National Recovery Plan for the Mountain Pygmy-possum *Burramys parvus*

Department of Environment, Land, Water and Planning

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This recovery plan was prepared by the Victorian Department of Environment, Land, Water and Planning, with Peter Menkhorst (Vic Dept. of Environment, Land, Water and Planning); Linda Broome (NSW Office of Environment & Heritage), Dean Heinze (Consultant Wildlife Biologist); Ian Mansergh (Consultant Wildlife Biologist), Karen Watson (Department of the Environment) and Emily Hynes (Consultant Wildlife Biologist) as lead contributors. 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.

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Cover photograph: Mountain Pygmy-possum (*Burramys parvus*) by Fredy Mercay.

References in the plan to the Department of Sustainability and Environment (DSE) and Department of Environment and Primary Industries (DEPI) refer to the former Victorian department now known as the Department of Environment, Land, Water and Planning (DELWP).

Contents

Summary

The Mountain Pygmy-possum *Burramys parvus* is one of the smallest Australian possums and is endemic to the alpine and subalpine regions of south-eastern Australia, where it is restricted to three geographically separated locations: Kosciuszko National Park in New South Wales, and Mt Bogong-Mt Higginbotham and Mt Buller in Victoria. The most significant threats to this species are habitat loss and fragmentation, predation from cats and foxes and climate change. The Mt Buller population is particularly threatened due to its small population size.

This is the first national recovery plan prepared for this species, and details its distribution, habitat, threats and recovery objectives and actions necessary to ensure its long-term survival.

Current Status

The Mountain Pygmy-possum is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is also listed as Endangered under the New South Wales *Threatened Species Conservation Act 1995* and as Threatened under the Victorian *Flora and Fauna Guarantee Act 1988*. The species is also listed as Critically Endangered on the 2008 IUCN Red List of Threatened Species.

International Obligations

This plan is consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that convention.

Species Description

The Mountain Pygmy-possum *Burramys parvus* (Broom 1896) is the largest of the five species of pygmy-possum (Family Burramyidae). It has a head-body length of 10–11 cm, a tail length of 13–15 cm and adults weigh from 35–80 g. The dorsal fur is uniformly mid-grey, tinged brown; the underparts and cheeks are cream or fawn. Conspicuous black patches surround the dark, round eyes. The tail is thin, pinkish-grey and naked except for the basal 2 cm which is furred (description from Menkhorst & Knight 2004).

Distribution and Populations

The Mountain Pygmy-possum is endemic to the Australian Alps IBRA bioregion (*sensu* DEH 2000) and is the only Australian mammal restricted to alpine and sub-alpine environments. The species was first described from fossil skeletal remains found at Wombeyan Caves near Mittagong in the NSW southern highlands in 1895 (Broom 1895). A living animal was first discovered at Mt Hotham Victoria in 1966, and populations were subsequently discovered in the Kosciuszko region of NSW in 1970 and on Mt Buller in 1996 (Calaby *et al*. 1971; Mansergh & Broome 1994; Heinz & Williams 1998). Further fossil remains recovered from caves in Victoria and New South Wales suggest that at the height of the last Pleistocene glacial period (*ca*. 20,000 years bp) the Mountain Pygmy-possum had a much wider distribution around the snowline of south-eastern Australia. Since that time its range has been contracting with a gradually warming climate and receding snowline (Caughley 1986; Mansergh & Broome 1994).

The Mountain Pygmy-possum now occurs in three geographically separate regions: Kosciuszko National Park (South Ramshead to Cabramurra) in New South Wales (Broome *et al*. 2005; 2013; Schulz 2011; Schulz *et al.* 2012a,b), Mt Bogong to Mt Higginbotham and Mt Buller in Victoria (Figure 1; Mansergh *et al.* 1989; Heinze *et al*. 2004). Animals in the Mt Bogong to Mt Higginbotham region are divided into three sub-populations: Mt Bogong,

Bogong High Plains and Mt Higginbotham/Mt Loch (Mansergh *et al*. 1989). These three groups are effectively isolated from one another by low elevation valleys containing unsuitable habitat for the species. Total population size (including a rough estimate of 330 adults in three new colonies and additional as yet unsurveyed potential sites in the northern region of Kosciuszko National Park) is estimated to be about 2,405 adults (1,805 females and 600 males), with about 685 in the Mt Kosciuszko region, 1,680 in the Mt Bogong to Mt Higginbotham region, and only 40 at Mt Buller (Heinze *et al*. 2004; Broome *et al*. 2013; Mitrovski *et al*. 2007b; L. Broome & D. Heinze unpubl. data). Populations of the three regions are highly genetically distinct (Osborne *et al*. 2000; Mitrovski *et al*. 2007a, b). Each region consists of a number of smaller sub-populations that function largely independently but maintain or have had recent genetic contact supporting the long-term persistence of these populations (NPWS 2002). Within each region, there is evidence of variation in local population dynamics, a small amount of dispersal between patches, density dependence at the local population level (McCarthy & Broome 2000; Broome 2001a), and extinctions and recolonisation of small habitat patches. Larger, stable, demographically productive local sub-populations, such as those across the Mt Higginbotham-Mt Loch area, probably have the highest impact on meta-population persistence (Broome 2001a) because they most likely act as source populations for surrounding, lower quality or smaller habitat patches that undergo periodic local extinctions and are recolonised from nearby populations.

The highest densities of Mountain Pygmy-possum are usually found at high elevations (close to mountain peaks) in naturally dispersed, cool, deep boulderfields that attract large numbers of Bogong Moths (*Agrotis infusa*), and also support Mountain Plum-pine (*Podocarpus lawrencei*) in association. In these areas, densities approaching 100 adults per hectare have been recorded. Elsewhere, densities are much lower, with some patches of habitat containing fewer than 10 adults. Due to their smaller boulder size and higher productivity, the basalt boulderfields of Victoria can support higher densities of Mountain Pygmy-possums than the granite boulderfields of Kosciuszko (Mansergh & Broome 1994, Heinze *et al.* 2004).

Up until the late 1990s, Mountain Pygmy-possum populations appeared to be density-dependent and strongly self-regulating (McCarthy & Broome 2000; Broome 2001a). Habitat availability was the major factor affecting Mountain Pygmy-possum abundance, with availability of nest and hibernacula (habitat sites for hibernation) being significant limiting factors in the NSW populations (Körtner & Geiser 1998; Broome 2001a, b). Bogong Moths were apparently abundant enough to not limit population size (Mansergh 1988; Broome 2001a). More recently, there are indications that suggest that early snowmelt, in some years before the arrival of Bogong Moths, may be affecting the survival of Mountain Pygmy-possums (Broome *et al*. 2012) and that numbers of Bogong Moths may be limiting in some years (Gibson 2007; L. Broome & D Heinze unpubl. data). The widespread drought throughout eastern Australia from the late 1990s to 2009 included all areas where Bogong Moths breed and may have caused low moth numbers at Mt Buller observed from around 1999–2009 (D. Heinze unpubl. data 2010).

