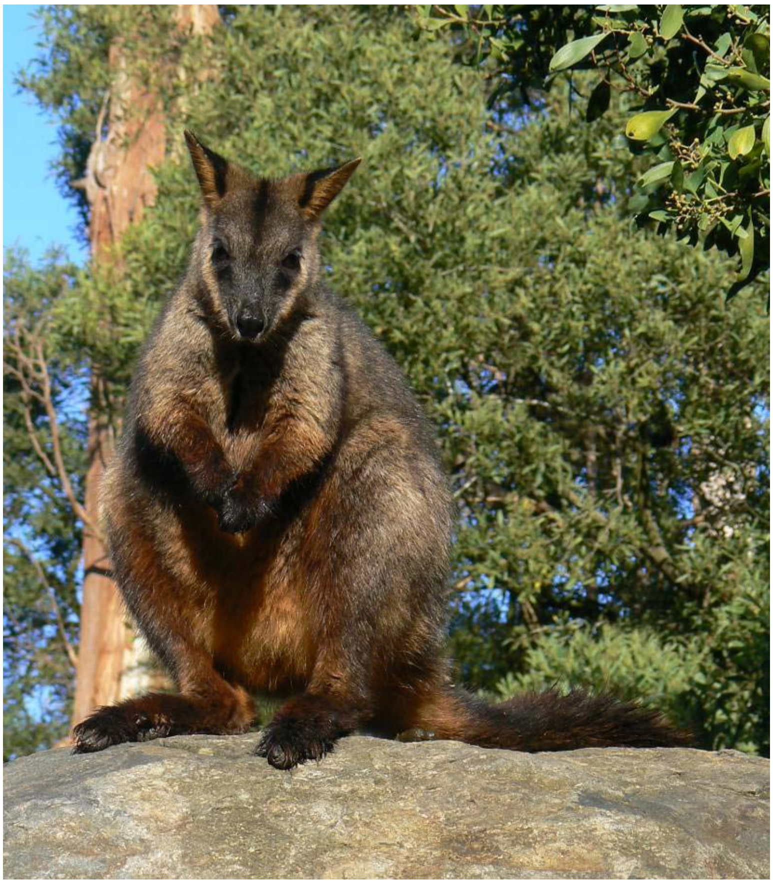
National Recovery Plan for the Brush-tailed Rock-wallaby *Petrogale penicillata*

Peter Menkhorst and Emily Hynes



Prepared by Peter Menkhorst and Emily Hynes, Department of Sustainability and Environment, East Melbourne.

Published by the Victorian Government Department of Sustainability and Environment (DSE) East Melbourne, November 2011.

Authorised by the Victorian Government, 8 Nicholson Street, East Melbourne.

ISBN 978-1-74242-488-0 (online)

This is a Recovery Plan prepared under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999, with the assistance of funding provided by the Australian Government.

The Australian Government, in partnership with the Department of Sustainability and Environment Victoria, Department of Environment, Climate Change and Water New South Wales and Department of Environment and Resource Management Queensland, facilitates the development of recovery plans to detail the actions needed for the conservation of threatened native flora and fauna.

This Recovery Plan has been developed with the involvement and cooperation of a range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

An electronic version of this document is available on the Department of the Environment, Water, Heritage and the Arts website www.environment.gov.au

For more information contact the DSE Customer Service Centre telephone 136 186

Citation: Menkhorst, P. and Hynes, E. 2010. National Recovery Plan for the Brush-tailed Rock-wallaby *Petrogale penicillata*. Department of Sustainability and Environment, East Melbourne.

Cover photograph: Brush-tailed Rock-wallaby *Petrogale penicillata* by Lucy Clausen © DSE

Contents

Summary

The Brush-tailed Rock-wallaby (*Petrogale penicillata*) is a medium-sized marsupial macropod that was formerly widely distributed in south-eastern Australia, from south-eastern Queensland through eastern and central New South Wales and the Australian Capital Territory to western Victoria. It has suffered a widespread decline in range and abundance, with a major range contraction and local extinctions in many areas, especially in the south and west of its distribution. The species now survives mostly on isolated rocky escarpments along the Great Dividing Range from south-eastern Queensland through eastern New South Wales to eastern Victoria. Historical and current threats include hunting, predation, habitat loss, competition with other species and loss of genetic diversity. The Brush-tailed Rock-wallaby is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. It is also listed as Vulnerable under the Queensland *Nature Conservation Act 1992*, Endangered under the New South Wales *Threatened Species Conservation Act 1995*, Endangered under the Australian Capital Territory *Nature Conservation Act 1980*, and Threatened under the Victorian *Flora and Fauna Guarantee Act 1988*. This Recovery Plan for the Brush-tailed Rock-Wallaby is the first national recovery plan for the species, and details its distribution, habitat, threats and recovery objectives and actions necessary to ensure its long-term survival.

Species Information

Description

The Brush-tailed Rock-wallaby (*Petrogale penicillata* Gray 1825) is a medium-sized, stocky wallaby with a head and body length of 53–59 cm and tail length of 51–70 cm for males (slightly smaller for females), and an adult weight of 6–11 kg for males and 5–8 kg for females. Colouration is generally dull brown above, tending to reddish-brown on the rump and to grey on the neck and shoulders, lighter underneath and with darker limbs. The head is darker, with a distinct pale stripe from the upper jaw through the cheek to the base of the ears. Juveniles are more distinctly marked than adults. The posterior third of the tail is distinctively bushy (description from Eldridge & Close 1995). Colour tends to be lighter and tails less bushy in northern populations of Brush-tailed Rock-wallabies, although there is considerable variation in colouring and patterning within and between populations (Bayne 1994), which often allows for individual identification of animals.

Biology and Ecology

The Brush-tailed Rock-wallaby can breed throughout the year, although usually with a peak of births in autumn (Joblin 1983; Wynd *et al.* 2006). The gestation period is about 30 days, with permanent pouch emergence occurring at about 204 days, and young are weaned at about 290 days of age (Lee & Ward 1989), although age at weaning can be quite variable (D. Ashworth pers. comm. 2010). Females reach sexual maturity at 18 months and males at 20–24 months (Lee & Ward 1989). Embryonic diapause occurs in this species and females can carry a pouch young while simultaneously suckling a young-at-foot (Wynd *et al.* 2006).

Mortality of young prior to weaning appears to be quite high. In one report from south-eastern Queensland, only 36% of young survived pouch life, with the majority of deaths occurring before the young was established in the pouch, although 26% of young established in the pouch subsequently died before emergence from the pouch. Significantly more of the young born in the autumn birth peak survived to emergence than of those born in summer or spring (Wynd *et al.* 2006).

Diet of the Brush-tailed Rock-wallaby consists mainly of short grasses, with *Acacia* flowers, forbs, leaves, fruit, bark and fruiting bodies of hypogeal fungi also eaten (Wakefield 1971; Short 1980, 1989; Jarman & Phillips 1989; Fleming 2000; Carter & Goldizen 2003). Most foraging occurs at night, in grassy habitats close to their daytime refuge. Rock-wallabies typically move from the refuge habitat to the foraging habitat around dusk, returning to the refuge habitat before dawn (Carter & Goldizen 2003). Individual foraging ranges are small, in south-eastern Queensland averaging 2–3 ha, within which animals fed in preferred patches of short grass often of less than 0.1 ha (Laws & Goldizen 2003). Animals will also climb into trees to browse (P. Jarman pers. obs. 2005).

Home-range areas of 6–30 ha (av. 15 ha) were recorded in southern NSW (Short 1980). The home range consists of a refuge area and a foraging range, linked by habitually-used commuting routes. Individuals usually use only one rocky refuge (e.g. a cave or a space between boulders) in which to retreat for much of the day, and one or a few resting sites close to the refuge. Individuals may also retreat under the cover of vegetation, which may be at ground level or the dense canopy of vines or of trees such as figs, sometimes climbing into trees. Rock-wallabies will also sit on resting sites for up to several hours, especially on cold sunny mornings when animals appear to bask in the sun (information from Short 1980; Joblin 1983; Jarman & Bayne 1997; Carter & Goldizen 2003; Laws & Goldizen 2003).

Female Brush-tailed Rock-wallabies tend to be highly philopatric, settling in or near their mother's range, while males mainly disperse between female groups within colonies, and less commonly between colonies (Joblin 1983; Bayne 1994; Hazlitt *et al.* 2004, 2010). Adults of both sexes may occupy the same individual home-ranges (S. Hazlitt pers. comm. 2006), but refuges and resting/sunning sites are usually persistently occupied by single adults of either sex, although a female will share sites with her dependent young (Joblin 1983; Bayne 1994).

Distribution

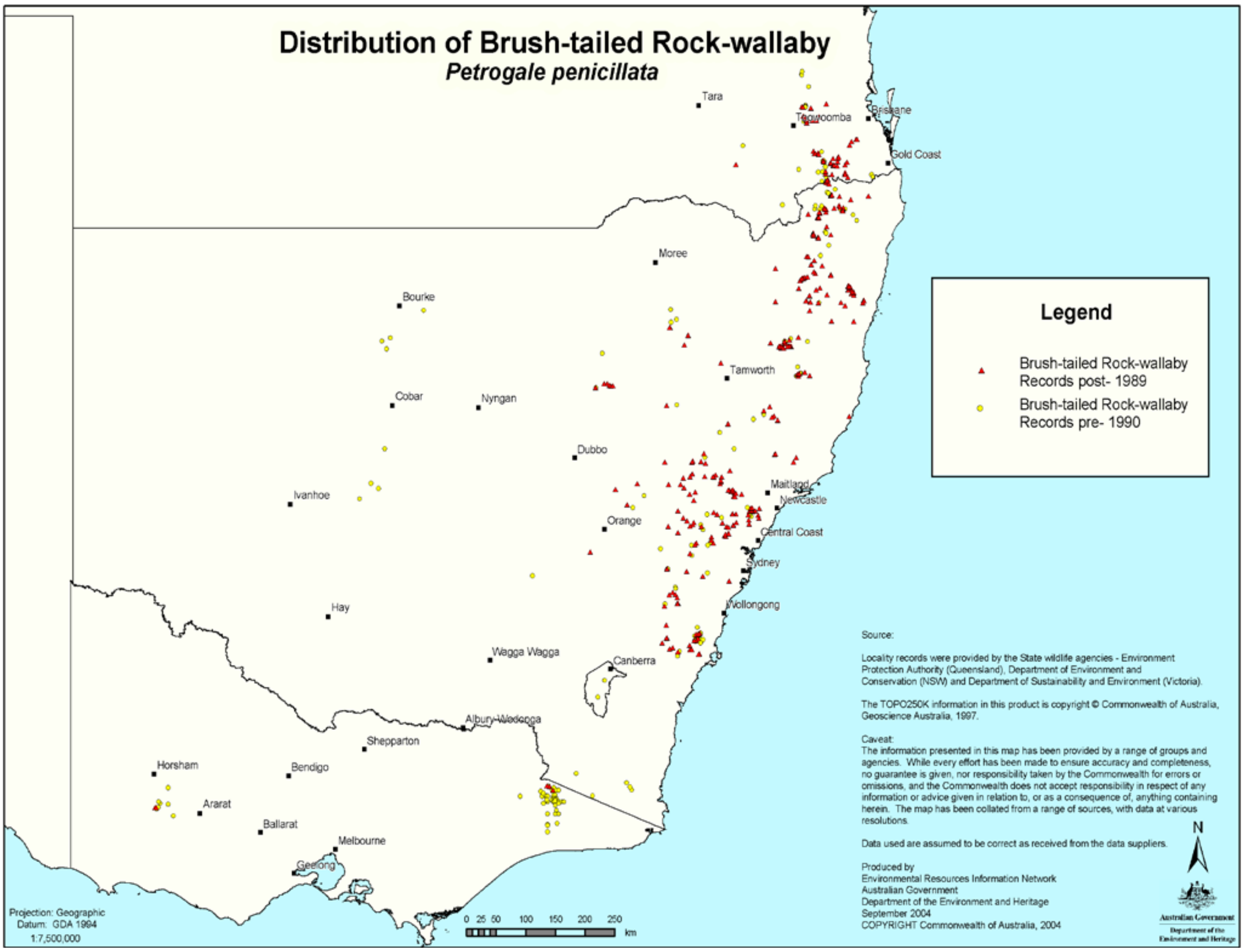


Figure 1. Distribution of the Brush-tailed Rock-wallaby

Past distribution

The Brush-tailed Rock-wallaby was formerly widely distributed in south-eastern Australia, from south-eastern Queensland through eastern and central New South Wales and the Australian Capital Territory, to western Victoria (Figure 1), occurring in the Brigalow Belt South, South Eastern Queensland, Darling Riverine Plains, Cobar Peneplain, Nandewar, New England Tablelands, NSW

North Coast, NSW South Western Slopes, Sydney Basin, South Eastern Highlands, South East Corner and Victorian Midlands IBRA bioregions (*sensu* DEH 2000).

