from the Northern ESU. Genotype all animals at ~10 microsatellite loci and compare with existing data from Central and Southern ESU populations. The feasibility of undertaking morphological analyses will be assessed.

Action to be carried out at three sites from the Northern Tablelands Gorge systems and one in south-eastern Queensland.

### **Responsibilities**

Microsatellite research will be conducted by Macquarie Research in collaboration with Regional DEC staff.

**Specific Objective 5 (Research).** *To gain a better understanding of BTRW ecology.*

**Research Priority Action 12.3.10.** Review and collate what is known of BTRW ecology.

**Aim**

To assist BTRW recovery management by providing centralised, accessible and updateable baseline data and information, and to encourage research into poorly known areas of BTRW ecology.

Tasks to achieve this aim are:

- Conduct a desktop review of published and unpublished literature to identify knowledge gaps;
- Collate this information into a reference summary report, and/or electronic network; and
- Make recommendations with regard to filling priority BTRW ecology information and data gaps.

**Performance Indicators**

- A review is carried out within the first 12 months of this plan.
- Summary report and/or electronic access network provided by end Year 2.

**Justification**

A large amount of information relating to the ecology and behaviour of BTRW exists in both documented and undocumented forms. This information needs to be collated and presented in a manner that facilitates the identification of the knowledge gaps. This will assist with the prioritisation, design and implementation of research and management programs.

**Methods**

A literature search will be carried out along with discussions with relevant rock-wallaby experts. These sources will be used to compile a written review document outlining the knowledge gaps in BTRW ecology. In addition, a summary of the information will be provided in the form of a reference list with summary information. An electronic network for accessing the information will be established. This may take the form of a website, and will be coordinated and linked with existing systems where relevant, eg. DEC website, Kangaroo Valley Friends of the BTRW website.

**Responsibilities**

BTRW coordinator position; contractor.

**Research Priority Action 12.3.11.** Conduct field research on BTRW ecology.

**Aim**

To provide a significantly improved knowledge base of BTRW ecology to assist the management of BTRW recovery.

Tasks to achieve this aim include:

- Identify key research areas for BTRW ecology research; and

- Develop research programs that address any intrinsic (eg. reproductive ecology, habitat requirements) or extrinsic (eg. fragmentation, fire, competition, predation) factors influencing BTRW population and metapopulation dynamics.

#### **Performance Indicator**

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

#### **Justification**

A greater understanding of BTRW ecology is essential to improve our understanding of how individuals, colonies and populations respond to threatening processes, and hence the way that we develop and implement threat abatement programs, and manage BTRW colonies and populations.

#### **Methods**

Identify key gaps in BTRW ecology information through Research Priority Action 12.3.10. Field research programs will then be developed using both standard and new BTRW survey, habitat assessment and threatening process techniques. This action may be carried out at the Fox TAP sites.

#### **Responsibilities**

DEC and other land management agencies as relevant at regional level in conjunction with Fox TAP and research institutes.

### **12.4 Site Management Objectives and Actions**

**Specific Objective 6 (Site Management).** *Ensure that a consistent approach is taken to documentation of management of BTRW sites/colonies.*

**Site Management Priority Action 12.4.1.** Establish a database to collate information on past and present occupation of BTRW sites and the management actions being undertaken at each site, and implement an ongoing review program for this information.

#### **Aim:**

To provide an ongoing assessment program of BTRW sites, threatening processes present and management actions.

Tasks associated with this action include:

- Provision of standardised monitoring tools, i.e. survey/data forms and guidelines, to all landowners and agency staff at BTRW sites;
- Liaison with and active support of stakeholders including landowners and land management agency staff to encourage evaluation of sites; and
- Development and implementation of review and feedback mechanisms for reporting and recording, including entry of data into site management database.

#### **Performance Indicators**

- Site data sheets are developed and distributed to areas within first 12 months of implementation of this plan.
- Recipients have completed site inspections and data sheets within first 18 months of implementation of this plan.

- Baseline database completed within first 2 years of implementation of this plan.

**Justification**

Site and management information is required to (i) establish a site and management baseline; (ii) allow prioritisation between sites for management actions; (iii) allow ongoing evaluation of sites and management to more effectively allocate resources over time.

**Methods**

(i) Design data sheets in-house; (ii) circulate site data sheets to DEC Area Offices and Regional Branches for evaluation; (iii) distribute collated information to relevant DEC Regional and Area Offices, NSW Forests regions, Rural Lands Protection Boards, researchers, landholders and other experts to provide information (using standardised techniques, as per Specific Objective 3 (Research) above); (iv) update information annually.