Bushfires in 2003, 2006 and 2013 impacted all three regional populations. Some fire-affected local populations including Mt McKay, Pretty Valley West and Mt Buller in Victoria, and Mt Blue Cow in NSW, are now at critically low levels and at risk of local extinction (Heinze 2012). Populations affected by fire at other sites such as Mt Higginbotham and Mt Loch in Victoria appear to have recovered with apparently no genetic loss (Mitrovski *et. al*. 2007b).

At its discovery in 1996 the Mt Buller population was estimated to include 350 individuals but from 1998 it experienced a sustained population and genetic diversity decline, only consisting of 40 in-bred animals in 2009 (Heinze 2010, Weeks *et al* 2011). A captive breeding colony of ~100 animals is held at Healesville Sanctuary in Victoria. Eleven animals (10 F + 1 M) were sourced from Mt Buller in 2005 and 2006 as founders for this captive colony. These founders have since been supplemented with 11 males sourced from Mt Higginbotham. The program is attempting to outbreed the Mt Buller females with the Mt Higginbotham males. The first hybrid young was produced in 2008. Captive-born possums were reintroduced to Mt Buller in 2013 with ongoing monitoring of all released animals. In both 2010 and 2011, 6 males were translocated from Mt Higginbotham to Mt Buller to effect wild cross breeding and produce more genetically robust young. This was successful and 50% (9 of 18 captured) of the 2012 cohort were cross-breds, being the first “genetic rescue” in Australia (Weeks *et al* 2011, 2012).

Important Populations

All populations and sub-populations of the Mountain Pygmy-possum are important to the survival of the species and its adaptive potential.

The entire population in New South Wales occurs within the Kosciuszko National Park, managed by the NSW Office of Environment and Heritage (OEH). Two of the best habitat sites for the NSW population occur within the leased ski resort areas of Mount Blue Cow (Perisher) and Charlotte Pass Ski Resort. In Victoria, populations on Mt Bogong to Mt Higginbotham occur in the Alpine National Park, managed by Parks Victoria, and on land within the Mt Hotham and Falls Creek Alpine Resorts, each managed by an alpine resort management board. A small area (0.2 ha) of habitat at Mt Hotham occurs on private land.

At Mt Buller the entire population of the Mountain Pygmy-possum occurs inside the Mt Buller and Mt Stirling Alpine Resort. Detailed information on distribution including maps is available from the Department of Environment, Land, Water and Planning (DELWP) for Victoria and OEH for NSW.