Present distribution

The Brush-tailed Rock-wallaby is now patchily distributed along the Great Dividing Range (GDR) from Yarraman (north of Toowoomba, Queensland) to the upper Snowy River in eastern Victoria (Figure 1). It is predominantly distributed on the eastern scarp of the GDR, with outlying populations occurring in the Warrumbungle Ranges and at Mt Kaputar, well inland of the GDR in northern New South Wales. The species is now extinct in the Darling Riverine Plains and Cobar Peneplain bioregions, and has been reintroduced into the Victorian Midlands bioregion.

Within this broad distribution, three Evolutionarily Significant Units (ESUs; as defined by Moritz 1994) that are substantially genetically distinct from one another have been identified: a Southern ESU (S-ESU) that is currently restricted to East Gippsland and a reintroduced population in the Grampians in western Victoria; a Central ESU (C-ESU) in central NSW; and a Northern ESU (N-ESU) in northern NSW and south-eastern Queensland (Browning *et al*. 2001). There is currently a substantial gap of about 320 km between the most easterly S-ESU population (Snowy River National Park: 37^{o} 05' S, 148^{o} 24' E) and the southern edge of the C-ESU range (Kangaroo Valley 34^{o} 45' S, 150^{o} 30' E), although many populations have been lost from this region since European colonisation. The precise location of the boundary between the C-ESU and N-ESU is not known, but there appears to be a contact zone between Woko National Park (31^{o} 44' S, 151^{o} 45' E) and Broke (32^{o} 27' S, 151^{o} 08') (Eldridge and Browning 2004).

The Brush-tailed Rock-wallaby was also introduced to New Zealand and Hawaii, where feral populations have become established (Lazel *et al.* 1984; Warburton & Sadlier 1995; Eldridge *et al*. 2001) (see Appendix 2).

Habitat

Brush-tailed Rock-wallaby habitat includes refuge habitat, feeding habitat, and routes in between. Refuge habitat includes rock faces or outcrops with large tumbled boulders, ledges and caves (often with vegetation cover) that provide shelter and some protection from predators. Preferred rocky habitat consists of three major types (Short 1982):

- 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.
- Isolated rock stacks, usually sheer-sided and often girdled with fallen boulders.

Rock refuges are usually on a steep slope (e.g. cliff lines, river banks, gorges, outcrops from hillsides, plateau edges). Extent of occupied refuge habitat may not be large, with some colonies persisting in refuge habitat that is less than 50 m long and 20 m high, although some large colonies occupy refuge habitat that is continuous for many hundreds of metres along cliff lines (Short 1982; Bayne 1994; Murray 2002; Waldegrave-Knight 2002; P. Jarman pers. obs. 2007). Most refuge sites have areas that receive sunlight for much of the day. Preferred refuge sites in East Gippsland had more than one entrance, several ledges, a northerly or easterly aspect, and occurred within a large area of rocky slope where the general slope was greater than 45° (Waldegrave-Knight 2002). Foraging habitat includes forest and woodland with a grassy understorey, and animals will forage in artificial clearings and pastures. Precise vegetation community type may not be critical in habitat selection as Brush-tailed Rock-wallabies eat a wide variety of plant material, although mainly grasses.

Prior to European settlement, the Brush-tailed Rock-wallaby may have also occurred in non-rocky forests and woodlands, especially those on steep slopes and with cover in the form of dense vegetation and large fallen logs or trees (Jarman & Bayne 1997). The apparent restriction of Brush-tailed Rock-wallabies to rocky habitats may be relatively recent, and is probably a consequence of threatening processes operating on the species.

Habitat critical to survival of the species includes rocky refuge habitat, foraging habitat and commuting routes between the two. This has not yet been precisely mapped for the species. Proposed recovery actions include determining habitat that is critical to survival of the Brush-tailed Rock-wallaby.

Important Populations

Little is known about the population structure of the Brush-tailed Rock-wallaby. The three ESUs were likely once contiguous along the south-east coast of Australia, however deep genetic divergence between the ESUs supports their long-term matrilineal isolation (Paplinska *et al.* in press). Borders between ESU's may be a result of isolation events during Pliocene and/or Pleistocene forest habitat contractions (Paplinska *et al*. in press). However, with the more recent habitat changes and threats leading to the extensive decline in range and abundance suffered by the species, many colonies within ESU's are now effectively isolated from one another, and probably represent discrete populations. Some important populations can be identified, based on populations at the limits of its range, outlying populations, stronghold populations, research populations and others where recovery actions (e.g. predator control, reintroductions) are being implemented. However, given the slow collapse of the Central ESU over the past decades, it is reasonable to consider populations in the Northern ESU as potentially very important to maintaining the species in NSW. There are likely to be some populations in NSW and south-eastern Queensland whose locations have not been recorded, and others whose general locality may be known but whose size and geographic extent are not documented. Based on current knowledge, populations important to the survival of the Brush-tailed Rock-wallaby include:

Victoria

- Grampians Range – a reintroduced population (East Gippsland provenance) comprising 11 animals at Moora Moora Creek (Grampians National Park).
- East Gippsland – about 20 wild and two released captive-bred animals (East Gippland provenance)in Little River Gorge area, south-east of Wulgulmerang (Snowy River National Park).

New South Wales

- Warrumbungle Range (outlying population; loss would cause substantial range contraction).
- Mt Kaputar (outlying population; loss would cause range contraction).
- Wollemi National Park and Jenolan Caves [stronghold populations where fox control may be most effective (due to distance from agricultural land) and so populations have the greatest chance of persisting into the long term].
- Nattai National Park population (loss would create a large range gap between the Shoalhaven population and populations further north).
- Shoalhaven (southernmost population in NSW).
- Macleay Gorges region (largest known populations).

Identification of populations important to the survival of the Brush-tailed Rock-wallaby is proposed as a recovery action in this plan.

Decline and Threats

The Brush-tailed Rock-wallaby was once widespread and common to abundant in suitable habitat throughout south-eastern Australia. However, the species has suffered a substantial decline in distribution and abundance since European settlement of Australia, especially in the southern and western parts of its range (Figure 1). Over 960 sites with evidence of Brush-tailed Rock-wallaby occupation have been documented across the range of the species (DECC 2008). Of these, 739 sites (77%) are known to be currently occupied, 145 sites (15%) were considered to be unoccupied, with occupancy at the remaining 78 sites undetermined. About one-half of these sites are within conservation reserves, about 10% are on other crown land, mostly state forest, and the remainder on private land. The species remains relatively common only in gorges in the upper reaches of coastal streams in north-eastern NSW and south-eastern Queensland, particularly the Macleay River and Clarence River gorge complexes. The Southern ESU is the most highly threatened, being reduced to a single small wild population and a reintroduced population. A significant proportion of populations in the Central ESU are also under serious threat – in the Shoalhaven region, three well-studied colonies each have fewer than 10 individuals remaining (M. Norton pers. comm. 2010). The status of populations in the Northern ESU is not known.

In Victoria (S-ESU), the Brush-tailed Rock-wallaby occurred in the Grampians in the west of the State, and in Gippsland in the east, from Mt Kent to near Deddick (Menkhorst 1995) and probably was contiguous with populations in southern New South Wales. The species was once widespread in the Grampians (Close *et al.* 1988), but by 1986 only four colonies remained (Norris & Belcher

1986). This decline continued until extinction; with the last known wild animal captured and taken into captivity in 1999. The species disappeared from almost all of its former distribution in Gippsland, and now survives in a few isolated colonies in the upper Snowy River area comprising perhaps 20 animals (Waldegrave-Knight & Stevens 2003).

In New South Wales, the species once occurred from the Victorian border north to the Queensland border (including the ACT) and west as far as Bourke and Mt Hope. The species is no longer found south of Nowra/Goulburn, including the ACT (where it was last recorded in 1959; EACT 1999); and from virtually all sites west of the GDR, including Coombie, Gundabooka, Mt Oxley and the Weddin Mountains (Short & Milkovits 1990; Dovey *et al.* 1997; DECC 2008). In this region small populations still occur in the Warrumbungle Range near Coonabarabran, and on Mt Kaputar. Remaining colonies are now almost entirely scattered along the GDR, from the few small, isolated colonies in the Shoalhaven area in the south to the numerous colonies close to the Queensland border. The species has generally disappeared from the GDR tablelands, but remains relatively common in the valleys and gorges of the eastern scarp of the GDR in north-east NSW. Many colonies still occur between that scarp and the coast.

Little is known of the extent of the decline in Queensland. A survey in the late 1990s found evidence of Brush-tailed Rock-wallaby presence at 131 sites (Capararo 1998). Half of these sites (65) were primarily on private land and 48 (74%) of these were occupied by rock-wallabies at the time of the survey. Fifty-four sites (41%) occurred in conservation reserves and 46 (85%) of these were occupied. None of the 12 (9%) sites in State Forest were shown to be occupied. The species is now apparently extinct on the western scarp of the GDR in the Stanthorpe district (Murray 2009).

The naturally fragmented nature of refuge habitat results in many distinct, separated colonies that are effectively isolated from one another. Many colonies consist of just a few animals and, even in the parts of their range where the species remains locally common, many colonies (perhaps most) number less than 12 adults (Jarman and Bayne 1997). While colonies as small as 2–4 adults can persist for some years, at this size they are very prone to demographic stochasticity and probably ultimately become extinct. However, in the Central and Northern ESU, some colonies contain 30–50 adults (Piggot *et al.* 2006b; P. Bayne unpubl. data 1994; A. Goldizen unpubl. data 2005).

The principal threats to the Brush-tailed Rock-wallaby are not well understood, and further investigation is required to clarify which of the likely threatening processes are the key ones. While some declines happened decades ago, the decline is continuing in some areas, as evidenced by the ongoing loss of individual colonies. Remaining populations are generally highly fragmented and isolated from one another. The disjunct nature of its distribution makes populations particularly susceptible to local extinction from stochastic events such as fire, drought and disease. However, the direct causes of any colony's extinction have never been established. There are several historic and current threats that have undoubtedly contributed to the decline of the Brush-tailed Rock-wallaby, as summarised in the following sections:

Hunting/persecution

The initial decline of the Brush-tailed Rock-wallaby, especially from locations in the south and west of its range, may well have been caused by large numbers of animals being killed for fur and meat, and as a supposed agricultural pest. Over half a million rock-wallabies were killed in NSW between 1884 and 1914 (Eldridge & Close 1995), while in East Gippsland (Vic), over 1,200 animals were killed during one winter alone near Suggan Buggan (Rogers, cited in Menkhorst 1995). By the time this persecution ceased, the species was already rare in the west and south of its range.