**Responsibilities**

BTRW recovery coordinator, DEC staff, relevant land management agencies.

**Site Management Priority Action 12.4.2.** Develop Best Management Practice Guidelines for Site Management.

**Aim**

To provide a consistent framework for the management for recovery of the species across its range.

Tasks associated with this aim include:

- Design draft manual including criteria for determining priority management sites as per Research Priority Action 12.3.7;
- Circulate draft manual to relevant DEC Regional Branches and Area offices for evaluation; and
- Complete and distribute to relevant land managers, CMAs, researchers, landholders and experts.

**Performance Indicator**

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

**Justification**

It is essential that the best management practices available are implemented in a consistent and repeatable way at BTRW sites and that the monitoring of the efficacy of those actions can be measured and compared across sites.

**Methods**

The manual will be developed by the recovery team in liaison with relevant land managers. The BTRW Site Management Manual will include the standardised site data sheets as they are developed through Site Management Priority Action 12.4.1 and projects outlined in Research Priority Actions 12.3.4 and 12.3.7.

**Responsibility**

BTRW recovery plan coordinator.

**Site Management Priority Action 12.4.3.** Develop site specific management programs for priority BTRW sites within the framework provided by the Best Practice Management Guidelines.

**Aim:**

To ensure more effective and efficient management responses to meet both the overall recovery and site specific needs of recovery management at priority sites.

Tasks associated with this action include:

- Develop methods for determining priority sites for management action.
- Establish and implement a framework for prioritising sites within ESU and within the State; and
- Develop site management plans and/or management programs for each identified priority site, or suite of sites.

**Performance Indicators**

- Sites prioritised at ESU level by Year 2;
- Management plans/programs prepared for each site or suite of sites by Year 4.

**Justification**

A range of management options are available for implementation at each site, ranging from active manipulation of populations to no management. In addition, the nature and degree of impacts of threatening processes vary from site to site. 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 sites will receive which specific management actions is required.

**Methods**

An expert panel will be convened to develop a framework and site prioritisation methodology that will be applied to the site database (Site Management Priority Action 12.4.1) at ESU level. The BTRW recovery plan coordinator will liaise with land managers and other stakeholders for their input into the prioritisation process at the ESU level. The BTRW coordinator and BTRW recovery team will develop management programs in liaison with relevant land managers. A review of the programs will be undertaken at two yearly intervals (coinciding with Site Management Priority Action 12.4.1 above). The implementation of these programs will be undertaken through relevant priority actions, eg. 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 (Site Management).** *To minimise the impact of introduced predators at sites where control of predation is identified as a priority management action under Site Management Priority Action 12.4.3 (above).*

**Site Management Priority Action 12.4.4.** Develop a coordinated management network for predator control across the species range.

**Aim**

To ensure more effective and efficient management of predators through the coordination of feral control efforts in each ESU. This will primarily focus on fox control efforts in each ESU, in conjunction with the Fox TAP and other DEC pest control programs, and with other stakeholders at sites where the need for fox control has been identified in the management programs under Site Management Priority Action 12.4.3 above.

Tasks to achieve this aim are:

- Identify where fox control is currently being undertaken;
- Design, implement and review individual fox control programs for sites identified for this action in Site Management Priority Action 12.4.3;
- Support the implementation of the Fox TAP as relevant to BTRW recovery objectives;
- Support the implementation of other relevant predator control programs e.g. feral cat control;
- Establish a schedule for review of coordinated programs.

**Performance Indicator**

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

**Justification**

The conservation of extant colonies may hinge on the efficacy of predator, primarily fox, control measures. Therefore it is critical that best management occurs at identified priority fox control sites, with the best available knowledge and appropriate monitoring.

**Methods**

Collation of information from sites where fox control is current (Site Management Priority Action 12.4.1). Establish a fox control sub-committee to design individual fox control programs at priority sites as identified in Site Management Priority Action 12.4.3. Alternative options for protecting BTRW from fox predation will be considered where relevant, eg fencing, trapping, provision/protection of refuges. The indirect effects of predator control on BTRW will be considered in determining appropriate management, for example, concurrent control of goats, rabbits. Close liaison will occur between the BTRW coordinator and Fox TAP coordinator, regional threatened species recovery coordinators and managers, DEC pest officers, and other relevant stakeholders; and relevant Rural Lands Protection Boards in particular. When a method for feral cat control becomes available its application should be considered at BTRW priority sites.