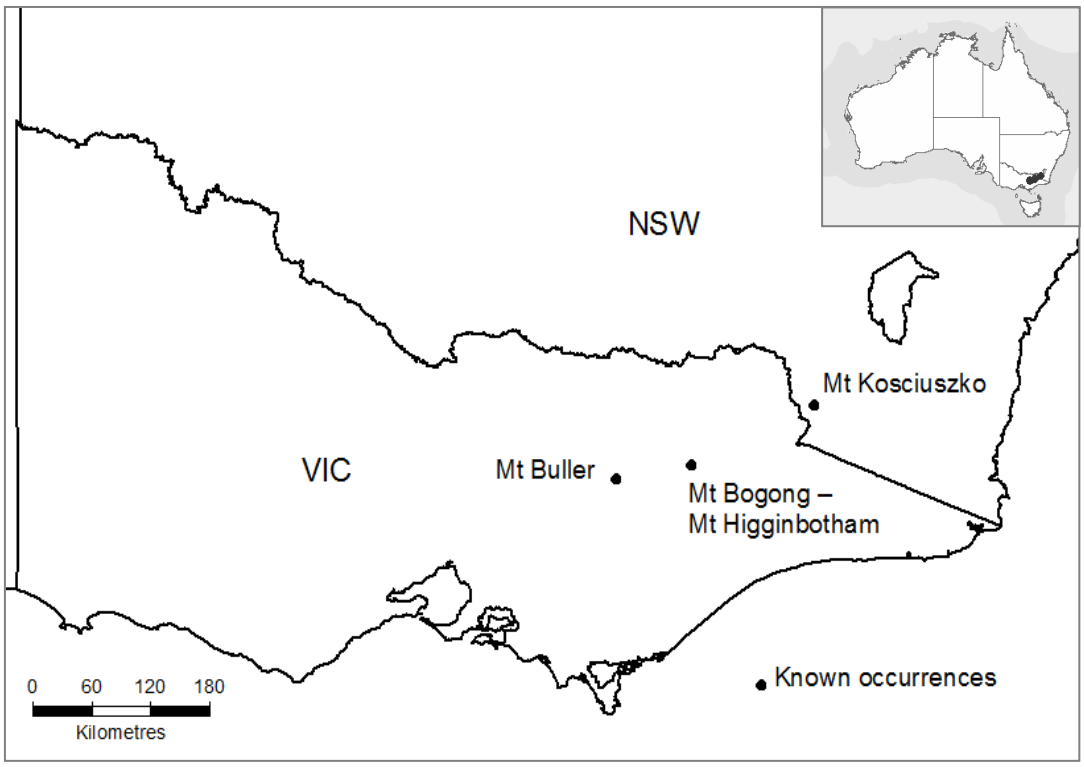

Figure 1. National distribution of the Mountain Pygmy-possum

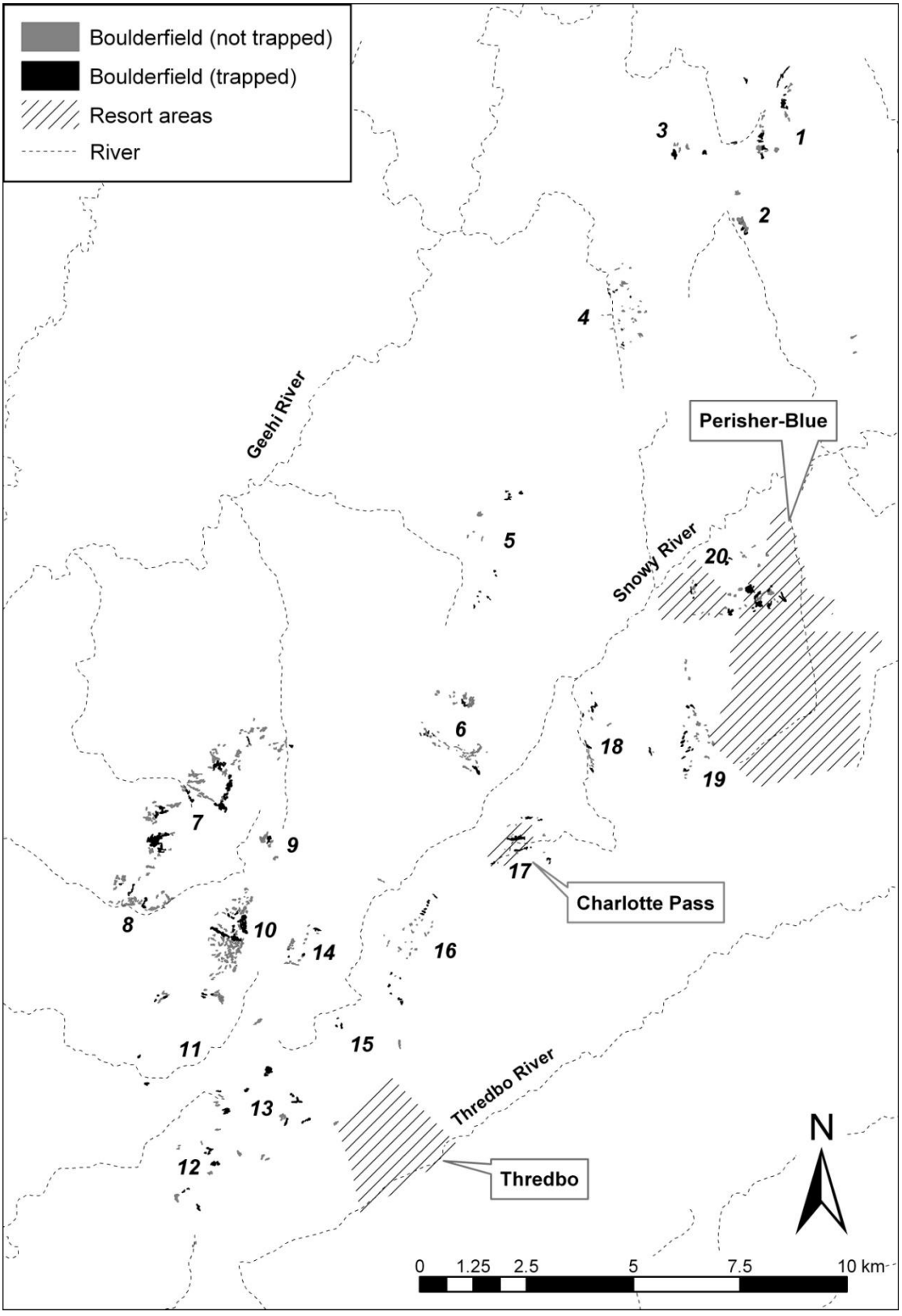

Figure 2. The distribution of boulderfields in the Kosciuszko Plateau region of southern Kosciuszko National Park. Numbers refer to boulderfield clusters described in Broome *et al* 2005.

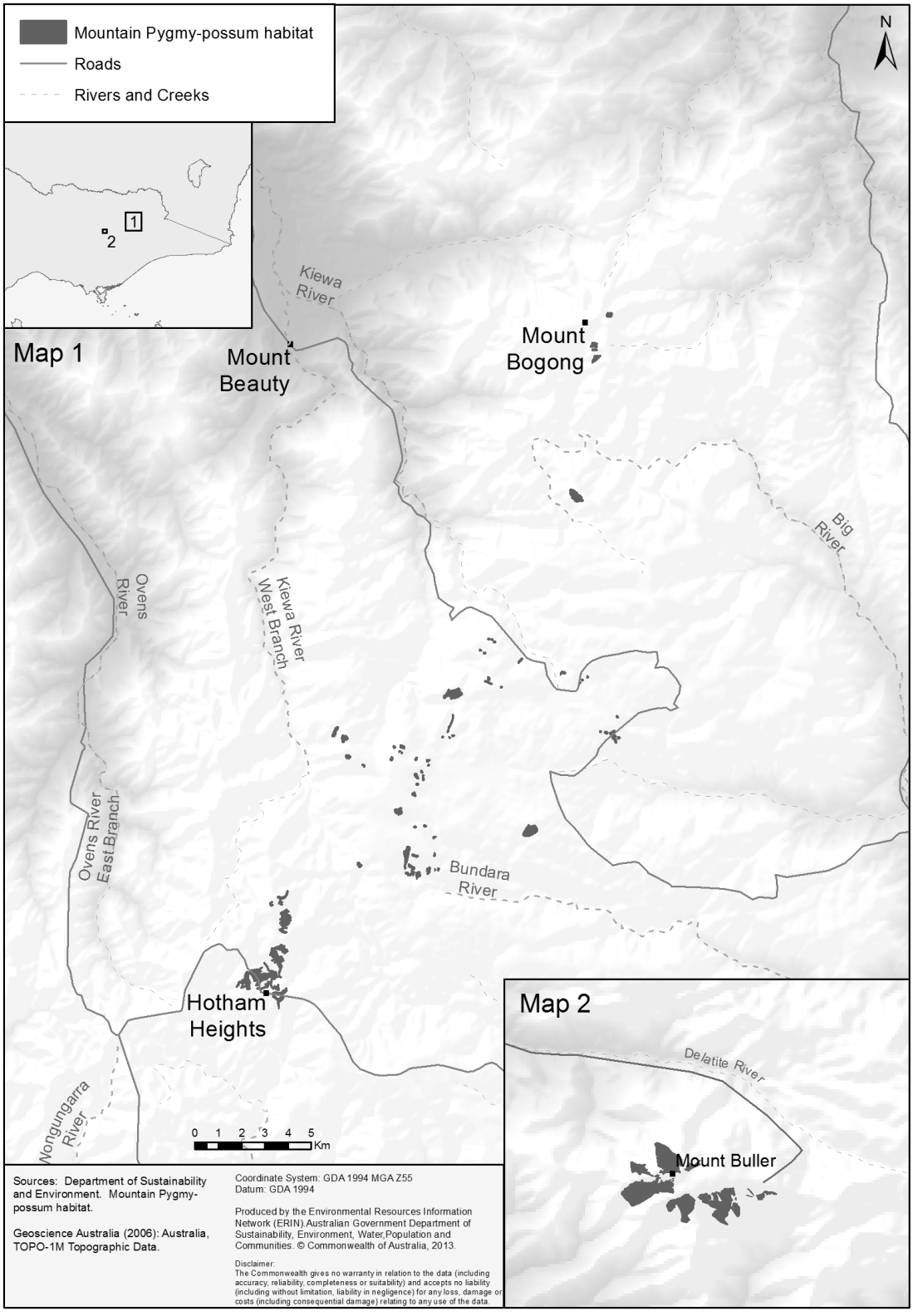

Figure 3. The distribution of Mountain Pygmy-possum habitat in Victoria.