Habitat Degradation and Loss

Degradation of the Brush-tailed Rock-Wallaby's habitat has been caused by a number of factors. Since European settlement, the effective isolation of many colonies has probably increased because the habitat between colonies has been degraded through vegetation clearance, livestock grazing and timber harvesting. This has probably reduced the frequency of successful dispersal between colonies and thus increased the isolation of colonies and populations (Jarman & Bayne 1997), leaving them even more vulnerable to inbreeding and loss of genetic diversity. Habitat modification continues due to rural residential and tourist developments adjacent to some colonies (especially in northern NSW), and the current trend of locating these developments near escarpments and cliff lines to maximise scenic opportunities. Such sites are often core Brush-tailed Rock-wallaby 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. The impacts of wildfires and managed fires on the animals and their habitat (especially food supply) are not known. Temporary abandonment of a colony site at Mount

Wallerawang after a fire, and subsequent recolonisation several years later, has been anecdotally reported (DECC 2008).

Predation

The Brush-tailed Rock-wallaby faces a range of both native and introduced predators, including the Dingo/wild Dog (*Canis lupus*), Red Fox (*Vulpes vulpes*), feral Cat (*Felis catus*), Wedge-tailed Eagle (*Aquila audax*), Spotted-tailed Quoll (*Dasyurus maculatus*) and Carpet/Diamond Python (*Morelia spilota*) (Bayne 1994; Menkhorst 1995; Jarman & Bayne 1997). Predation by introduced predators, especially the Red Fox and possibly feral Cat, poses a significant threat to small mammals (Risbey *et al.* 2000), including the Brush-tailed Rock-wallaby (Hill 1991; EACT 1999; Waldegrave-Knight & Stevens 2003; DECC 2008). Because of their reliance on particular secure refuges, Brush-tailed Rock-wallabies are susceptible to predators that can learn the location of refuges, and movement pathways to and from them (Jarman & Bayne 1997). A single feral Cat on an isolated population of the Allied Rock-wallaby *Petrogale assimilis* (weight to 4.5 kg), killed five (45.5%) of the young, one (14.2%) of the sub-adults and at least two (4.6%) of the adult population (Spencer 1991). The current restriction of rock-wallabies to rocky habitat is possibly relatively recent, and may well be an artefact of fox predation (as well as habitat destruction), with foxes able to prey more easily on rock-wallabies in structurally less complex habitat. In forest areas in eastern NSW, proximity to cleared freehold land or intensive logging was associated with increased abundance of the Red Fox (Catling & Burt 1995). Therefore, distance to cleared land, or highly disturbed land, including vehicle tracks and logging coupes, may be an important variable in determining the persistence of Brush-tailed Rock-wallaby colonies.

Competition

Other native and introduced herbivores may compete with Brush-tailed Rock-wallabies for food and shelter. Rock-wallabies frequently share their foraging habitat with European Rabbit (*Oryctolagus cuniculus*), feral Goat (*Capra hircus*), feral Horse (*Equus caballus*), Eastern Wallaroo (*Macropus robustus*), Eastern Grey Kangaroo (*Macropus giganteus*), Whiptail Wallaby (*Macropus parryi*), Red-necked Wallaby (*Macropus rufogriseus*), Black Wallaby (*Wallabia bicolor*), Mountain Brushtail Possum (*Trichosurus cunninghami*) and Common Brushtail Possum (*Trichosurus vulpecula*). If competing species reach high densities they could pose a threat to the Brush-tailed Rock-wallaby, through reduced food supply, reduced condition, breeding success and survival. Goats have been observed to displace rock-wallabies from their refuge areas, and monitoring in Warrumbungle Range demonstrated a negative correlation between the density of goat pellets and rock-wallaby pellets in both foraging and refuge areas (Moss *et al*. 1997). Goats were also speculated to have been the cause of the extirpation of the Dingo Creek colony in Warrumbungle National Park (Moss *et al.* 1999). Short and Milkovits (1990) suggested that goats have had more of a detrimental impact on Brush-tailed Rock-wallabies west of the Great Dividing Range than in the coastal ranges.

Genetic decline

In most parts of its range the Brush-tailed Rock-wallaby probably always occurred as a metapopulation comprised of colonies centred on areas of high-quality rock habitat that provided adequate refuges within reach of reliable food resources. Although adults show high fidelity to refuge sites, sub-adults (mostly males) did move between colonies, which probably overcame genetic problems associated with isolation of small populations. However, since European settlement of eastern Australia, the isolation of many colonies has probably increased because the habitat between colonies has been degraded and as a consequence of a high level of predation. When this isolation is coupled with decreased population size, as is the case with the Victorian and many NSW populations, the rate of loss of genetic diversity due to founder effects and genetic drift is greatly increased, and this variation is not readily replenished in isolated populations. Small isolated populations are also often subject to increased rates of inbreeding (Charlesworth & Charlesworth 1987). The loss of genetic variation in a population reduces the ability of the population to respond to environmental change and increases the risk of extinction, through increased inbreeding and genetic drift causing increased homozygosity (Charlesworth & Charlesworth 1987). Increased homozygosity can have negative effects on individual fitness both because there is an intrinsic advantage to heterozygosity for some genes and gene complexes (Ferreira & Amos 2006) and it can lead to an increase in the frequency of expression of recessive deleterious alleles (Charlesworth & Charlesworth 1987).

The remnant genetic diversity within the Southern ESU is lower than that of the other two ESUs. However, because of the extremely significant differentiation between the ESUs, interbreeding of ESUs to increase genetic diversity would be considered only as a last resort because of the risk of outbreeding depression (the loss of individual fitness through hybridising genetically distinct populations). Genetic analysis of several colonies in East Gippsland indicated very low genetic diversity (among the lowest reported for wild marsupial populations), genetic differentiation between colonies, and a very high level of inbreeding (Bowyer *et al.* 2002). Similar patterns of genetic partitioning between colonies, even when geographically close, have been found in animals along the Wolgan River, NSW (Central ESU) (Piggott *et al*. 2006b). Significant genetic differentiation between colonies is evident even when colonies are separated by only 2–4 km of pristine continuous habitat, with no apparent barriers to dispersal (Hazlitt *et al*. 2006a; 2010). These high levels of genetic differentiation appear to be due to extremely limited breeding dispersal between colonies (Hazlitt *et al*. 2006b; 2010). The East Gippsland population graphically illustrates the negative impact on genetic diversity of isolation and decreasing population size, and provides a model of the fate that awaits other rock-wallaby populations if their size decreases and isolation increases. The decline of the Jenolan Caves population from about 90 to seven individuals over just seven years resulted in a substantial reduction in genetic diversity (Eldridge *et al*. 2004).

Areas Under Threat

Areas occupied by Brush-tailed Rock-wallabies that are under threat have not been precisely defined. However, sites on private land (about 40% of current or recently occupied sites are on private land: DECC 2008) are probably more at risk than those in parks and reserves (although the generally rugged nature of rocky habitat reduces options for land use). The expansion of rural residential and tourist developments adjacent to some colonies, especially in northern NSW, and the current trend of locating these developments near escarpments and cliff lines to maximise landscape views, is probably a threat. Such sites are often core Brush-tailed Rock-wallaby habitat and development increases the risk of colony fragmentation, permanent changes to potential dispersal corridors, an increase in the numbers of domestic animals and predators, and the removal of tree cover.

Populations Under Threat

There is some information to enable identification of populations under threat. Both populations of the Southern ESU (Grampians reintroduced and East Gippsland), and most (if not all) remaining populations in the Central ESU are under threat and require active, ongoing management. Little is known of which Northern ESU populations are under threat.

Table 1. Listed Threatening Processes likely to affect the Brush-tailed Rock-wallaby

Threatening Process	**Legislation**
Predation by the feral Cat *Felis catus*	EPBC, TSC, FFG
Predation by the European Red Fox *Vulpes vulpes*	EPBC, TSC, FFG
Competition and habitat degradation by feral goats	EPBC, TSC
High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.	TSC, FFG
Land clearance/Clearing of native vegetation	EPBC, TSC
Habitat fragmentation	FFG
Inappropriate fire regimes causing disruption to sustainable ecosystem processes and loss of biodiversity	FFG
Invasion of native vegetation by environmental weeds	FFG, TSC

EPBC – Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; TSC – NSW *Threatened Species Conservation Act 1995*; FFG – Victorian *Flora and Fauna Guarantee Act 1988*

Recovery Information

Current Conservation Initiatives

The Brush-tailed Rock-wallaby has been the subject of considerable management attention for several decades, and a number of conservation initiatives have been implemented. Regional recovery teams have been established in Victoria and New South Wales to coordinate implementation of recovery actions. Current recovery actions are discussed below.

Planning

A considerable amount of planning has been undertaken for recovery of the species. Nationally, a research recovery plan was prepared (Hill 1991) and partially implemented (Wong *et al.* 1994). A number of documents have been prepared and plans implemented at the state/territory level:

- Victoria – Action Statement (Hill & Baker-Gabb 1991); field management strategies (Waldegrave-Knight & Stevens 2003, DSE 2008); captive management plan (Andrews *et al.* 2009); re-introduction strategy (Delaney *et al.* 2005); reintroduction site assessment (Taggart *et al.* 2008); a reintroduction plan for the Grampians National Park (Bramwell *et al.* 2008), and a husbandry manual (Dobroszczyk 2007).
- New South Wales – State Recovery Plan (DECC 2008); recovery plan for the population in the Warrumbungle National Park (NPWS 2003); captive management plan for animals of central ESU provenance (ARAZPA 2005).
- Australian Capital Territory – Action Plan (EACT 1999)

Surveys and Monitoring

Surveys of historical and current Brush-tailed Rock-wallaby sites have been conducted across its range (e.g. Close *et al*. 1988; Lobert & Waters 1988; Reside & Martin 1997; Capararo 1998; Waldegrave-Knight & Cunningham 1999). Regular monitoring of East Gippsland populations was established in 2000 and remote cameras have been used there since 2005. Colonies in the Shoalhaven (including Kangaroo Valley), Hunter Valley and Wollemi National Park have been closely monitored since 1998 (Piggott *et al.* 2006a). Colonies in the Warrumbungle Range have been surveyed many times since 1993 (NPWS 2003), and the Jenolan caves colony has been monitored since 1999 (D. Ashworth pers. comm. 2010). Periodic assessment of populations has been undertaken in south-eastern Queensland since 1999 (DERM unpubl. data 2003). A major advance in population monitoring was the development of DNA analysis of faecal pellets (Piggott *et al.* 2006a, b). These techniques have been used to estimate population size, reproductive success and movements (Piggott *et al.* 2006a, b). The DNA analysis of faecal pellets is being used in combination with trapping and remote cameras at both populations in Victoria to gain important information on movement and survival of individuals (M. Bramwell, pers. comm. 2010). The DNA analysis of faecal pellets is being used in combination with radio tracking and remote cameras at all release sites in NSW (Shoalhaven, Jenolan Caves and Wurrumbungle) to monitor survival, movement and successful breeding (D. Ashworth, pers. comm. 2010).

Predator Control

In NSW, fox control programs to protect the Brush-tailed Rock-wallaby are being conducted at a number of sites including Kangaroo Valley, Warrumbungle National Park, Jenolan Caves Karst Conservation Reserve, Wollemi National Park (Wolgan River, Bulga to Durie, Kandos to Capertee, Baerami and Widden Valley), Yengo National Park (Growee Gulph, Nulla Mountain), Goulburn River National Park and near Attunga in the New England area. In Victoria, fox control is occurring in both East Gippsland and the Grampians.