**Responsibilities**

DEC Fox TAP coordinator, DEC Cat TAP coordinator, DEC pest control officers, BTRW recovery plan coordinator; relevant land managers (including Rural Lands Protection Boards).

**Specific Objective 8 (Site Management).** *To minimise impact of introduced competitors at sites where mitigation of competitor impacts is identified as a priority management action under Site Management Priority Action 12.4.3 (above).*

**Site Management Priority Action 12.4.5.** Develop a coordinated management network for feral competitor control across the species range and implement control programs at priority sites.

**Aim**

To ensure more effective and efficient management of introduced competitors through the coordination of competitor control efforts in each of the ESU, and with other stakeholders at sites where the need for competitor control has been identified in the management programs under Site Management Priority Action 12.4.3 above.

Tasks to achieve this aim are:

- Identify where competitor control is currently being undertaken;
- Design, implement and review individual competitor control programs for sites identified for this action in Site Management Priority Action 12.4.3;
- Establish a schedule for review for coordinated programs.

**Performance Indicator**

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

**Justification**

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

**Methods**

Collation of sites where competitor control is current (Site Management Priority Action 12.4.1). Establish a competitor control sub-committee to design individual competitor control programs at priority sites as identified in Site Management Priority Action 12.4.3. The indirect effects of competitor control on BTRW will be considered in determining appropriate management, eg. concurrent control of foxes. Implement competitor control programs at these priority sites. Close liaison will occur between the BTRW coordinator, regional threatened species recovery coordinators and managers, and other relevant stakeholders, and in particular relevant Rural Lands Protection Boards.

**Responsibilities**

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



**Specific Objective 9 (Site Management).** *To more effectively implement predator and competitor control programs by improving the acceptance and level of implementation of control programs within the general community.*

**Site Management Priority Action 12.4.6.** Develop a broader, more robust community-wide support base for ongoing predator and competitor control programs.

### **Aim**

To maintain and enhance support for current predator control programs and for the establishment of new programs at priority sites identified in Site Management Priority Action 12.4.3, with an emphasis on working with landholders at a local level.

Tasks to achieve this aim are:

- The DEC continuing to support current community based control programs at Kangaroo Valley and northern Yengo NP;
- Informing, training and instructing other authorities and landholders about use of 1080 baiting in environmentally sensitive areas;
- Dependent on the availability of resources, the supply of the necessary materials for predator and competitor control on private lands at priority sites.

### **Performance Indicators**

- Land owners at priority sites are provided with information, support and, where possible, resources to undertake coordinated control programs throughout the life of this plan.
- Level and breadth of support increases as indicated by on-going feedback from land owners and other stakeholders through Site Management Priority Action 12.4.1 and Community Involvement Priority Action 12.6.2.

### **Justification**

The impacts of foxes and goats in particular have been informally identified as key threatening processes across wide areas of the species range. In order to be most effective, control of these impacts needs to be coordinated across large areas, and often includes liaison with neighbouring property owners and land managers. Gaining increased levels of support from these stakeholders will greatly assist on site management actions.

### **Methods**

Identify priority sites under Site Management Priority Action 12.4.3 on private land and initiate Site Management Plans in consultation with landholders and key stakeholders. Where possible, liaison will be coordinated with Community Involvement Priority Action 12.6.2. All control plans involving private lands will be developed in liaison with local landowners, and in accordance with the conditions of any consent given by relevant landholders and legal and policy requirements of the relevant land management agencies and the relevant Rural Lands Protection Boards.

### **Responsibilities**

BTRW coordinator; Forests NSW; relevant RLPB; relevant land managers.

**Specific Objective 10 (Site Management).** *To manage BTRW habitat at priority sites to reduce or reverse actions and processes leading to habitat degradation.*

**Site Management Priority Action 12.4.7.** Identify sites and appropriate land management mechanisms to ameliorate significant impacts caused by habitat loss where such specific management actions are required.

### **Aim**

To provide support for addressing habitat loss as a threatening process, at both the local and regional scales.

Tasks to achieve this aim are:

- The identification of areas or regions where habitat loss or degradation is a significant threat to BTRW populations;
- The development of specific habitat protection guidelines to protect significant BTRW habitats;
- The promotion of habitat management at sites within the identified areas to promote 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 at identified priority sites for habitat protection.

### **Justification**

Habitat destruction and degradation impact BTRW populations both directly and indirectly, eg. inter-relationships with predators, competitors, fires and weeds. Addressing both the proximal causes, eg land clearing, as well as the ultimate causes of these impacts eg. foxes, weed invasion, will significantly increase the long-term likelihood of successful recovery of BTRW at site, regional ESU and species levels.