Habitat

The habitat of the Mountain Pygmy-possum is naturally restricted and disjunct, occurring as a series of patches of boulders with associated shrubby heath vegetation within the broader alpine and subalpine environments. The species is largely confined to naturally-occurring boulderfields (accumulations of boulders on or below mountain peaks technically described as block fields and block streams that are formed by periglacial freezing and thawing processes, Rosengren and Peterson 1989) and rock screes in alpine and subalpine areas at altitudes above 1400 m (extending to 2228 m on Mt. Kosciuszko). Individuals have occasionally been observed as low as 1300 m in the montane zone at Mt. Buller and 1200 m in northern areas of Kosciuszko National Park (Heinze unpubl. data; Schulz *et al*. 2012a,b)

Most of these habitat patches are small (<1 ha, and few are greater than 5 ha) and are separated from each other by distances of several hundred metres to several kilometres. Densities and carrying capacities vary markedly (see above).

The Kosciuszko and Mt Bogong to Mt Higginbotham populations have the most available habitat, with in excess of 70 habitat patches each. The extent of habitat is smallest at Mt Buller, where there are only four habitat patches, although each is greater than 5 ha. The total area of occupancy of the Mountain Pygmy-possum is estimated to be less than 6 km², with less than 3 km² in NSW and, in Victoria, less than 2 km² in the Mount Bogong to Mt Higginbotham area and less than 1 km² at Mt Buller.

The Mountain Pygmy-possum has specific habitat requirements and there is habitat partitioning between the sexes. Generally, females tend to occupy the higher quality, higher elevation habitat and males move to these female habitats during the breeding season. After breeding, the males disperse to lower elevation habitats, or to habitat having a more westerly or northerly aspect. Male habitats usually accumulate less snow, have earlier snow melt or have lower densities of Bogong Moths, are generally lower in altitude and the boulderfields are often shallower than those in female habitats (Mansergh 1988; Mansergh & Scotts 1990; Walter 1996; Körtner & Geiser 1998; Broome 2001b; Heinze *et al.* 2004).

The boulders provide shelter, sites for hibernation and seasonal food sources. Rock crevices are used as summer aestivation sites for migratory Bogong Moths, an important food source of the Mountain Pygmy-possum (Mansergh *et al*. 1990; Smith & Broome 1992). The preferred boulderfield habitat is also strongly associated with alpine shrubby heathland (Mansergh & Walsh 1983; Gullan & Norris 1984; Caughley 1986), which supplies nectar in spring and summer, seeds and fruit in autumn and a substrate for a variety of arthropods included in the diet (Mansergh *et al.* 1990; Mansergh & Broome 1994; Broome 2001b; Gibson 2007). This heathland is characterised by the presence of Mountain Plum-pine (*Podocarpus lawrencei*) and can include Alpine Pepper (*Tasmannia xerophila*), Dusty Daisy Bush (*Olearia phlogopappa*), Alpine Rice Flower (*Pimelea alpina*), Snow Beard-heath (*Leucopogon montanus*), Mountain Baeckea (*Baeckea utilis*), Alpine Grevillea (*Grevillea australis*), Royal Grevillea (*G. victoriae*), Ovate Phebalium (*Nematolepsis ovatifolium*) and several species of *Epacris*. Flowering forbs, some grasses (e.g. Snow Grass *Poa* spp., Ribbony Grass *Chionochloa frigida*), sedges, ferns (e.g. Mother Shield-fern *Polystichum proliferum*) and mosses occur in the intervening spaces (Gullan & Norris 1984; Caughley 1986; Broome 2001b, Schulz *et al.* 2012a). Some areas have an overstorey of Snow Gum (*Eucalyptus pauciflora* or *E. stellulata*). Shrublands with scattered boulders between the main boulderfields are also used for foraging and occasionally nesting (Mansergh *et al*. 1989; Broome 1992; Walter 1996; Heinze & Olejniczak 2000, Schulz *et al.* 2012c). At Mt Blue Cow, The Paralyser and Happy Jacks Valley (Kosciuszko), nesting and hibernation sites have been located in areas up to 200 m from the main boulderfields, where there are only sparse surface rocks (Walter 1996; Broome 1992, 2001b, Schulz *et al.* 2012c).

Habitat Critical to Survival of the Species

Habitat critical to the survival of the Mountain Pygmy-possum populations is all habitat that is used by males and females for feeding, nesting and hibernation, and the areas that provide current, former or potential movement corridors between male and female habitat or for dispersal between habitat patches. This habitat has not been accurately mapped for all locations, but this is proposed as a recovery action (Action 3.3). Habitat requires a suitable buffer of intact native vegetation.

The major limiting factors for persistence and recovery of the species are the very small areas of suitable habitat and the apparent requirement of an insulating cover of snow to enable successful hibernation for up to seven months of the year (Geiser & Broome 1991, 1993; Broome & Geiser 1995; Körtner & Geiser 1997; Walter & Broome 1998, Broome *et al.* 2013).

In NSW a critical and limiting habitat requirement for the survival of this species is considered to be the availability of suitable hibernacula and nesting sites (Körtner & Geiser 1998; Broome 2001a, b). In Charlotte Pass Village (Kosciuszko), hibernacula were often outside the normal summer habitat, indicating potential seasonal differences in habitat requirements (Körtner & Geiser 1998). Animals have very specific thermal requirements for their hibernation and have been found to frequently change their hibernacula during the hibernation period, suggesting that hibernacula differ in quality (Geiser & Broome 1993; Körtner & Geiser 1998). The best hibernacula occur in deep boulderfields with an insulating layer of snow. Boulderfields in Victoria are structurally different and more complex; therefore hibernacula may not be limiting (D. Heinze, unpubl. data).