Competitor control

In Warrumbungle National Park, Jenolan Caves, and Nattai National Park, goats are being controlled in areas where Brush-tailed Rock-wallabies are found. Goat control is also occurring in the core Brush-tailed Rock-wallaby habitat of Oxley Wild Rivers National Park. Goats have not yet invaded all this area but may be expanding their range. Continuing goat control and preventing goat populations from expanding are priorities for the protection of this largest-known Brush-tailed Rock-wallaby population

Captive breeding

Southern ESU: Captive breeding for population supplementation and reintroductions is an important component of the recovery program. In Victoria, 16 animals (6 males, 10 females) from East Gippsland and the lone surviving animal in the Grampians were captured and used to establish a captive population. There have been 127 births in captivity (Andrews *et al.* 2009). The reproductive rate has been increased through the use of cross-fostering, a technique in which the young of the Brush-tailed Rock-wallaby is fostered to the pouch of another wallaby (generally a Yellow-footed Rock-wallaby *Petrogale xanthopus* or Tammar Wallaby *Macropus eugenii*) allowing the Brush-tailed Rock-wallaby female to breed again around 30 days later. There are currently 35 adult animals (19 males, 16 females) in the captive population housed in five captive institutions across south-eastern Australia, at Adelaide Zoo, Dunkeld Pastoral Company, Waite Institute, Tidbinbilla Nature Reserve and Waterfall Springs Wildlife Sanctuary (Andrews *et al.* 2009).

Central ESU: The captive breeding population for the central ESU is currently derived from 19 animals taken from eight colonies from across the distribution of the Central ESU and four animals of ex-Kawau Island origin (New Zealand). Current population size is 45 animals (19 males, 26 females) (D. Ashworth pers. comm. 2010), housed in five captive institutions: Waterfall Springs Wildlife Sanctuary, Taronga Zoo and Western Plains Zoo (Taronga Conservation Society), Currumbin Wildlife Sanctuaryand Blackbutt Reserve.

Reintroduction/translocation

Southern ESU: In November 2005, two captive-bred male Brush-tailed Rock-wallabies were released into a colony in East Gippsland that comprised only two females (Bramwell & O'Neill 2005). Since the release, one female subsequently produced an offspring. This was confirmed to be a wild conception from one of the introduced males through genetic analysis of the offspring (M. Bramwells, pers. comm. 2010). In November 2008, six females and four males were reintroduced into the Grampians National Park, followed by three females and two males in August 2009. Four of the released animals have since died.

Central ESU: Since 2001, there have been nine separate releases of a total of 45 Brush-tailed Rock-wallabies to supplement declining colonies in the Shoalhaven, at Jenolan caves and in Warrumbungle National Park (D. Ashworth pers. comm. 2010). There have been mixed results from these releases and high variability in survival of released wallabies between sites and at the same site through time. However, of animals that have survived, many have established stable home ranges and some are successfully breeding with local resident animals (D. Ashworth pers. comm. 2010).

Genetic research

Rock-wallaby colonies are typically confined to discrete patches of suitable habitat, with limited opportunities for dispersal between them. This has provided a rich field for research into genetic population structuring and its implications for taxonomy and conservation management (e.g. Briscoe *et al.* 1982; Browning *et al.* 2001; Close *et al.* 1994; Eldridge & Close 1992, 1997; Piggott *et al.* 2006a,b; Sharman *et al.* 1990). Multifaceted genetic analyses of the Brush-tailed Rock-wallaby have shown substantial genetic structuring, at multiple levels and geographic scales (Browning *et al.* 2001). Of particular importance from a strategic planning perspective is the identification of three distinct molecular lineages that constitute three separate Evolutionarily Significant Units. This research has provided a basis on which to make judgements about population management for the Brush-tailed Rock-wallaby. The desirability of maintaining the genetic integrity of each of the three ESUs is a central factor in most objectives of this plan.

Strategy for Recovery

The strategy for recovery of the Brush-tailed Rock-wallaby will concentrate on the identification and management of threats to the species. Of particular importance from a strategic planning perspective is the recognition of three separate ESUs: Northern, Central and Southern. The desirability of maintaining the genetic integrity of each ESU is a central factor of this plan, with the conservation of the species being addressed by treating the three ESUs as separate management units. Identification of ESU boundaries for conservation management is an important objective in this recovery program. Captive populations for the Southern and Central ESUs will be maintained (and the need for a captive breeding program for the Northern ESU assessed), to provide animals to supplement and build existing colonies, and for reintroductions to establish new colonies. For the Southern ESU, successful captive management is essential to guard against extinction (Waldegrave-Knight 2002; Waldegrave-Knight & Stephens 2003). For the Central ESU captive breeding and translocation are highlighted as likely strategies for re-establishment of populations at sites where the species has declined or become extinct (DECC 2008). Further research into key aspects of biology and ecology will assist conservation management, and additional community and stakeholder support for conservation efforts will be sought.

Recovery Objectives

The Specific Objectives for recovery of the Brush-tailed Rock-wallaby are to:

1. Determine and manage threats to the Brush-tailed Rock-wallaby and its habitat.
2. Determine distribution, abundance, population trends and viability for the Brush-tailed Rock-wallaby.
3. Establish and maintain separate, viable captive populations derived from the Southern and Central ESUs.
4. Undertake translocations to improve the genetic and demographic robustness of populations and to establish new colonies of Brush-tailed Rock-wallabies.

5. Investigate key aspects of Brush-tailed Rock-wallaby biology and ecology for conservation management.
6. Increase community awareness and support for Brush-tailed Rock-wallaby conservation.

Program Implementation and Evaluation

This Recovery Plan guides recovery actions for the Brush-tailed Rock-wallaby. Potential contributors to implement actions are included in this document: they include relevant state nature conservation agencies, educational institutions, regional natural resource management authorities and community groups (subject to availability of appropriate resources). In New South Wales and Victoria, implementation of state plans is facilitated and coordinated by state recovery teams. The desirability of formalising a national Recovery Team will be explored. Technical, scientific, habitat management or education components of the Recovery Plan will be referred to specialist groups as required. Contact will be maintained between the state/territory agencies on recovery issues concerning the species. The Recovery Plan will be reviewed by responsible agencies within five years of the date of its adoption under the EPBC Act, and revised if required.

Recovery Actions

A summary of recovery objectives, performance criteria and actions is provided in Table 2. Details of each recovery action are described in Appendix 1.

Implementation Cost

The estimated cost of implementing the national recovery plan is $14.9 million over five years.

Year 1	Year 2	Year 3	Year 4	Year 5	Total Cost
1	2	3	4	5	0

Table 2: Summary of Recovery Objectives, Performance Criteria and Actions

OBJECTIVES	PERFORMANCE CRITERIA	ACTIONS
1. Determine and manage threats to the Brush-tailed Rock-wallaby and its habitat.	There is no further loss of isolated colonies of Brush-tailed Rock-wallabies and there is an increase in the numbers of animals in target populations where threat abatement occurs.	1.1 Identify priority populations in the Central and Northern ESUs for management attention. 1.2 Develop and implement threat abatement programs for priority sites identified in Action 1.1. 1.3 Assess the relative efficiency and effectiveness of feral predator control strategies relevant to Brush-tailed Rock-wallaby conservation. 1.4 Maintain or initiate predator control programs at key population sites. 1.5 Monitor numbers of feral predators at both controlled and uncontrolled sites to determine the effectiveness of control programs and impact of feral predators 1.6 Maintain or initiate competitor control programs at key populations where required. 1.7 Encourage and support predator and competitor control activities on private land with or adjoining key populations.
2. Determine distribution, abundance, population trends and viability for the Brush-tailed Rock-wallaby.	Comprehensive surveys for Brush-tailed Rock-wallaby across its range are developed and undertaken, representative sites across the range of the species are monitored annually, population viability analysis of selected populations have been conducted and the results used for conservation management of the Brush-tailed Rock-wallaby.	2.1 Develop standardised survey techniques for determining presence/absence. 2.2 Conduct a comprehensive survey of Brush-tailed Rock-wallaby distribution within the Central and Northern ESUs. 2.3 Develop a predictive model of colony distribution for each ESU. 2.4 Develop standardised population monitoring techniques. 2.5 Conduct annual monitoring of Brush-tailed Rock-wallabies at key population sites. 2.6 Produce a Population/Habitat Viability model for the Brush-tailed Rock-wallaby and undertake population viability analyses of key/vulnerable populations. 2.7 Undertake molecular analysis of Brush-tailed Rock-wallaby colonies to identify the boundaries of ESUs. 2.8 Identify important populations of the Brush-tailed Rock-wallaby across its total range.
3. Establish and maintain separate, viable captive populations derived from the Southern and Central ESUs.	Captive populations for the S-ESU and C-ESU are successfully breeding, maintaining gene diversity above 90% of that currently in the wild population, and each producing offspring for reintroduction/supplementation.	3.1 Prepare a management plan for the S-ESU and C-ESU captive populations. 3.2 Revise the captive husbandry manual for the Brush-tailed Rock-wallaby. 3.3 Maintain separate captive populations for S-ESU and C-ESU to the level of ZAA Category 1 species. 3.4 Implement the use of cross-fostering of pouch young to increase breeding productivity of the S-ESU captive population. 3.5 Assess the need for a captive breeding population for the Northern ESU.

4. Undertake translocations to improve the genetic and demographic robustness of populations and establish new colonies of Brush-tailed Rock-wallabies.	At least one reintroduction and one population re-enforcement are initiated.	4.1 Prepare a population management plan for the remaining Southern ESU colonies. 4.2 Prepare a genetic enhancement strategy for key populations in the Northern and Central ESUs. 4.3 Prepare and implement a translocation strategy for the S-ESU and C-ESU.
5. Investigate key aspects of Brush-tailed Rock-wallaby biology and ecology for conservation management.	Key elements of the life history of the Brush-tailed Rock-wallaby are determined and incorporated into conservation management of the species.	5.1 Determine the effects of predation on populations. 5.2 Investigate the response of the species to different fire regimes and establish appropriate fire regimes for conservation management of the species and its habitat. 5.3 Determine habitat that is critical to survival of the Brush-tailed Rock-wallaby across its range. 5.4 Conduct dietary studies to determine seasonal preferences and potential for competition. 5.5 Investigate dispersal patterns of the Brush-tailed Rock-wallaby.
6. Increase community awareness and support for Brush-tailed Rock-wallaby conservation.	There is increased community involvement in reporting of sightings, population monitoring and predator/competitor control.	6.1 Expand Brush-tailed Rock-wallaby support groups. 6.2 Facilitate community involvement in the recovery program. 6.3 Provide species and habitat management advice to landholders. 6.4 Publicise results of recovery to the community.

Management Practices

Management practices necessary to avoid further significant adverse impact on the Brush-tailed Rock-wallaby include:

- Policies and processes to avoid further clearing or fragmentation of habitat.
- Landscape-scale predator control.
- Controlling potential competitors (both introduced and native) with Brush-tailed Rock-wallaby for food and shelter.

Any developments that are likely to exacerbate any of these issues will need to be carefully assessed. This would include:

- Wild dog/dingo control programs that resulted in greater populations of foxes or cats in areas surrounding rock-wallaby colonies.
- Habitat disturbance within several kilometres of a rock wallaby site that could result in increased access by foxes.
- Increased population densities of sheep, goats or other macropods in areas where rock-wallabies forage.
- Reduction in control of introduced herbivores adjacent to rock-wallaby colonies.

Biodiversity Benefits

The Brush-tailed Rock-wallaby has been the focus of a great deal of research and development into facets of threatened species recovery. In particular, research on this species has greatly enhanced understanding of the relevance of genetic population structuring, and genetic bottlenecks, to population management of other declining threatened species. Further, assisted reproduction techniques aimed at increasing the rate of reproduction in marsupials have been pioneered on this species, as has the use of DNA extracted from faecal pellets to monitor populations. This work has already had major benefits for other threatened species recovery efforts and these benefits will continue to accrue. Predator control will also benefit other threatened mammals such as the Long-nosed Potoroo (*Potorous tridactylis*) (EPBC-Vulnerable) and Southern Brown Bandicoot (*Isoodon obesulus*) (EPBC-Vulnerable) that may occur with Brush-tailed Rock-wallabies. The species has potential to become a flagship species for improved management of rocky escarpment and gorge country throughout its range, and it has become a high-profile threatened species in the south of its range, where it is most at risk.