### **Methods**

Sites will be identified where habitat degradation is a major threatening process. An expert panel will be convened to develop habitat protection guidelines. Strategic input of these guidelines into planning mechanisms affecting habitat at the identified sites, for example, Local Environment Plans, Catchment Management Plans, Regional Conservation Plans, fire management planning, timber harvesting operations, and weed control programs, will be sought. Where appropriate, protection of important habitat will be sought through negotiation of Voluntary Conservation Agreements with relevant private landholders, incentives under the Property Vegetation Plans, relocation of recreational activities away from identified sites, and consideration of strategic, voluntary acquisition of lands in high priority areas that are otherwise poorly represented by the reserve system;.

### **Responsibilities**

BTRW coordinator; DEC Relevant land managers, Forests NSW, relevant Rural Lands Protection Boards, and relevant local councils.

## 12.5 Captive Breeding and Translocation Objectives and Actions

**Specific Objective 11 (Captive Breeding and Translocation).** *Establish a policy that provides a framework and protocols for captive breeding and translocation of BTRW.*

**Captive Breeding and Translocation Priority Action 12.5.1.** Develop a policy paper which clearly articulates the criteria for captive breeding and translocation.

### Performance Indicator

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

### Aim

To ensure captive breeding and translocation programs are consistent with best practice management for recovery of BTRW.

Tasks to achieve this aim are:

- Prepare Draft Translocation and Captive Breeding Strategy;
- Produce final policy paper ratified by BTRW recovery team;
- Prepare Australasian Species Management Program (ASMP) Captive Management Plan for the BTRW.

### Justification

The declining status of a large number of BTRW sites has led to the recent extinction of some colonies and is likely to lead to regional extinctions within the next 5 to 20 years particularly in the Central ESU. In order to preserve this species across its range, a number of these sites are likely to require both intensive management of threatening processes as well as supplementation of breeding stock due to low viability and in-breeding depression of genetic variation. A rigorous and strategic approach is required to ensure minimal risk of unwanted genetic mixing of populations and the most effective and efficient management for recovery.

### Methods

Draft Translocation and Captive Breeding Strategy to be prepared. Draft to be reviewed and endorsed by the BTRW recovery team. Recovery team to seek support of ARAZPA to prepare ASMP Captive Management Plan for the BTRW and plan to be endorsed by the recovery team.

### Responsibilities

BTRW recovery team.

**Captive Breeding and Translocation Priority Action 12.5.2.** Develop protocols for evaluating the effectiveness of translocation events in terms of the animals survival and breeding potential.

### Performance Indicators

- Protocols to be endorsed by recovery team by Year 2.

**Aim**

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

Tasks to achieve this aim are:

- Develop criteria for evaluating effectiveness;
- Develop techniques of evaluation in liaison with relevant experts;
- Produce a report on evaluation with recommendations.
- Implement protocols as per recommendations.

**Justification**

Translocation is an intensive and interventionist management option for maintaining genetic variation and/or population range in a species. In order to ensure translocation efforts are strategically targeted with optimum chances for success, the effectiveness of programs needs to be evaluated and information feedback provided for 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 desired survival and breeding potential of translocations. Definitions of effectiveness to be produced by the BTRW recovery team. Develop proposed techniques of evaluation in liaison with relevant experts. Produce report on evaluation with recommendations. Implement techniques as per recommendations.

**Responsibilities**

BTRW recovery team.

**Specific Objective 12 (Captive Breeding and Translocation).** *Maintain and enhance robust populations in captivity.*

**Captive Breeding and Translocation Priority Action 12.5.3.** Establish and maintain a genetically healthy captive population.

**Performance Indicators:**

- Programs are identified and resources allocated;
- ASMP Captive Management Plan completed as per Priority Action 12.5.1;
- Captive Husbandry Manual to be completed by Year 2;
- Incorporate sourced stock into captive population by Year 2 and as necessary to maintain genetic diversity in subsequent years.

**Aim**

To provide an effective ‘backup’ for management of wild populations through maintaining and enhancing the genetic stock and numbers of BTRW in captivity. This will entail the expansion of captive populations to levels where re-introductions and/or enhancements of threatened populations are possible.

Tasks to achieve this aim are:

- Maintain Studbook for the species;
- Develop Captive Husbandry Manual;
- Implement the ASMP Captive Management Plan;
- Identify source populations for establishing, maintaining and enhancing captive breeding stock;
- Identify issues for achieving and maintaining genetically robust breeding stock and amelioratory steps which need to be taken.