Biology and Ecology

The lower altitudinal distribution of the Mountain Pygmy-possum roughly corresponds with the lower limit of the winter snowline, around 1200–1400 m on the south east Australian mainland (Budin 1985; Slatyer *et al*. 1985; Davis 1998) and the species is thought to be snow-dependent (Mansergh & Broome 1994; Körtner & Geiser 1998; Walter & Broome 1998, Broome *et al*. 2012). Unlike most possums, it is mainly terrestrial, inhabiting alpine and subalpine boulderfields and heathlands around or above the treeline. The life history of the Mountain Pygmy-possum is shaped by the seasonally extreme environment in which it lives. Reproduction, growth and independence are completed within the 5-month period between snow melt in late spring, when animals breed and the onset of cold weather in autumn, by which time they need to have acquired enough body fat to survive the hibernation period over winter.

Diet

Arthropods, especially Bogong Moths, comprise over 50% of the diet in spring and early summer (Mansergh *et al*. 1990; Smith & Broome 1992; Gibson 2007). The Bogong Moth is a migratory species that breeds in inland grasslands and agricultural lands on the plains and slopes of Victoria, NSW and Queensland (Common, 1954). Each spring, moths migrate to the cooler mountains from their lowland breeding areas to aestivate over summer, and large numbers mass in rock crevices. Bogong Moths provide the primary and most abundant food source for Mountain Pygmy-possums, especially at high elevations.

Mountain Pygmy-possums also eat a range of seeds, drupes and berries, especially those of Mountain Plum-pine*,* Snow Beard-heath and Alpine Rice Flower. Nectar is consumed in spring and summer from a range of flowering heathland shrubs and forbs (Gibson 2007). Captive Mountain Pygmy-possums have been observed to take seeds into their nests and store caches of seeds around their cages (Dimpel & Calaby 1972; Kerle 1984) but it is not known how important caching behaviour is in the wild. Most hibernating possums arouse for only short periods and do not appear to feed during the winter hibernation period (Broome & Geiser 1995; Körtner & Geiser 1998) so perhaps caches are used early in winter or during other periods of food shortage. Plant material is important during late summer and early autumn, especially for juveniles and males (Smith & Broome 1992), when animals gain maximum weight prior to hibernation.

Elevation has a strong effect on the availability of particular food resources. Bogong Moths are most abundant at high elevations, and flowers, seeds and berries are most abundant at lower elevations (Common 1954; Mansergh 1989; Smith & Broome 1992; Broome *et al*. 2005, 2013). Females consume more arthropods and less seeds and berries than do males, which may reflect the female preference for higher elevation habitats and differing nutritional requirements (Smith & Broome 1992).

Hibernation

The Mountain Pygmy-possum hibernates during the coldest months of the year, beginning in March/April as temperatures drop sharply and food supplies decline, and lasting until September/October, with emergence broadly coinciding with a rise in temperature and the disappearance of snow, the arrival of Bogong Moths and the spring equinox (Geiser & Broome 1993; Mansergh & Broome 1994; Körtner & Geiser 1998). Hibernation consists of periods of torpor, during which the body temperature drops to a minimum of 2^{o}C, and metabolic rate is substantially reduced, interspersed with periods of arousal ranging from a few hours to several days (Geiser & Broome 1991; Broome & Geiser 1995; Körtner & Geiser 1998). Optimal energy conservation occurs when the micro-climate in the hibernacula is around 2^{o}C, with temperatures above and below this resulting in increased energy expenditure due to increased metabolic rates and more frequent arousals from torpor (Geiser & Broome 1993). Snow melt allows the possums access to Bogong Moths that migrate to the boulderfields in September–October to aestivate. Males emerge first from hibernation, to allow regrowth of testes, resumption of spermatogenesis and migration into the home ranges of females (Körtner & Geiser 1998).

Breeding and survival

Females can live for up to 12 and males up to five years, the majority of individuals of both sexes survive for only one to three years but the 15% of females that extend the age pyramid provide population persistence through successive poor seasons (Mansergh & Scotts 1990; Broome 2001a). Differential survival means that there are usually fewer males at breeding time. Mountain Pygmy-possums are polygamous (both males and females having more than one mate at a time) and multiple paternity of litters has been confirmed in captivity (A. Weeks pers. comm. August 2012). In the highest density sub-populations, e.g. at Mt Higginbotham, females and their young often have almost sole use of the best quality habitat (high altitude, deeper boulderfields, with more Bogong Moths), males appear to be excluded by aggressive females following breeding and the social organisation in these situations has been described as female resource defence polygyny (Mansergh 1988). The females defend the optimal high elevation boulderfield habitat, leaving the males to use the lower suboptimal habitat that has fewer hibernacula and food resources. Travelling between the lower and higher elevation habitat for feeding and breeding opportunities can make males more susceptible to predation. This has potentially contributed to skewed sex ratios (Mansergh 1988, Heinze *et al.* 2004).

Mating begins soon after emergence from hibernation, the time from mating to weaning is very short, about 9–10 weeks, and growth of young is rapid, an adaptation to the short alpine summer (Heinze *et al*. 2004). The female of the species has a forward facing pouch providing four teats but usually produces supernumerary (more than four) young which are born in October and November. A maximum of four young are weaned from late December to late January (depending on location and time of snow melt). Most young leave their natal site within a month of weaning, with males departing first (Mansergh & Broome 1994).

Some females at Mt Higginbotham had second litters in late summer (Mansergh and Scotts 1990) and this has been observed recently at Mt Buller and Charlotte Pass, D. Heinze, L. Broome unpubl. data). Mansergh and Scotts (1990) suggested that late second litters may be detrimental to both mothers and young as they may not gain sufficient fat reserves to survive the following winter. Females that survived winter were on average 12% heavier in autumn than those that were not retrapped the following spring (Mansergh and Scotts 1990) and autumn body weight was also shown to affect winter survival in juvenile possums at Mt Blue Cow (Broome, 2001b). It is therefore likely that young from second litters born in late summer will have low survival rates as they are less likely to reach sufficient weight prior to entering hibernation.

Sex ratios of populations can change markedly, from 1:1 at birth and independence to between 1:1 and 1:22 female bias as breeding adults (Mansergh & Scotts 1990; Broome 2001a; Heinz *et al*. 2004). This bias and the lower longevity of males may be a result of their exclusion from the best quality habitat, higher predation rates as they travel to, from and within natal areas to access females and lower survival during winter due to their choice of slightly warmer (more risky) hibernacula (Mansergh & Scotts 1990; Broome 2001a; Heinze *et al*. 2004).

History of Decline

Collection of population and habitat data continuously over 30 years (since 1981 in Victoria and 1986 in NSW) provides a unique knowledge base and window into the population status of the Mountain Pygmy-possum.