Affected Interests

The actions in this Recovery Plan will require close collaboration among land managers whose land contains rock-wallaby habitat, or is close to rock-wallaby habitat. This includes both Government land management agencies (primarily national park and state forest managers) and freehold land owners. In the Central and Northern ESUs, a significant proportion of rock-wallaby colonies occur on freehold land and their conservation will require cooperation from land owners. The captive management and release component of the plan will require considerable input from contributing zoos and wildlife parks, under the auspices of Zoo and Aquarium Association. Organisations with an interest in the recovery program for the Brush-tailed Rock-wallaby include:

- Department of Sustainability and Environment, Victoria
- Parks Victoria
- Department of Environment, Climate Change and Water, New South Wales
- Department of Environment and Resource Management, Queensland
- Parks, Conservation and Lands, Australian Capital Territory
- Adelaide Zoo
- Dunkeld Pastoral Co
- Halls Gap Zoo
- Waite Institute
- Tidbinbilla Nature Reserve
- Waterfall Springs
- Taronga Conservation Society Australia

- Currumbin Wildlife Sanctuary
- Zoo and Aquarium Association
- Friends of the Brush-tailed Rock-wallaby

Role and Interests of Indigenous People

Comprehensive consultation with Indigenous people across the range of the Brush-tailed Rock-wallaby has not yet occurred, although there has been local consultation in some areas. For some Brush-tailed Rock-wallaby populations occurring in parks and reserves, consultation with Indigenous people has been addressed through the relevant park or land management processes. The extent of involvement of Indigenous people varies between regions, from occasional consultation to continuous co-management. An Indigenous Land Use Agreement (ILUA) between the Githabul People and the NSW Government covers in north-eastern NSW covers several parks and state forests where the species occurs. In Victoria, the Grampians (Gariwerd) National Park (where the species has been reintroduced) is co-managed with the Barengi Gadjin Land Council, Gunditj Mirring Traditional Owners Aboriginal Corporation and Djab Wurrung (Martang Pty Ltd), who have been consulted and involved with recovery of the species.

Social and Economic Impacts

Social and economic impacts resulting from implementation of this recovery plan are expected to be low. However, there may be isolated negative impacts in some areas, through foregone development opportunities, for landowners with rock-wallaby colonies on their property or adjacent to it. Economic benefits to farmers are possible due to increased lamb survival through broad scale predator control on and around property. In some instances, particularly in the Northern ESU, the presence of rock-wallaby colonies may influence the placement of infrastructure such as roads and dams. In Victoria all known active rock-wallaby sites are in Crown land conservation reserves, as are all former sites in the ACT. In NSW and Queensland, over 25% of rock-wallaby sites occur on freehold land, and many sites on public land are on the edge of escarpments and close to freehold land. Therefore, even for public land sites, it is often vital for neighbouring landholders to be generally supportive of recovery actions, and to be directly involved in control programs for predators or competitors. Introduced predator control activities associated with protection of rock-wallaby colonies will require collaboration and contributions from neighbouring landholders, but should benefit neighbouring farms by reducing livestock losses from dogs/dingoes and foxes.

Acknowledgements

The authors would like to thank the following people who provide information for and/or comment on the recovery plan: Mick Bramwell and Dr Natasha McLean (Dept. Environment & Sustainability Vic), Dr Murray Evans and David Dobroszczyk (Parks, Conservation & Lands ACT), Dr Geoff Lundie-Jenkins (Dept. Environment & Resource Management, Qld), Dr Deborah Ashworth, Dr Todd Soderquist, Shane Ruming, Mel Norton and Suzanne O'Neil (Dept. Environment, Climate Change & Water, NSW), Professor Peter Jarman (University of New England), Dr Mark Eldridge (Macquarie University), Alison Colyer (Threatened Species Network, WWF), Stephanie Hazlitt (University of Queensland) and Caroline Lees (ARAZPA). Maris Ozolins from Environmental Resources Information Network, Department of Environment and Heritage, kindly prepared the distribution map.

References

ARAZPA 2005. ASMP Captive management plan for Brush-tailed Rock-wallaby *Petrogale penicillata* (Central ESU). Australasian Regional Association of Zoological Parks and Aqauria, Sydney.

Andrews, L., Schulz, D. and Taggart, D. 2009. Victorian Brush-tailed Rock-wallaby *Petrogale penicillata penicillata* Captive Management Plan. Unpublished report.

Ashworth, D. 2010. Personal communication. Department of Environment and Conservation, New South Wales.

Bayne, P. 1994. Behaviour of the Brush-tailed Rock-wallaby, *Petrogale penicillata*, and the recognition of individuals. Master of Natural Resources Thesis. University of New England, Armidale.

Bayne, P. 1994. Unpublished data. University of New England, Armidale, New South Wales.

Bowyer, J.C., Newell, G.R. and Eldridge, M.D.B. 2002. Genetic effects of habitat contraction on Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) in the Australian Wet Tropics. *Conservation Genetics* 3: 61–69.

Bramwell, M. D. 2010. Personal communication. Department of Sustainability and Environment, Bairnsdale, Victoria.

Bramwell, M.D., Andrews, L., Brook, L., Corrigan, T., Stevens, M., Schultz, D. and Taggart, D. 2008. Reintroduction plan for the release of Brush-tailed Rock-wallabies (*Petrogale penicillata*) into Moora Moora Creek, Grampians National Park, Victoria. Department of Sustainability and Environment, Bairnsdale, Victoria.

Bramwell, M.D. and O'Neill J. 2005. Supplementation proposal for the release of two male Brush-tailed Rock-wallabies (*Petrogale penicillata*) into the Farm Creek Colony, East Gippsland, Victoria. Department of Sustainability and Environment, Bairnsdale, Victoria.

Briscoe, D. A., Calaby, J.H., Close, R.L., Maynes, G.M., Murtagh, G.M. and Sharman, G.B. 1982. Isolation, introgression and genetic variation in rock-wallabies. Pp. 73–87 in *Species at Risk: Research in Australia*. ed. by R.H. Groves and W.D.L. Ride. Australian Academy of Science, Canberra.

Browning, T.L., Taggart, D.A., Rummery, C., Close, R.L. and Eldridge. M.D.B. 2001. Multifaceted genetic analysis of the 'Critically Endangered' Brush-tailed Rock-wallaby in Victoria, Australia: implications for management. *Conservation Genetics* 2: 145–156.

Capararo, S. 1998. A survey of the Brush-tailed Rock-wallaby (*Petrogale penicillata*) in Queensland. Queensland Department of Environment, Brisbane.

Carter, K. and Goldizen, A.W. 2003. Habitat choice and vigilance behaviour of Brush-tailed Rock-wallabies (*Petrogale penicillata*) within their nocturnal foraging ranges. *Wildlife Research* 30: 355–364.

Catling, P.C. and Burt, R.J. 1995. Why are red foxes absent from some eucalypt forests in eastern New South Wales? *Wildlife Research* 22: 535–545.

Charlesworth, A. and Charlesworth, R. 1987. Inbreeding depression and its evolutionary consequences. *Annual Review of Ecology and Systematics* 18: 237–268.

Close, R.L., Ingleby, S., van Oorschot, R.A.H., Gooley, A.A., Briscoe, D.A. and Sharman, G.B. 1988. Identification of Rock-wallabies *Petrogale penicillata* (Gray 1825), from the Grampians, Victoria, and comparison with conspecifics by examination of chromosomes, blood proteins, cell surface antigens, parasites and morphology. *Australian Journal of Zoology* 36: 99–110.

Close, R.L., Eldridge, M.D.B., Bell, J.N. and Reside, J. 1994. A genetic study of the Brush-tailed Rock-wallaby *Petrogale penicillata* in East Gippsland and relevance for management of the species in Victoria. *Pacific Conservation Biology* 1: 367–371.

DECC 2008. Approved NSW Recovery Plan for the Brush-tailed Rock-wallaby *Petrogale penicillata*. Department of Environment and Climate Change, New South Wales, Sydney.

DEH 2000. *Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the Development of Version 5.1. - Summary Report*. Department of the Environment and Heritage, Canberra.

DERM 2003. Unpublished data. Department of Environment and Resource Management, Queensland.

Delaney, R., Temple-Smith, P. and McLean, N. 2004. Report on the potential translocation of Brush-tailed Rock-wallabies in Victoria. Envirosense Consulting and Department of Sustainability and Environment, Melbourne.

Delaney, R., Temple-Smith, P. and McLean, N. 2005. Translocation strategy for the brush-tailed rock wallaby in Victoria. EnviroSense Consulting and Department of Sustainability and Environment, Melbourne.

Dempster, J.K. 1962. What's to be done for Rock-wallaby? *Fur, Feathers and Fins* 46: 3–8.

Dobroszczyk, D. 2007. Husbandry manual for the Brush-tailed Rock-wallaby, *Petrogale penicillata*. Healesville Sanctuary, Victoria.

Dovey, L., Wong, V. and Bayne, P. 1997. An overview of the status and management of rock-wallabies (*Petrogale*) in New South Wales. *Australian Mammalogy* 19: 113–122.

DSE 2008. Brush-tailed Rock-wallaby: East Gippsland Field Management Strategy. Department of Sustainability and Environment, Bairnsdale, Victoria.

EACT 1999. Brush-tailed Rock-wallaby (*Petrogale penicillata*): An endangered species. Action Plan No. 22. Environment ACT, Canberra.

Elridge, M. D. B. and Browning, T. L. 2004. Genetic analysis of Brush-tailed Rock-wallabies in Woko National Park. Unpublished report to the New South Wales Department of Environment and Sustainability, Hursteville.

Eldridge, M.D.B. and Browning, T.L. 2002. Molecular genetic analysis of the naturalised Hawaiian population of the Brush-tailed Rock-wallaby, *Petrogale penicillata* (Marsupialia: Macropodidae). *Journal of Mammalogy* 83: 437–444.

Eldridge, M.D.B., Browning, T.L. and Close, R.L. 2001. Provenance of a New Zealand Brush-tailed Rock-wallaby (*Petrogale penicillata*) population determined by mitochondrial DNA sequence analysis. *Molecular Ecology* 10: 2561–2567.

Eldridge, M.D.B. and Close, R.L. 1992. Taxonomy of Rock Wallabies, *Petrogale* (Marsupialia, Macropodidae).1. A Revision of the Eastern Petrogale With the Description of 3 New Species. *Australian Journal of Zoology* 40: 605–625.

Eldridge, M.D.B. and Close, R.L. 1995. Brush-tailed Rock-wallaby *Petrogale penicillata*. Pp. 383–384 in *The Mammals of Australia* ed. by R. Strahan. Australian Museum/Reed Books, Sydney.

Eldridge, M.D.B. and Close, R.L. 1997. Chromosomes and evolution in rock-wallabies, *Petrogale*. *Australian Mammalogy* 19: 123–136.

Eldridge, M.D.B., Rummery, C., Bray, C., Zenger, K.R., Browning, T.L. and Close, R.L. 2004. Genetic analysis of a population crash in Brush-tailed Rock-wallabies (*Petrogale penicillata*) from Jenolan Caves, south-eastern Australia. *Wildlife Research* 31: 229–240.

Ferreira, A. and Amos, N. 2006. Inbreeding depression and multiple regions showing heterozygote advantage in *Drosophila melanogastor* exposed to stress. *Molecular Ecology* 15: 3885–3893.

Fleming, P.J.S. 2000. Brush-tailed Rock-wallaby, *Petrogale penicillata* (Marsupialia: Macropodidae), observed feeing on fallen *Acacia* inflorescences. *Australian Mammalogy* 22: 63.

Goldizen, A. 2005. Unpublished data. University of Queensland, Brisbane, Queensland.