### **Justification**

The populations within the Central ESU and Southern ESU are deemed to be most at risk, and most likely to require artificial maintenance of some populations/colonies. As the population numbers 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 in order to improve the success of potential supplementation programs.

### **Methods**

Maintain Studbook for the species. Develop Captive Husbandry Manual. Identify source populations for maintaining captive breeding stock. Issues identified for achieving and maintaining genetically robust breeding stock and amelioratory steps taken to address these issues.

### **Responsibilities**

The captive metapopulation is to be managed by the zoological industry, in liaison with relevant state conservation government agencies, as part of the current ASMP and Taxon Advisory Group (TAG) processes. Potential source populations for maintenance of captive stock to be identified by BTRW recovery team.

**Specific Objective 13 (Captive Breeding and Translocation).** *Identify priority sites for trial BTRW translocation into the wild.*

**Captive Breeding and Translocation Priority Action 12.5.4.** The recovery team to identify priority sites for each ESU as appropriate using the criteria established in the policy papers.

### **Performance Indicators**

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

### **Aim**

To ensure translocation is only undertaken at sites where this is the most effective and efficient management response to achieve BTRW recovery at the local, regional, ESU and National level.

Tasks to achieve this aim are:

- Develop a clearly articulated rationale and need for translocation;
- Assess feasibility of trial release programs;
- Identify priority sites for translocation;
- Develop translocation proposal for trial sites;
- Undertake translocation release trials.

### **Justification**

The release of animals into the wild is highly resource intensive and should only be undertaken where no other management actions are likely to be effective and where threat abatement programs are in place. It is critical that sites for possible translocation are rigorously evaluated to ensure outcomes for the most effective and efficient recovery of the species at the local, regional, ESU and national levels.

### **Methods**

A document prioritising sites for translocation and a translocation proposal for trial sites is to be developed and ratified by recovery team and relevant land management agencies. A list of priority sites for each ESU is compiled with supporting documentation detailing requirements, timeframes and management considerations (i.e., in terms of genetic match, population demography, threatening process control, not interfering with current colony research/management, having an existing monitoring program in place). The feasibility of trial release programs to be assessed, and implemented as relevant, and will include close post-release monitoring. Experimental trial release programs will be assessed 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 to be identified as relevant by the BTRW recovery team, in consultation with relevant land managers. DEC and other land management agencies as relevant at regional level will collaborate with universities to develop and undertake research projects.

## **12.6 Community Involvement Objectives and Actions**

**Specific Objective 14 (Community Involvement).** *To raise level of community awareness and support for the recovery of BTRW.*

**Community Involvement Priority Action 12.6.1.** Develop and distribute generic community information and participation kit.

### **Aim**

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

Tasks to achieve this action are:

- Review wildlife management programs (especially rock-wallaby programs) that incorporate community involvement and encourage community participation;

- Develop and produce generic community information and participation kit containing information relevant to the community in order to raise community awareness and support;
- Develop a list of opportunities for community participation in BTRW recovery management to include in the kit.

### **Performance Indicators**

- Community information kit is completed within one year of the commencement of the plan and distributed thereafter within the life 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**

A number of colonies occur on private lands, or adjacent to private lands. Information needs to be made available to the public on BTRW, their management, and how the community can help in monitoring and management. Through raising community awareness we are more likely to achieve community support for and participation in BTRW recovery programs.

### **Methods**

A community information kit manager will be appointed who will be responsible for the development, production and initial distribution of the kit.

This kit will provide information applicable to landholders, community groups (recreational, wildlife etc), schools, government departments and other interested parties. The kit will be designed for use as a resource tool from which relevant information can be extracted for the target audience.

A list of opportunities for community involvement will be developed by the community kit manager, for inclusion in the kit, following liaison with other wildlife programs which include community involvement.

The distribution of the kits should be within areas identified as priority BTRW sites and any other areas where community support or involvement is encouraged. It should be made available at local libraries and through relevant websites, eg. the Friends of the BTRW and DEC websites. The kit will be reviewed and updated as required, coordinated with Site Management Priority Action 12.4.1.

### **Responsibilities**

BTRW coordinator; relevant land managers (primarily DEC Highlands Area and Hunter Valley BTRW staff); Friends of the BTRW.

**Specific Objective 15 (Community Involvement).** *To raise the level of community involvement in BTRW recovery management.*

**Community Involvement Priority Action 12.6.2.** Promote opportunities for community involvement in implementation of the BTRW recovery program under this recovery plan.