In 1994, based on potential habitat mapped earlier by Caughley (1986) the total number of adult Mountain Pygmy-possums was estimated at about 2,600 with 1,300 adults in the Mt Bogong to Mt Higginbotham region of Victoria and 1,300 in New South Wales (Mansergh & Broome 1994). However, ground-truthing of many of the areas identified by Caughley (1986) between 1986 and 1996 indicated much of these potential habitat areas were unsuitable. It was then recognised that the 1994 total population estimates for the Kosciuszko region were over-estimates and these were revised to around 600 adults in 2000 (Broome *et al*. 2005, 2013).

When the population at Mt Buller was discovered in 1996, it was estimated to number about 300 adults (Heinze & Williams 1998). From around the late 1990s, declines in the populations at Mt Buller and the Kosciuszko region were observed. In 2010, the total number of adults across the three regions was estimated to be about 2405 adults (1805 females & 600 males), with variations annually (Broome *et al*. 2005; Mitrovski *et al*. 2007b; L. Broome & D. Heinze unpubl. data).

Recent (November 2010–November 2011) discoveries of colonies in the northern section of Kosciuszko National Park resulted in the capture of an additional 140 adults (110 females, 30 males) (Schulz *et.al.* 2012a,b,; Broome & Bates unpubl. data), suggesting there may be an additional 250-350 adults in this region, based on trapping densities and mapping of potential habitat (Broome *et al.* 2013, L. Broome unpubl. data).

Table 1. Estimates of total population sizes and percentage decline from 1990 to 2010.

Populations vary annually and are subject to natural fluctuations.

Year	NSW KNP Sth	NSW KNP Nth**	Bogong High Plains	Mt Buller *	Total
1990 – 96*	615 (395 F+ 220 M)	N/A	1735 (1350 F+385 M)	300 (270 F+30 M)	2650
2010	355 (225 F+130 M)	330 (250 F + 80 M)	1680 (1300 F+380 M)	40 (30 F+10 M)	2405
% change	-42	N/A	-3	-87	-22***

* population at Mt Buller discovered in 1996

** population at Nth Kosciuszko discovered in 2010

*** calculation excludes Nth Kosciuszko population

The most marked decline in numbers has been on Mt Buller, from about 300 adults in 1996 to only 40 (30F + 10 M) in 2010, which represents a population decline of 87% (Mitrovski *et al*. 2007b; D. Heinze unpubl. data)[1]. Genetic diversity was estimated to be two-thirds lower than in 1996, and by 2007 the population consisted almost entirely of females, with only one or two males present (Mitrovski *et al*. 2007b), and this population was considered to be facing imminent extinction (Mitrovski *et al*. 2007b, Weeks *et al.* 2012). The sex ratio improved in 2010 but inbreeding continued to lower the genetic robustness.

Causes of the decline on Mt Buller are attributed to a combination of habitat loss and fragmentation due to ski resort development and increased predation risk from cats and foxes and consequent inbreeding (Mitrovski *et al*. 2007b). Observations of relatively low numbers of Bogong Moths at Mt Buller since 1999/2000 suggest a decline in the availability and abundance of moths may also have contributed to the decline in possum numbers and magnified the effects of inbreeding (D. Heinze unpubl. data).

The population in the Mt-Bogong to Mt Higginbotham region appears to have maintained overall numbers at around 1,250–1,350 females and 380 males in 2010. Declines were detected at some sites after extensive bushfires in 2003 and 2006, although numbers appear to have recovered since, except for some locations (e.g. Mt McKay, Pretty Valley West) where numbers are still low (Mitrovski *et al*. 2007b; D. Heinze, unpubl. data) however recolonisation remains prospective.

Sub-population sizes in the Kosciuszko region are smaller than most of the Victorian sites, where numbers of females frequently range from 50 to 100. Up until 1997 there were four 'large' (greater than 25 females) populations in the (Southern) Kosciuszko region (Broome *et al*. 2005, 2013). The population at Mt Blue Cow declined from an average of 29 females before 2000 to three in 2009; at Charlotte Pass from an average of 26 females before 1998 to 10 in 2009. Only five females were recorded at Mt Townsend in 2009. At the Mt Kosciuszko monitoring site the population declined from over 30 females in 2005 to 14 in 2009 (L. Broome unpubl. data). Declines in these four key subpopulations range from 38 to 77% between 1998-2009. By contrast, numbers in the smaller monitored populations (Summit Road and Paralyser) show no significant change (see table 2 below). Population size in the southern Kosciuszko region was estimated at as few as 355 adults (225 females and 130 males) in 2009 (L. Broome, *et al.* 2012, L. Broome, unpubl. data). However, following 4 years of high rainfall (2010-2013) populations at most of the southern Kosciuszko monitored sites had recovered in November 2013 to pre-drought sizes, with a partial (50%) recovery at Mt Blue Cow (Broome *et al*. 2013, L. Broome unpubl. data).

[1] In 2005 and 2006 10 females and one male were also removed from this population to establish the captive breeding colony at Healesville, Victoria.

Threats

Major reasons for the decline of the Mountain Pygmy-possum include habitat disturbance and destruction from ski resort development and road construction, reduced snow cover and early snow melt, and competition with or predation from other mammalian species (Mansergh *et al*. 1989; Mansergh 1991; Broome 1992; Mansergh & Broome 1994; NPWS 2002; Anon. 2005; Broome *et al*. 2005; Mitrovski *et al*. 2007b; Broome *et al.* 2012).

Summary of threats

Major threats to the Mountain Pygmy-possum include:

- Loss, degradation and fragmentation of habitat
- Erosion and sedimentation
- Predation by cats and foxes
- Genetic loss and small populations
- Winter impacts from ski resort operations and snowsports activity
- Bushfire and planned fuel hazard reduction burns
- Climate Change and indirect effects
- Decline in Bogong Moths
- Weed Invasion and competition from introduced species

Loss, degradation and fragmentation of habitat

Loss and degradation of habitat are among the greatest immediate threats to the continued viability of the Mountain Pygmy-possum populations. Approximately 80% of Victorian Mountain Pygmy-possums live in or immediately adjacent to ski resorts (Mt Hotham, Mt Buller, Falls Creek). At Mt Buller and the eastern slopes of Mt Hotham, up to one-third of optimal breeding habitat has been lost to ski resort development.

In Kosciuszko National Park, 40% of the southern population of Mountain Pygmy-possums occurs within the ski resort lease areas, with the remainder distributed in small patches of habitat within a 30 x 8 km region between South Ramshead (near Thredbo) and Gungartan Pass, including on the peaks and western fall of Mt Townsend and Mt Kosciuszko (Broome *et al*. 2005, 2013).