Hazlitt. S.L. 2006. Personal communication. University of Queentland, Brisbane, Queensland.

Hazlitt, S.L., Eldridge, M.D.B. and Goldizen A.W. 2004. Fine-scale spatial genetic correlation analyses reveal strong female philopatry within a Brush-tailed Rock-wallaby colony in southeast Queensland. *Molecular Ecology* 13: 3621–3632.

Hazlitt, S.L., Eldridge, M.D.B., and Goldizen, A.W. 2006a. Significant patterns of population genetic structure and limited gene flow in a threatened macropodid marsupial despite continuous habitat in southeast Queensland, Australia. *Conservation Genetics* 7: 675–689.

Hazlitt, S.L., Sigg, D.P. Eldridge, M.D.B., and Goldizen, A.W. 2006b. Restricted mating dispersal and strong breeding group structure in a mid-sized marsupial mammal. *Molecular Ecology*. 15: 2997–3007.

Hazlitt, S.L., Eldridge, M.D.B. and Goldizen, A.W. 2010. Strong matrilineal structuring in the brush-tailed rock-wallaby confirmed by spatial patterns of mitochondrial DNA. Pp. 87–95 in *Macropods: the biology of kangaroos, wallabies and rat-kangaroos*. Ed. by G. Coulson and M.D.B. Eldridge. CSIRO Publishing, Melbourne.

Hill, F.A.R. 1991. A research recovery plan for the Brush-tailed Rock-wallaby *Petrogale penicillata* (Grey 1825), in south-eastern Australia. Report to Australian National parks and Wildlife Service, Canberra.

Hill, R. and Baker-Gabb, D. 1991. Flora and Fauna Guarantee Action Statement Number 19: Brush-tailed Rock-wallaby *Petrogale penicillata*. Department of Sustainability and Environment, East Melbourne.

Jarman, P. J. 2005. Personal observation. University of New England, Armidale, New South Wales.

Jarman, P.J. and Bayne, P. 1997. Behavioural ecology of *Petrogale penicillata* in relation to conservation. *Australian Mammalogy* 19: 219–228.

Jarman, P.J. and Phillips, C.M. 1989. Diets in a community of macropod species. Pp. 143-149 in *Kangaroos, Wallabies and Rat-kangaroos*. Ed. by G. Grigg, P. Jarman and I. Hume. Surrey Beatty and Sons, Chipping Norton.

Joblin, K.P.W. 1983. Behaviour and ecology of the Brush-tailed Rock-wallaby, *Petrogale penicillata*, in the New England Region. Department of Ecosystem Management, University of New England, Armidale.

Laws, R.J. and Goldizen A.W. 2003. Nocturnal home ranges and social interactions of the Brush-tailed Rock-wallaby *Petrogale penicillata* at Hurdle Creek, Queensland. *Australian Mammalogy* 25: 169–176.

Lazell, J.D., Sutterfield, T.W. and Giezentanner, W.D. 1984. The population of rock wallabies (genus *Petrogale*) on Oahu, Hawaii. *Biological Conservation* 30: 99–108.

Lee, A.K. and Ward, S. 1989. Life histories of macropoid marsupials. Pp. 105-115 in *Kangaroos, Wallabies and Rat-kangaroos*. Ed. by G. Grigg, P. Jarman and I. Hume. Surrey Beatty and Sons, Chipping Norton.

Lobert, B. and Waters, R. 1988. The brush-tailed rock-wallaby (*Petrogale penicillata*) in the Grampians National Park and the Black Range, Victoria. Part 1 - Survey. Arthur Rylah Institute of Environmental

Research Technical Report Series No. 64. Department of Conservation, Forests and Lands, Heidelberg.

Menkhorst, P.W. 1995. Brush-tailed Rock-wallaby species account. Pp. 149–151 in *Mammals of Victoria: Distribution, Ecology and Conservation*. ed. by P.W. Menkhorst. Oxford University Press, Melbourne.

Moritz, C. 1994. Defining `Evolutionarily Significant Units' for conservation. *Trends in Ecology and Evolution* 9: 373–375.

Moss, G.L., Miller, A., Taylor, D. and Gracie, J. 1999. The Brush-tailed Rock-wallaby (*Petrogale penicillata*) in the Warrumbungles: colony status based upon scat abundance. Unpublished report to the NSW National Parks and Wildlife Service.

Moss, G.L., Taylor, D. and Miller, A. 1997*.* Implementation of a monitoring program for the Brush-tailed Rock-wallaby at the Warrumbungle National Park. Unpublished report to the NSW National Parks and Wildlife Service.

Murray, J. 2002. Analysis and habitat modelling of the Brush-tailed Rock-wallaby (*Petrogale penicillata*) in southeast Queensland. Bachelor of Applied Science (Hons) thesis. University of Queensland, Brisbane.

Murray, J. 2009. Spatial modelling for the conservation of threatened species: distributions, habitats and landscape connectivity of the brush-tailed rock-wallaby (*Petrogale penicillata*). PhD Thesis. University of Queensland, Brisbane.

Norris, K.C. and Belcher, C.A. 1986. *The Brush-tailed Rock-wallaby in Gippsland, 1986*. Report to Department of Conservation, Forests and Lands, Bairnsdale, Victoria.

Norton, M. 2010. Personal communication. Department of Environment and Conservation, New South Wales.

NPWS 2003. Warrumbungle Brush-tailed Rock-wallaby Endangered Population Recovery Plan. NSW National Parks and Wildlife Service, Hurstville.

Paplinska, J. Z., Corrigan, T., Austin, J. J., Eldridge, M. D. B. and Taggard, D. A. In press. Using DNA from museum specimens to preserve the integrity of Evolutionarily Significant Unit boundaries in threatened species. Corresponding author Dr. Justyna Paplinska, The University of Melbourne, Victoria.

Piggott, M.P., Banks, S.C., Stone, N., Banffy, C. and Taylor, A.C. 2006a. Estimating population size of endangered Brush-tailed Rock-wallaby (*Petrogale penicillata*) colonies using faecal DNA. *Molecular Ecology* 15: 81–91.

Piggott, M.P., Banks, S.C and Taylor, A.C. 2006b. Population structure of Brush-tailed Rock-wallaby (*Petrogale penicillata*) colonies inferred from analysis of faecal DNA. *Molecular Ecology* 15: 93–105.

Reside, J. and Martin, R. 1997. The status of the Brush-tailed Rock-wallaby *Petrogale penicillata* in the Australian Alps National Parks. Department of Conservation and Environment, Bairnsdale.

Risbey, D.A., Calver, M.C., Short, J. Bradley, J.S. and Wright, I.W. 2000. The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* 27: 223–235.

Sharman, G.B., Close, R.L. and Maynes, G.M. 1990. Chromosome evolution, phylogeny and speciation of Rock-wallabies (*Petrogale*, Macropodidae). *Australian Journal of Zoology* 37: 351–363.

Short, J. 1980. Ecology of the Brush-tailed Rock-wallaby (*Petrogale penicillata* Griffith, Smith and Pidgeon). Master of Science Thesis. University of Sydney, Sydney.

Short, J. 1982. Habitat Requirements of the Brush-Tailed Rock-wallaby, *Petrogale penicillata*, in New South Wales. *Wildlife Research* 9: 239–246.

Short, J. 1989. The Diet of the Brush-tailed Rock-wallaby in New-South-Wales. *Wildlife Research* 16: 11–18.

Short, J. and Milkovits, G. 1990. Distribution and status of the Brush-tailed Rock-wallaby in South-eastern Australia. *Wildlife Research* 17: 169–179.

Spencer, P.B.S. 1991. Evidence of predation by a feral cat, *Felis catus* (Carnivora: Felidae) on an isolated rock-wallaby population in tropical Queensland. *Australian Mammalogy* 14: 143–144.

Taggart, D., Clausen, L., Stevens, M., Bramwell M. and Corrigan, T. 2008. *Brush-tailed Rock-wallaby reintroduction site assessment guide for the Grampian National Park, Victoria*. Department of Sustainability and Environment, Bairnsdale.

Wakefield, N.A. 1971. The Brush-tailed Rock-wallaby, *Petrogale penicillata* in western Victoria. *Victorian Naturalist* 88: 92–102.

Waldegrave-Knight, L. 2002. History, habitat and management: Consideration in the selection of reintroduction and translocation sites for the Brush-tailed Rock-wallaby *Petrogale penicillata*, in East Gippsland, Victoria. Master of Science Thesis. Department of Zoology, University of Melbourne, Melbourne.

Waldegrave-Knight, L., and Cunningham, C. 1999. *Brush-tailed Rock-wallaby and Spot-tailed Quoll Survey 1998/9*. Mid Gippsland Regional Forest Agreement. East Gippsland Flora and Fauna Group Report No. 4. Department of Natural Resources and Environment, Bairnsdale.

Waldegrave-Knight, L. and Stevens, J. 2003. Brush-tailed Rock-wallaby field management strategy. Department of Sustainability and Environment, Bairnsdale.

Warburton, B.W. and Sadlier, R.M.F. 1995. Brush-tailed Rock-wallaby. Pp. 58–64 in *The Handbook of New Zealand Mammals*. Ed. by C. King. Oxford University Press, Auckland.

Wong, V., Law, B., Rummery, C., Dovey, L. and Lunney, D. 1994. Brush-tailed Rock-wallaby (*Petrogale penicillata*) research recovery plan implementation. Report to Australian Nature Conservation Agency, Canberra.

Wynd, N.M., Sigg, D.P., Pople, A.R., Hazlitt, S.L. and Goldizen, A.W. 2006. Factors affecting female reproductive success and the survival of pouch young in the threatened Brush-tailed Rock-wallaby, *Petrogale penicillata*. *Australian Journal of Zoology* 54: 61–7.

Implementation Costs and Schedule

	Action	Priority	Potential Contributors	Cost Estimate ($) Year 1	Year 2	Year 3	Year 4	Year 5	Total
1	*Control known threats*								
1.1	Identify priority populations	1	DECCW, NSW Rec Team, DERM	$20,000	$20,000	$20,000	$0	$0	$40,000
1.2	Implement threat abatement	1	DECCW, DERM	$250,000	$250,000	$250,000	$250,000	$250,000	$1,250,000
1.3	Assess predator control	1	DECCW FNSW DSE	$150,000	$150,000	$150,000	$150,000	$150,000	$750,000
1.4	Control predators	1	DECCW, DERM, DSE, PV	$1,250,000	$1,250,000	$1,250,000	$1,250,000	$1,250,000	$6,250,000
1.5	Monitor predator numbers	2	DECCW, DERM, DSE, PV	$250,000	$250,000	$250,000	$250,000	$250,000	$1,250,000
1.6	Control competitors	2	DECCW, DERM	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
1.7	Support community threat control	2	DECCW, DERM, DSE, PV	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
2	*Determine distribution, abundance*								
2.1	Develop survey techniques	2	DECCW, DERM, DSE, research institutions	$25,000	$0	$0	$0	$0	$25,000
2.2	Conduct surveys	2	DECCW, DERM, research institutions	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
2.3	Develop predictive model	3	DECCW, DERM, DSE, research institutions	$0	$0	$50,000	$50,000	$0	$100,000
2.4	Develop population monitoring	1	DECCW, DERM, DSE, research institutions	$25,000	$0	$0	$0	$0	$25,000
2.5	Conduct monitoring	1	DECCW, DERM, DSE, PV	$200,000	$200,000	$200,000	$200,000	$200,000	$1,000,000
2.6	Produce PHVA model	2	DECCW, DERM, DSE, PV	$0	$0	$0	$50,000	$0	$50,000
2.7	Undertake molecular analysis	2	DECCW, DERM, research institutions	$0	$0	$50,000	$50,000	$0	$100,000
2.8	Identify important populations	1	DECCW, DERM, DSE, PV	$0	$0	$0	$0	$25,000	$25,000
3	*Establish captive populations*								
3.1	Prepare captive mgt plans	2	ZAA, zoos/wildife parks	$20,000	$0	$0	$0	$0	$20,000
3.2	Revise husbandry manual	2	ZAA, zoos/wildife parks	$10,000	$0	$0	$0	$0	$10,000
3.3	Maintain ESU captive populations	2	zoos/wildife parks, ZAA, DECCW, DSE	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
3.4	Use pouch cross-fostering	2	zoos/wildife parks, ZAA	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
4	*Undertake translocations*								
4.1	Prepare S-ESU mgt plan	3	DSE	$20,000	$0	$0	$0	$0	$20,000
4.2	Prepare enhancement strategy	2	DECCW	$20,000	$0	$0	$0	$0	$20,000
4.3	Implement translocation strategy	2	DECCW, DSE, PCL	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
5	*Investigate biology, ecology*								
5.1	Determine predation impact	1	DECCW, DERM, DSE, PV	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
5.2	Investigate fire regimes	2	DECCW, DERM, DSE, research institutions	$0	$0	$100,000	$100,000	$100,000	$300,000
5.3	Determine critical habitat	2	DECCW, DERM, DSE	$0	$0	$50,000	$50,000	$50,000	$150,000
5.4	Conduct dietary studies	3	DECCW, DERM, DSE, research institutions	$0	$0	$50,000	$50,000	$50,000	$150,000
5.5	Investigate dispersal	3	DECCW, DERM, DSE, research institutions	$0	$0	$100,000	$100,000	$100,000	$300,000
6	*Increase community awareness*								
6.1	Establish support groups	2	DECCW, DERM, DSE, PV	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
6.2	Facilitate community involvement	3	DECCW, DERM, DSE, PV	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
6.3	Provide mgt advice	2	DECCW, DERM, DSE, PV	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
6.4	Publicise results	3	DECCW, DERM, DSE	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
			Total Cost	$17,000.00	$17,000.00	$17,000.00	$17,000.00	$17,000.00	$85,000.00