### **Aim**

To actively involve the community in the implementation of this recovery plan at identified BTRW priority sites and other areas where community support or involvement will meet recovery objectives.

Tasks to achieve this action are:

- Identify appropriate communities, i.e. where demographics and BTRW sites are suitable for community involvement;
- Identify, and implement as relevant, appropriate management programs and tasks that the community can be involved in;
- Liaise with CMA about opportunities for landholder involvement in this recovery program;
- Provide CMA with guidelines on best management practice site management as per Site Management Priority Action 12.4.2. In the absence of the formal guidelines, DEC to liaise with CMA to ensure BTRW community projects are consistent with this recovery plan.

### **Performance Indicators**

- Opportunities are identified and promoted within 2 years of the commencement of the plan;
- CMA specific guidelines prepared within 12 months;
- DEC and CMA working together to assist landholders develop community conservation projects that support the recovery plan;
- Landholders in each priority CMA are involved in the implementation of this plan by Year 5.

### **Justification**

A number of colonies are on private lands, or adjacent to private lands. Community involvement is an important aspect of conservation both on and off reserves and should be a greater component of the future direction of conservation projects in order to benefit BTRW recovery and conservation management generally. The CMA play an important role in respect to expanding community involvement in species management programs, and funding conservation projects. To ensure best practice approach to species management and maximise their effectiveness, community programs must complement rather than compete with existing programs and/or actions under this recovery plan. For example, if developing a community fox baiting program it is vital that CMA and landholders in BTRW areas have a comprehensive understanding of BTRW ecology, best practice fox control methods, BTRW and fox monitoring techniques, bait density, buffer zones, how to protect non-target species (eg. quolls, domestic dogs).



**Methods**

Identify areas where community involvement in BTRW management is suitable. Then identify and promote appropriate participation opportunities for these communities from those listed in the kit (see Community Involvement Priority Action 12.6.1).

Timetables of works where opportunities exist for volunteer community involvement will be compiled on a regional or project level. These timetables could be incorporated into a newsletter format with additional information on the outcomes/successes of the activities held and the larger projects being conducted. If developed, these newsletters will be made available to the local community through mail outs, at local libraries, in local newspapers and on the Friends of the BTRW and DEC websites.

Where community involvement in BTRW management is already occurring, this should be supported and developed further.

**Responsibilities**

BTRW coordinator; relevant land managers.

**Community Involvement Priority Action 12.6.3.** Continue to foster efforts of the Friends of the BTRW in Kangaroo Valley.

**Aim**

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

Tasks to achieve this aim are:

- Provision of technical and administrative assistance as relevant.
- Maintain and enhance liaison between DEC and the Friends of the BTRW.

**Performance Indicator**

- Friends of the BTRW continues to be active in BTRW recovery within 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 the broader scale community involvement in the Shoalhaven.

**Methods**

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

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

**Responsibilities**

DEC Highlands Area Office, South Coast Region, overseen by BTRW coordinator.

**Community Involvement Priority Action 12.6.4.** Establish, where feasible, community support groups within each ESU, at the regional or priority BTRW site level.

**Aim**

To ensure continued community support and involvement in BTRW management.

Tasks to achieve this aim are:

- Assess the feasibility of establishing support groups;
- Coordinate work at the regional/ priority area levels;
- Investigate feasibility of broadening role of the Friends of the BTRW to provide broader regional or statewide networks.

**Performance Indicators**

- The feasibility of support groups similar to, or an extension of, the Friends of the BTRW in Kangaroo Valley, is assessed within two years of the commencement of the plan;
- Support groups, if feasible, are established within the life of this plan.

**Justification**

Community involvement has been a major success factor in the conservation of the Shoalhaven BTRW colonies. The creation/extension of community support groups for other regions will assist in conserving BTRW in those regions, and in raising the level of community involvement in BTRW recovery management and the awareness of general conservation issues overall.

**Methods**

Assess the feasibility of establishing support groups in other regions and provide recommendations for future management actions in this regard, including whether such groups would be best formed at the local, regional or ESU level.

These support groups would assist in the implementation and promotion of the community involvement opportunities identified in Community Involvement Priority Action 12.6.2. Input will be sought from the Friends of the BTRW and from other DEC staff already working on projects involving the community.

The feasibility of the Friends of the BTRW to expand their role and membership to an ESU level will also be assessed. This option will be examined further by DEC and the group.