Habitat connectivity is of particular importance for this species, as it enables movement of individuals between the disjunct habitat patches, maintaining metapopulation structure and genetic diversity. It also is essential for enabling males to migrate to the females during the breeding season (Mansergh & Scotts 1989). Fragmentation of connective habitat increases predation risk, particularly for male movements (e.g. Mt Buller, Mt Blue Cow).

Alpine heath vegetation is susceptible to damage as it has a very short growing season, growth is slow and recovery from damage can take many years. This means that damage tends to be cumulative and recovery slow (Bell & Bliss 1973; Costin *et al*. 1979). Damage to heathland vegetation can occur from bushfire, exotic grazing animals such as European Rabbits (*Oryctolagus cuniculus*), European Hares (*Lepus europaeus*) and deer, snow compression from snow grooming and snow sports activities particularly when snow cover is shallow. Summer activities can also cause damage, such as by summer slope grooming and management activities and trampling by visitors.

Habitat fragmentation through the past planting of exotic rhizomous grasses for ski runs (e.g. *Festuca rubra)* has altered the structure of habitat, and these grasses have the potential to invade into heath. This different habitat structure is likely to impede or reduce the movement of small mammal species and make them more vulnerable to predation.

Erosion and Sedimentation

Mountain Pygmy-possum habitat is susceptible to sedimentation. Degradation of boulderfield habitat can occur from runoff from surrounding areas where soil and silt can be deposited between and under rocks into nesting and hibernation spaces. Erosion is exacerbated by loss of vegetation cover from road and track batters, fire and trampling. Sources of sediment movement include construction works and mechanical disturbance such as snow-grooming.

Predation by Cats and Foxes

Predation by the Red Fox (*Vulpes vulpes*) and feral Cat (*Felis catus*) is a significant threat to Mountain Pygmy-possums (Mansergh *et al*. 1989; Mansergh 1991; Broome 1992; Mansergh & Broome 1994; NPWS 2002; Heinze *et al.* 2004, Anon. 2005; Broome *et al*. 2012). Predation by foxes and predation by feral cats have been listed as key threatening processes under the EPBC Act.

These species prey on the possums and have been observed foraging amongst boulderfields. Feral cats have been found to use boulderfield habitat for denning locations in the non-snow covered periods (Watson 2006). Additionally, the food resources available in the boulderfields, such as Bogong Moths and high densities of small mammals, may be attractive to foxes and cats. Between 1997-2000 and 2010, sub-populations of possums at Charlotte Pass and Mount Blue Cow experienced large declines (the start and extent of decline varying by year, sex and site, Broome unpubl. data). These declines are thought to be due in large part to predation by feral cats and foxes, combined with the effects of drought and low snow cover (Broome & Ford 2005, McDougall & Broome 2007, Broome *et al*. 2012). The impact of foxes (Green 2003) and cats (Watson 2006) on the Mountain Pygmy- possum may be increased if snow melt occurs before Bogong Moths arrive in early spring and possums are prompted to forage outside the shelter of boulderfields for alternative food resources (Broome *et al.* 2012). Foxes hunt in relatively open areas such as along ski runs, roads and in areas that have been cleared of protective cover. The small numbers of males in some sub-populations, such as on the Bogong High Plains, suggests that males may be particularly susceptible to the effects of fox predation when they move between isolated patches of habitat where shrub cover is low (Mansergh 1988, Heinze *et al*. 2004).

Genetic loss and small populations

Although overall genetic variability of Mountain Pygmy-possums is high compared to many other threatened marsupial populations, the disjunct nature of the distribution of the species both within and between populations makes it particularly susceptible to genetic loss. Loss of genetic variation is likely to reduce evolutionary potential and reproductive fitness, making this species susceptible to extinction at both the local and overall population level.

This is demonstrated by the Mt Buller population experiencing the most rapid loss of genetic diversity ever recorded in a mammal (Mitrovski *et al*. 2007b). Management of this threat is further complicated by the high genetic differentiation between the regional populations. The high population fragmentation within each regional population (particularly the Kosciuszko and Mt Bogong to Mt Higginbotham regions) means that populations are particularly prone to loss of genetic variation through further fragmentation, depletion of males and reductions in population size.

One key risk factor to the maintenance of genetic diversity is loss of habitat connectivity and therefore gene flow between sub-populations within each of the three regional populations. Barriers to gene flow include not only geographic distance but also anthropogenic barriers such as roads, dams, villages, habitat clearing and ski resort development. A further threat to genetic diversity is any reduction in population size (McCarthy & Broome 2000; Mitrovski *et al*. 2007b). A reduction in effective population size is associated with increased levels of inbreeding and genetic drift, leading to an overall loss of genetic variation, increases in genetic load and consequent loss of fitness (Mitrovski *et al*. 2007a, b; Weeks *et al.* 2012).

The often extreme bias in sex ratios characteristic of this species, with ratios as biased as one male to 22 females being recorded at Mt Buller, make it particularly susceptible to extinction from genetic loss (Mitrovski *et al*. 2007b). If such trends continue, this will further reduce the effective population size and increase the genetic load of populations.

Winter impacts from ski resort operations and snow-sport activities

Prime areas of Mountain Pygmy-possum habitat overlap with areas used for skiing and snowboarding. Activities relating to these snow sports, if not managed correctly, are a threat to this species. Over-snow vehicles such as snow-groomers and snow-mobiles and snow sports activities (skiing, snowboarding), in addition to damaging the underlying vegetation when snow is shallow, can increase the compaction of snow and eliminate the subnivean[2] space (Sanecki *et al*. 2006). Studies suggest under snow temperatures stabilise when snow depth is above 50–100 cm, with the ground surface remaining in the range of 0 - 2^{o}C (Broome 1992, Shi 2012). Compacting snow results in decreased insulation due to an increase in snow density. This is of particular concern since it may disturb hibernation, through hibernacula temperatures fluctuating above or below the optimal 2^{o}C, causing increased energy expenditure through elevated metabolic rates and more frequent arousals.

Noise and vibration from these machines may also cause more frequent arousals. These energy-expensive arousals could be fatal if they occur too often. The elimination of the subnivean space was apparent in areas where snow grooming occurred where the vegetation consisted of low heath or snow grass and snow cover was less than 50 cm (Broome 1992). Sanecki *et al*. (2006) suggested that super grooming of ski slopes would eliminate the subnivean space, analogous to the result observed during removal of vegetation by fire. Loss of these spaces may hinder movement between hibernacula. These movements are important for enabling Mountain Pygmy-possums to locate hibernacula with the best thermodynamics (Körtner & Geiser 1998). Therefore, snow compression potentially has the two-fold deleterious effects of causing more frequent arousal and preventing movement to more suitable sites.