Abbreviations: DECCW=Dept. Environment, Climate Change & Water (NSW); DERM=Dept. Environment & Resource Mgt (Qld); DSE=Dept. Sustainability & Environment (Vic); PV=Parks Victoria

Appendix 1. Detail of Recovery Actions

Objective 1 Determine and manage threats to the Brush-tailed Rock-wallaby and its habitat.

Performance Criterion: There is no further loss of isolated colonies of Brush-tailed Rock-wallabies and there is an increase in the numbers of animals in target populations where threat abatement occurs.

<u>Action 1.1</u> Identify priority populations in the Central and Northern ESUs for management attention.

An assessment of threats acting on sub-populations across the Central and Northern ESUs, and current management responses to those threats, will be undertaken to allow prioritisation of management needs, including outlying populations on the inland side of the species range. This information will be used to select sub-populations with the greatest potential to respond to management and to provide the greatest benefit to the conservation of the species.

Potential Contributors: DECCW (NSW), NSW recovery team, DERM (Qld)

<u>Action 1.2</u> Develop and implement threat abatement programs for priority sites identified in Action 1.1.

Although several likely threatening processes have been documented in management plans for the Brush-tailed Rock-wallaby, they are mostly based on conjecture, and evidence of their actual impact on populations is scant. If management actions can be designed to include hypothesis testing, via comparisons between different treatments and careful monitoring of outcomes, the relative importance of different threatening processes could be clarified. This information can then inform future recovery plans and priorities. An adaptive experimental management approach to management of Brush-tailed Rock-wallaby populations and their habitat will be used, so that the relative significance of different threats can be elucidated.

Potential Contributors: DECCW (NSW), DERM (Qld)

<u>Action 1.3</u> Assess the relative efficiency and effectiveness of feral predator control strategies relevant to Brush-tailed Rock-wallaby conservation.

Although there is some predation on the Brush-tailed Rock-wallaby from native predators, the added predation pressure imposed by introduced predators is recognised as a key threatening process (Hill 1991; ACT 1999; Waldegrave-Knight & Henry 2003; DECC 2008). Feral predator control has been used as a tool for many years to conserve threatened species and populations across several states, and there is a considerable body of experience from a range of control programs. There is a need to review the range of predator control strategies used by state agencies, especially broad-scale versus intensive localised baiting, to determine the most efficient and effective methods for sustained control of feral predators. The range of control strategies, such as broad-scale baiting used in East Gippsland (Waldegrave-Knight & Stevens 2003) will be reviewed, and a recommended program aimed specifically at assisting the recovery of the Brush-tailed Rock-wallaby will be developed.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

<u>Action 1.4</u> Maintain or initiate predator control programs at key population sites.

Using the results of Action 2.1, and adopting an adaptive experimental management approach, feral predator control programs aimed at reducing Red Fox, wild Dog and feral Cat numbers will be implemented at key sites across the range of the Brush-tailed Rock-wallaby. The aim of these programs will be to reduce predation to levels that do not significantly constrain population growth or dispersal between colonies, and that will allow colonies to expand to include refuge habitat that was unsuitable in the presence of introduced predators. Care will be necessary to ensure that predator baiting programs do not adversely affect populations of non-target species, particularly the Spotted-tailed Quoll. A potentially detrimental affect of wild Dog/Dingo control is the possible subsequent increase in numbers of Red Fox and Cat (through reduction of Dog/Dingo numbers), and this will require close monitoring of the results, and an adaptive approach by the land managers.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

Action 1.5 Monitor numbers of feral predators at both controlled and uncontrolled sites to determine the effectiveness of control programs and impact of feral predators.

The effectiveness of control programs in reducing fox and wild Dog numbers will be monitored. There is also evidence from Western Australia that the numbers of feral Cats can increase following fox control programs and that Cat predation can constrain population growth rates of the Brush-tailed Rock-wallaby (Short *et al.* 1992). Therefore, there is a need to monitor changes in Cat populations in areas where fox and Dog baiting is occurring, with a view to undertaking Cat control if required. Monitoring of rock-wallaby numbers will occur under Objective 3.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

Action 1.6 Maintain or initiate competitor control programs around key populations where required.

Competitor control programs at key sites will be maintained or initiated where competition is deemed to be a threat.

Potential Contributors: DECCW (NSW), DERM (Qld)

Action 1.7 Encourage and support predator and competitor control activities on private land with or adjoining key populations.

Building on Action 2.2, appropriate community groups and individuals will be engaged to provide a broader, more robust, community-wide support base for predator control programs on freehold land around key rock-wallaby sites.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

Specific Objective 2 Determine distribution, abundance, population trends and viability for the Brush-tailed Rock-wallaby.

Performance Criterion: Comprehensive surveys for Brush-tailed Rock-wallaby across its range are developed and undertaken, representative sites across the range of the species are monitored annually, population viability analysis of selected populations have been conducted and the results used for conservation management of the Brush-tailed Rock-wallaby.

Action 2.1 Develop standardised survey techniques for determining presence/absence.

Determining the presence of the Brush-tailed Rock-wallaby at a given site can be difficult, so there is a need for guidelines that define survey methods and effort required to be reasonably confident that the search outcomes reflect reality. Standardised survey techniques will be developed for application across the species' range, and guidelines will also be set for defining the process of reporting and curating survey results.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), research institutions

Action 2.2 Conduct a comprehensive survey of Brush-tailed Rock-wallaby distribution within the Central and Northern ESUs.

Using the guidelines developed under Action 2.1, comprehensive surveys of Brush-tailed Rock-wallaby distribution in each ESU will be planned and undertaken, with the highest priority being the Northern ESU as that is where information is most lacking.

Potential Contributors: DECCW (NSW), DERM (Qld), research institutions

Action 2.3 Develop a predictive model of colony distribution for each ESU.

A predictive model of the distribution of colonies in each ESU will be developed, using GIS topographic and vegetation layers, combined with known Brush-tailed Rock-wallaby sites and habitat characteristics. This information will be especially useful for detecting isolated populations that may warrant extra conservation attention and for identifying priority areas for conservation management.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), research institutions

Action 2.4 Develop standardised population monitoring techniques.

Several different methods for estimating the size of Brush-tailed Rock-wallaby colonies have been trialled, including trapping grids, scat counts and spotlight transects and faecal DNA analyses. Faecal DNA analysis can complement information gained from other monitoring methods for rare species, by providing data on sex ratios, the reproductive success of individuals and information on movement. While it is likely that the most effective technique will vary according to site conditions and resources available, monitoring guidelines and standards will be developed to ensure the accuracy and value of data, and that the information is comparable across sites and over time.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), research institutions

Action 2.5 Conduct annual monitoring of Brush-tailed Rock-wallabies at key population sites.

Monitoring of Brush-tailed Rock-wallaby populations, especially following predator control/habitat management activities is necessary to understand the response of the species to management intervention and determine ongoing requirements to manage the species. A strategic subset of colonies will be selected for monitoring of population trends. These will include colonies subjected to active management, as well as colonies not receiving active management, to help assess the effectiveness of that management. Monitoring will be undertaken at least annually at all key sites for the species and expanded where possible to cover the full distribution of the species, to determine overall population and species trends. The results of population monitoring will be reviewed on a regular basis and management activities adapted where necessary.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

ACTION 2.6 Produce a Population/Habitat Viability model for the Brush-tailed Rock-wallaby and undertake population viability analyses of key/vulnerable populations.

When adequate information is available from the other recovery actions, population modelling and viability analysis will be utilised to assess extinction risk, compare management scenarios and to assess factors likely to affect the probability of persistence of key/vulnerable populations. This will enable refinement of management guidelines and determination of appropriate management.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

Action 2.7 Undertake molecular analysis of Brush-tailed Rock-wallaby colonies.

The locations of the boundaries between the three ESUs are not known with any precision. The boundary between the Northern and Central ESUs passes somewhere between Broke and Woko National Park, and between Warrumbungle National Park and Armidale (Eldridge & Browning 2004). Populations that lie between these locations cannot currently be assigned to an ESU for management purposes. The location of the boundary between the Central and Southern ESUs is of somewhat academic interest because all intervening populations are thought to be extinct. However, an improved understanding of the location of the boundary will assist the selection of the most appropriate founder stock for reintroductions to sites south of Kangaroo Valley, NSW, including the ACT. Colonies and museum specimens will be selected and samples collected for the genetic analyses, to determine if a clear disjunction in haplotypes can be identified. Boundaries will be defined and mapped, and the results will be used to better target conservation management of the species.

Potential Contributors: DECCW (NSW), DERM (Qld), research institutions

Action 2.8 Identify important populations of the Brush-tailed Rock-wallaby across its total range.

While some populations of the species have been identified, there has been no comprehensive identification of important populations across the entire range. As information from monitoring, surveys, predictive distributional studies and molecular analysis becomes available, populations important to the survival of the species can be comprehensively determined.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

Specific Objective 3 Establish and maintain separate, viable captive populations derived from the Southern and Central ESUs.

Performance Criterion: Captive populations for the S-ESU and C-ESU are successfully breeding, maintaining gene diversity above 90% of that currently in the wild population, and each producing offspring for reintroduction/supplementation.

Action 3.1 Prepare a captive management plan for the S-ESU and C-ESU captive populations.

Captive populations originating from Southern and Central ESU animals are already established, and will be managed separately. A captive management plan will be developed for each ESU, stating targets for that population and the strategies and protocols required to achieve them. Central ESU captive animals will be managed to maintain gene diversity above 90% of that currently in the wild population. The Southern ESU captive population will be managed to at least 95%, because this population is so small and is the only source of animals for reintroductions.

Captive management plans will include the need to:

- Determine the proportion of wild gene diversity present in the captive population using sampling theory and pedigree analysis
- Maximise gene diversity over time using breeding strategies aimed at equalising founder representation and controlling the rate of inbreeding
- Calculate required breeding rates using life-table analyses
- Maintain a studbook to support the required analyses

The captive management plans will help ensure that all participants understand the aims and objectives, and the approved protocols and standards for captive management, including selection of animals for breeding and release.