**Responsibilities**

BTRW coordinator; relevant land managers; Friends of the BTRW; contractor.

**Community Involvement Priority Action 12.6.5.** Seek to engage the corporate sector in financing components of the plan eg. 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 2 years
- Private sponsorship achieved within 5 years

**Justification**

Effective and efficient delivery of the BTRW recovery program will be maximised using an integrated approach to site management and threat mitigation. 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 this 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 work with 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

## 13.0 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, eg biological control of foxes. If any are considered likely 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 within this recovery plan.

### 13.1 Alternative Action 1 – Translocation between ESU

Within NSW, this recovery plan restricts translocation to within ESU, i.e. no transfer of genetic stock between the Central ESU and Northern ESU. 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 ESU may be considered by the recovery team if the priority actions fail to recover the populations within the Central or

Southern ESU in the long-term. This action involves translocation of individuals from colonies in the Northern ESU to supplement populations in the Central or Southern ESU. Proposals for translocation would need to be developed in accordance with the proposed Captive Breeding and Translocation Policy for BTRW and approved by the DEC. Any translocations will only be implemented with 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 medium-term. This action involves captive breeding following accelerated breeding techniques researched by Bell and Close (1994). The technique has been used successfully in Victoria with Southern ESU BTRW, and involves cross-fostering of BTRW young to other macropod species, eg. 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.

## **14.0 Implementation**

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

## **15.0 Preparation details**

The preparation of this recovery plan was coordinated by Mike Cavanagh and Suzanne O'Neil, Biodiversity Management Unit 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 each 5 years from the date of adoption, or earlier if a radical departure from the implementation schedule is warranted by new information.

## 16.0 Acronyms and abbreviations

ACT – Australian Capital Territory  
ARAZPA – Australasian Regional Association of Zoological Parks and Aquaria  
ASMP – Australasian Species Management Program  
BMU – Biodiversity Management Unit  
BTRW – Brush-tailed Rock-wallaby/ies  
CMA – Catchment Management Authority/ies  
DEC – Department of Environment and Conservation (NSW)  
DPI (Forests) – NSW Department of Primary Industries (Forests NSW)  
EP&A Act – *Environmental Planning and Assessment Act 1979*  
EPBC Act – *Environment Protection and Biodiversity Conservation Act 1999*  
ESU – Evolutionary Significant Unit/s  
IBRA – Interim Biogeographic Regionalisation for Australia  
LALC – Local Aboriginal Land Council  
LGA – Local Government Area  
mtDNA – mitochondrial Deoxyribose Nucleic Acid  
NPWS – National Parks and Wildlife Service  
NP – National Park  
NR – Nature Reserve  
NSW – New South Wales  
PMP – Population Management Plan  
RLPB – Rural Lands Protection Board/s  
SA – South Australia  
SF – State Forest  
SRA – State Recreation Area  
TAP – Threat Abatement Plan  
TSC Act – *Threatened Species Conservation Act 1995*  
YFRW – Yellow-footed Rock-wallaby

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## Appendix 1. Recovery Plan Cost Schedule

No.	Action	Priority	Year 1 (\$)	Year 2 (\$)	Year 3 (\$)	Year 4 (\$)	Year 5 (\$)	Total Cost (\$)	Responsible Agency	In-Kind (\$)	Cash (\$)	Additional funds required (\$)
12.2.1.	BTRW recovery coordinator	1	45 000*	45 000*	45 000*	45 000*	45 000*	225 000*	DEC	225 000*		
12.3.1.	Document threatening processes	1	□	1 000				1 000	DEC		1 000	
12.3.2.	Assess threat abatement programs	1		□	□				DEC			
12.3.3.	New threat abatement techniques	2		27 000	9 000	9 000	9 000	54 000	DEC			54 000
				3 000	1 000	1 000	1 000	6 000	DPI (Forests)			6 000
12.3.4.	Information on distribution	2		15 000	15 000	5 000	5 000	40 000	DEC			40 000
				5 000	5 000			10 000	DPI (Forests)			10 000
12.3.5.	Standardise survey techniques	2		12.3.4	12.3.4	12.3.4	12.3.4		DEC			
				12.3.4	12.3.4	12.3.4	12.3.4		DPI (Forests)			
12.3.6.	Standardise monitoring techniques	2		10 000	5 000			15 000	DEC			15 000
12.3.7.	Monitoring network	2	4 000	500	500	500	500	6 000	DEC	6 000		
			1 000	500	500	500	500	3 000	DPI (Forests)	3 000		
12.3.8.	Determine geographic genetic boundaries	2	10 000	10 000				20 000	DEC			20 000
12.3.9.	Determine degree of taxonomic separation	3	10 000	10 000	10 000			30 000	DEC			30 000
12.3.10.	Review of ecology	2	5 000	□				5 000	DEC		5 000	
12.3.11.	Ecological field research	2		15 000	15 000	15 000	15 000	60 000	DEC			60 000
12.4.1.	Collate management information	1	□		□		□		DEC			
12.4.2.	Best management guidelines	2	2 000					2 000	DEC	2 000		
12.4.3.	Develop site plans	1	2 000	500	500			3 000	DEC	2 000	1 000	
12.4.4.	Develop predator control network	1	15 000**	15 000**	15 000**	15 000**	15 000**	75 000**	DEC	75 000**		
			5 000**	5 000**	5 000**	5 000**	5 000**	25 000**	DPI (Forests)	25 000**		
12.4.5.	Develop feral competitor	2	7 500	7 500	7 500	7 500	7 500	37 500	DEC	37 500		