Potential Contributors: ZAA, in association with contributing zoos and wildlife parks.

Action 3.2 Update the captive husbandry manual for the Brush-tailed Rock-wallaby.

There is now considerable experience in the captive management of the Brush-tailed Rock-wallaby, including assisted reproductive techniques such as cross-fostering of pouch young. All of the captive management institutions contributing to this recovery program will need to be aware of the best available techniques, and the standards and management protocols required for the conservation management of the captive populations, especially the management of animals suitable for reintroduction. The current husbandry manual (Muranyi 2000) will be updated to reflect these recent advances.

Potential Contributors: ZAA, in association with contributing zoos and wildlife parks.

Action 3.3 Maintain separate captive populations for the S-ESU and C-ESU to the level of ZAA Category 1 species.

The captive populations of Southern and Central ESUs will be managed to their respective captive management plans. While few options are available for the Southern ESU population, the Central ESU captive population will be expanded to ensure that there are at least 20 founders, at least 16 of which need to be wild-caught animals from across the Central ESU. A small number of Kawau Island animals could be included but their genetic line will need to be carefully controlled to avoid over-representation.

Potential Contributors: Contributing zoos and wildlife parks, ZAA, DSE (Vic), DECCW (NSW)

Action 3.4 Implement the use of cross-fostering of pouch young to increase breeding productivity of the S-ESU captive population.

One factor that strongly influences the probability of inbreeding depression in small populations is the number of generations spent at that small size. An effective means of minimising the genetic impact of a population bottleneck is to rapidly increase the population. Rapid increases in the population also serve to buffer against extinction through some catastrophic event. Extensive trials have shown that reproductive output of the species can be enhanced by the removal of pouch young from their mother's pouch and their placement in the pouch of a captive foster mother for rearing (Taggart *et al.* 2002). Upon losing her pouch young, the biological mother can quickly become pregnant again, thus maximising reproductive output for both captive and wild populations. This will be the primary technique for quickly increasing captive population numbers to meet genetic management and reintroduction targets for the S-ESU populations. The successful trials of this technique will be upgraded into a routine species management protocol, based on specially-managed captive populations of Brush-tailed Rock-wallaby and/or Tammar Wallabies housed at appropriate collaborating ZAA-accredited institutions. This process is especially important for the Southern ESU, where so few animals remain. Given the tiny size of this captive and wild population, it is essential to conserve as much of the remaining genetic diversity as possible. Therefore, it is highly desirable to obtain pouch young from each remaining wild female.

Potential Contributors: Contributing zoos and wildlife parks, ZAA.

Action 3.5 Assess the need for a captive breeding population for the Northern ESU.

The need for a captive population of Northern ESU animals to be established as insurance against continuing any decline in the wild will be assessed.

Potential Contributors: DECCW, DERM.

Specific Objective 4 Undertake translocations to improve the genetic and demographic robustness of populations and establish new colonies of Brush-tailed Rock-wallabies.

Performance Criterion: At least one reintroduction and one population re-enforcement are initiated and genetic success is determined.

Action 4.1 Prepare a population management plan for the remaining Southern ESU colonies.

There are fewer than 10 individuals left in the remaining two colonies of the Southern ESU, and as such there are several difficult management issues that require further consideration and decision-making guidelines. A management plan for the Southern ESU population will be developed, including assessing the relative merits and costs of translocations to re-enforce remaining colonies or establishing new colonies in East Gippsland and/or the Grampians. The plan will also address trigger points for deciding when to take remaining wild animals into captivity.

Potential Contributors: DSE (Vic)

Action 4.2 Prepare a genetic enhancement strategy for key populations in the Central ESU.

There is strong genetic partitioning between many sub-populations, even when they are separated by less than one kilometre. As sub-populations become increasingly isolated and their size declines, the risk of inbreeding depression rises. Under these circumstances artificial supplementation of some colonies will be required to mimic successful dispersal events and maintain or improve genetic and demographic robustness of sub-populations. This may be very important for the long-term conservation of outlying sub-populations that are now well separated from other sub-populations. A strategy to achieve this will be developed, taking into account ESU boundaries, critical sub-populations and outlying populations.

Potential Contributors: DECCW (NSW)

Action 4.3 Prepare and implement a translocation strategy for each ESU.

Translocations include reintroductions to establish new colonies, and reinforcement to supplement existing colonies. Translocation of captive-bred animals to the wild is essential for the survival of the Southern ESU in the wild, and is likely to be an important component of the management strategy for the Central and Northern ESUs. The best strategy to achieve a successful outcome will vary between ESUs according to the varying needs of each ESU and the other factors such as the availability of animals for release. Previous macropod translocations will be reviewed to design and then test options covering the range of situations. The Victorian translocation strategy (Delaney *et al*. 2004) is an important start to this process. The aims of translocation will vary between ESUs and need to be clearly understood and supported by all participants. Strategies will include an agreed set of criteria against which to evaluate success. The Central ESU strategy will include investigation of the feasibility of reintroduction to former sites in the ACT.

Potential Contributors: DECCW (NSW), DSE (Vic), PCL (ACT)

Specific Objective 5 Investigate key aspects of Brush-tailed Rock-wallaby biology and ecology for conservation management

Performance Criterion. Key elements of the life history of the Brush-tailed Rock-wallaby are determined and incorporated into conservation management of the species.

Action 5.1 Determine the effects of predation on populations.

Predation by the Red Fox is thought to be a major threat to the species. Understanding the impact of predation, especially on dispersing individuals, and changes in predation levels before and after habitat disturbance (e.g. clearing, road construction), is essential for effective conservation management of the species. The response of Brush-tailed Rock-wallaby populations to predation and predator control will also lead to a better understanding of the level of predator control required (for each location) for the short- and long-term management of the species.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria.

Action 5.2 Investigate the response of the Brush-tailed Rock-wallaby to different fire regimes and establish appropriate fire regimes for conservation management of the species and its habitat.

Since the Brush-tailed Rock-wallaby is associated with a variety of vegetation types and climatic regions, there is no single fire regime that can be specified for all habitat types. Specific fire regimes would ideally be determined for each key population and account for factors such as food availability, cover, predation levels and disturbance. The role of fire in promoting the growth of key plants in the diet, and the interactions between fire and total grazing/browsing pressure need to be better understood, and will be investigated. Where managed fire is thought to be beneficial for the Brush-tailed Rock-wallaby, trial ecological burns will be undertaken at selected sites to determine their effectiveness as a conservation management tool.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

Action 5.3 Determine habitat that is critical to survival of the Brush-tailed Rock-wallaby across its range.

While there is a considerable amount of information on aspects of habitat utilised by the Brush-tailed Rock-wallaby, there are still key aspects of habitat use that are not known, especially how habitat varies across the distribution of the species, and habitat used in the absence of predation pressure from feral mammals. Obtaining this information is important for conservation management of the species, and a project will be established to determine these factors and determine habitat that is critical to survival of the species across its total range.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

Action 5.4 Conduct dietary studies to determine seasonal preferences and potential for competition.

Studies of dietary ecology of Brush-tailed Rock-wallaby and other herbivores at key sites in each ESU will be undertaken to determine the potential for dietary competition and the need for competitor control programs. The available information suggests that the Brush-tailed Rock-wallaby is a generalist grazer and browser, with grass an important component of the diet. However, key dietary components will vary between sites, as will the species of terrestrial mammalian herbivores sharing each site. Investigations of dietary ecology, including overlap and the potential for competition with other herbivores, native and introduced, will provide a sound basis for management. Scat analysis techniques will be used to determine seasonal variation in dietary preferences, and degree of dietary overlap with other terrestrial mammal herbivores, at key sites in each ESU.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), research institutions

<u>Action 5.5</u> Investigate dispersal patterns of the Brush-tailed Rock-wallaby.

It is thought that there is generally limited dispersal of Brush-tailed Rock-wallabies away from their natal site (especially of females), but the factors influencing dispersal remain largely unknown. In a study on population structure of four colonies in south-east Queensland, female dispersal among colonies was low, despite some colonies being separated by only 1 to 2 km of suitable habitat. There was evidence of multiple, spatially distinct female groups within colonies, which represent discrete breeding groups (Hazlitt *et al.* 2010). In contrast, males tended to disperse among breeding groups, coupled with infrequent among-colony dispersal (Hazlitt *et al*. 2010). Habitat familiarity was thought to be an important element for the survival of individuals. A study of dispersing Brush-tailed Rock-wallabies is required to investigate factors such as the success of dispersal, distance travelled, use of corridors and exposure to predators. This will provide important information in planning and undertaking recovery actions such as assisted dispersal to minimise loss of genetic variability amongst colonies of rock-wallabies.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), research institutions

Specific Objective 6 Increase community awareness and support for Brush-tailed Rock-wallaby conservation.

Performance Criterion: There is increased community involvement in reporting of sightings, population monitoring and predator/competitor control.

<u>Action 6.1</u> Expand Brush-tailed Rock-wallaby support groups.

Any threatened species recovery program relies heavily upon close collaboration between all groups with an interest in the outcome, or with an interest in the surrounding land. In cases where threatening processes such as introduced predators are dispersed widely through the surrounding landscape, the cooperation of neighbouring landholders is essential to a successful outcome. The Friends of the Brush-tailed Rock-wallaby group already assists recovery actions in southern NSW. Where feasible, additional regional, community-based rock wallaby support groups will be established in each ESU to support recovery efforts.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

<u>Action 6.2</u> Facilitate community involvement in the recovery program.

Community volunteers and landholders supporting rock-wallaby conservation will be trained and involved in methods for finding and estimating the size of Brush-tailed Rock-wallaby colonies, and avenues for reporting this information to appropriate wildlife authorities.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

<u>Action 6.3</u> Provide species and habitat management advice to landholders.

An information package outlining key elements of Brush-tailed Rock-wallaby biology, habitat requirements and management guidelines will be developed and provided to landholders in key locations for Brush-tailed Rock-wallaby conservation.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic), Parks Victoria

<u>Action 6.4</u> Publicise results of recovery to the community.

A regular newsletter that will report on recovery program news and progress will be developed and circulated to local communities and other interested stakeholders.

Potential Contributors: DECCW (NSW), DERM (Qld), DSE (Vic)

Appendix 2 - Extralimital Populations

Populations of the Brush-tailed Rock-wallaby have become established in New Zealand and Hawaii. In New Zealand, animals were deliberately released on Motutapu Island and Kawau Island in Hauraki Gulf by the Governor of New Zealand, Sir George Grey, in about 1863. Wallabies from Motutapu Island naturally colonised the adjoining Rangitoto Island (Warburton & Sadlier 1995). There is some uncertainty about whether the Kawau Island animals were obtained independently from Australia or whether they came from Motutapu Island. However, genetic analyses confirm that the Kawau Island population originates from central NSW (i.e. the Central ESU) (Eldridge *et al*. 2001). The New Zealand populations have long been regarded as pests. The populations on Motutapu and Rangitoto Islands were eradicated during the 1990s and the Kawau Island population is currently being reduced with the goal of eradication. Past control programs included capture for export to captive institutions, and an unknown number of animals were exported to overseas zoos. As a result, animals derived from the New Zealand island populations are now strongly over-represented in captive populations worldwide (C. Lees pers. comm.). Brush-tailed Rock-wallabies are also found on the island of Oahu, Hawaii, where a wild population became established in 1916 after animals escaped from captivity (Lazell *et al*. 1984). Genetic analyses clearly show that the founders of this population came from the northern ESU, most probably from south-east Queensland (Eldridge & Browning 2002). Some animals of New Zealand provenance have been used in the recovery program. However, the role that animals from these extralimital populations can play in the recovery of the Brush-tailed Rock-wallaby requires careful management, given their limited provenance and genetic history.