No.	Action	Priority	Year 1 (\$)	Year 2 (\$)	Year 3 (\$)	Year 4 (\$)	Year 5 (\$)	Total Cost (\$)	Responsible Agency	In-Kind (\$)	Cash (\$)	Additional funds required (\$)
	control programs											
			2 500	2 500	2 500	2 500	2 500	12 500	DPI (Forests)	12 500		
12.4.6.	Community support base for control programs	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		DEC			
12.4.7.	Ameliorate habitat degradation	2	2 000	2 000	1 000	1 000	1 000	7 000	DEC			7 000
12.5.1.	Policy paper	1	<input type="checkbox"/>						DEC			
12.5.2.	Evaluating effectiveness	1		<input type="checkbox"/>					DEC			
12.5.3.	Enhance captive breeding sites	1	2 500					2 500	DEC	2 500		
12.5.4.	Identify priority sites	1	<input type="checkbox"/>	10 000	10 000	10 000	10 000	40 000	DEC			40 000
12.6.1.	Community information kit	1	10 000	5 000				15 000	DEC			15 000
12.6.2.	Community involvement opportunities	2		500	500	500	500	2 000	DEC		2 000	
12.6.3.	Kangaroo Valley FBTRW	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1 000	DEC		1 000	
12.6.4.	Other support groups	2	1 000	1 000	1 000	1 000	1 000	5 000	DEC		5 000	
12.6.5.	Seek corporate sponsorship	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		DEC			
	<b>TOTAL</b>							<b>702 500</b>		<b>390 500</b>	<b>15 000</b>	<b>297 000</b>

\* cost relates to the salary and on-costs of the recovery plan coordinator, based on the position being a Project Officer Grade 3-4.

\*\* 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 DEC 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. Making a submission regarding this draft recovery plan**

**SUBMISSION**

Name Individual/Organisation: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Postal Address: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Postcode: \_\_\_\_\_ Contact Number(s): \_\_\_\_\_

Date: \_\_\_\_\_

**Draft Recovery Plan: Petrogale penicillata Brush-tailed Rock-wallaby**

The DEC will consider all written submissions received during the period of public exhibition and must provide a summary report of those submissions to the Minister for the Environment prior to final approval of this recovery plan.

Please note, that for the purposes of the NSW *Privacy and Personal Information Protection Act 1998* any comments on this draft recovery plan, including your personal details, will be a matter of public record and will be stored in DEC records system. Following approval of the plan by the Minister, copies of all submissions, unless marked “confidential,” will be available, by arrangement, for inspection at the DEC Office responsible for the preparation of the recovery plan.

Should you not wish to have your personal details disclosed to members of the public once the plan of management has been adopted, please indicate below whether you wish your personal details to remain confidential to DEC and not available for public access. Further information on the *Privacy and Personal Information Protection Act 1998* may be obtained from any office of the DEC or available from the website: [www.environment.nsw.gov.au](http://www.environment.nsw.gov.au)

- Yes, please keep my personal details confidential to DEC

Submissions should be received no later than Friday October 21, 2005. Submissions should be addressed to:

Director-General  
 c/- Brush-tailed Rock-wallaby Recovery Planning Coordinator  
 Biodiversity Management Unit  
 Reform and Compliance Branch  
 Environment Protection and Regulation Division  
 Department of Environment and Conservation (NSW)  
 PO Box A290  
 SYDNEY SOUTH NSW 1232

**SUBMISSION:**

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Department of  
**Environment and  
Conservation (NSW)**