Bushfire and planned fuel hazard reduction burns

Fire suppression activities and planned fuel hazard reduction burns close to habitat are a threat to the Mountain Pygmy-possum through loss of vegetation cover, food sources and movement corridors. This might include burning areas adjacent to boulderfield habitat within ski resort leases for ski resort asset protection or ski runs.

Bushfires also pose a serious threat. In 2003, bushfires burnt through approximately 20% of the Mountain Pygmy-possum habitat in the southern region of Kosciuszko National Park and over 80% of the habitat in northern Kosciuszko. The Mt Bogong to Mt Higginbotham area in Victoria was burnt to varying degrees (Broome & Ford 2005; Heinze 2005, L. Broome unpubl. data). In 2006 and 2007 substantial areas of habitat were burnt at Mt Buller (Harvey 2007) and some habitat patches were burnt in the Bogong-Higginbotham areas, including some that had previously been burnt in 2003 (i.e. Mt McKay).

While key local sub-populations of Mountain Pygmy-possums in Victoria have persisted since the 2003 fires, there have been substantial changes to the population size and structure, including declines, at some locations. Where habitat was severely burnt, no animals have been trapped since the fires. However, impact varied between sites and for some sites in the Mt Bogong to Mt Higginbotham area, there was little difference between pre-fire and post-fire trapping rates and animal captures (Mitrovski *et al*. 2007a). In NSW, habitat at Mt Blue Cow was severely damaged, with areas of boulderfield habitat losing old-growth (up to 400 years of age) Mountain Plum-pine stands (McDougall *et al*. unpubl. data) through the intensity of the fire. Pygmy-possum numbers were reduced immediately after the fires and although shrub cover is slowly recovering, possum numbers are still low. Apparent low densities in the northern part of Kosciuszko National Park may be in part related to the large scale, severe burning in this region (L. Broome unpubl. data).

Fire management and suppression activities in the Victorian ski resorts are guided by strategic bushfire management planning, which includes consideration of Mountain Pygmy-possum habitat needs.

[2] The subnivean space is the space formed between the ground layer and the underside of the winter snow pack, usually held in place by vegetation within the space, which provides small animals with a relatively stable environment in which to maintain activity close to the ground during the winter snow-covered period.

Climate change and indirect effects

Climate change is the greatest long-term threat to the Mountain Pygmy-possum, because the species is restricted to the alpine and sub-alpine environments, does not occur below the winter snowline and is adapted to predictable, marked seasonal changes. The populations predicted to be initially impacted by global warming are those that are small, at low elevations or on westerly aspects (Broome 2001a). There is also likely to be other unpredictable effects of climate change on the survival of the Mountain Pygmy-possum within the alpine habitat.

World-wide cold climate (high altitude/ latitude) areas are vulnerable to climate warming and the Australian Alps are recognised as being particularly at risk (IPCC 2007). Global-scale decline of snow and ice has been especially evident since 1980 and has been increasing during the past decade (Lemke *et al*. 2007), and dangerous climate change (+2° C) may occur sooner than suggested by the IPCC (2007) (Steffen 2009).

Hennessey *et al*. (2003) presented low impact and high impact scenarios for projected changes in natural snow conditions in the Australian Alps for 2020 and 2050. Under these scenarios the area with at least 60 days of snow cover is predicted to decrease by 38–96% by 2050. More recent projections of temperature increases of 2.5–3.8° C by 2070 (Suppiah *et al*. 2007) are suggesting that the high impact scenarios are increasingly likely. Significant decreases in rainfall during autumn, winter and spring and a small increase in summer rainfall are also predicted for south eastern Australia (Suppiah *et al*. 2007; OEH 2010). Brereton *et al*. (1995) predicted that the present bioclimatic range of the Mountain Pygmy-possum will disappear with a 1° C rise in temperature.

Loss of snow cover and higher temperatures through climate change are predicted to lead to lower survival rates of possums, loss or degradation of habitat, increased impacts of feral predators, especially cats and increased competition from a range of other small mammal species that are able to move to or better persist in higher altitude habitat (Brereton *et al*. 1995; NPWS 2002; McDougall & Broome 2007, Broome *et al.* 2012). A possible scenario is that Mountain Pygmy-possum may lose its competitive advantage and lower altitude species such as the Bush Rat, and Antechinus spp. may become increasingly abundant and persistent in the alpine environment.

'Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases' has been listed as a key threatening process under the EBPC Act.

Climate change, snow ecology and effects on hibernation

Climate change is predicted to cause unprecedented reductions in the spatial extent and duration of snow cover in the Australian Alps within the next 30–70 years (Whetton *et al*. 1996; Whetton 1998). Associated increases in temperature will result in significant changes in alpine and subalpine areas, specifically reduced snow depth and consequential changes in ecological processes (Hennessy *et al*. 2003).

Time of formation, depth, duration of snow cover and time of snow melt strongly influence survival and recruitment of Mountain Pygmy-possums in its natural environment. Survival and recruitment are substantially reduced in years of very long snow cover duration and late melt and increasingly, in years of very short snow cover duration and early melt. Preliminary modelling suggests optimal snow cover duration for Mountain Pygmy-possum survival is around 130–150 days (McDougall & Broome 2007; Broome *et al.* 2012). Survival may also be reduced when extremely low temperatures occur before the formation of insulating snow cover in early winter or when rain causes a mid-season melt (Körtner & Geiser 1998; McDougall & Broome 2007; L. Broome unpubl. data).

High temperature spikes in winter that cause snow melt and rain events may disrupt hibernation, resulting in increased energy demand, winter mortality and potentially reduced reproductive success (Körtner & Geiser 1998). Increased temperatures will raise energy demands in two ways. Firstly, entry into hibernation will be later and emergence will be earlier, reducing the period of energy conservation (Körtner & Geiser 1998). Secondly, temperatures of hibernacula may experience greater variability due to loss of insulative snow cover, reducing the number of suitable hibernacula (i.e. within the optimal 2° C temperature range), at some sites, further limiting an already scarce but essential habitat resource (Körtner & Geiser 1998; Broome 2001a).

Temperatures outside the optimal range in hibernacula would result in greater energy use through higher metabolic rates, shorter bouts of torpor and increased activity as possums expend energy searching for better hibernacula (Broome & Geiser, 1995; Körtner & Geiser, 1998). Males would be particularly susceptible to the increased energy demands of a warmer climate since they emerge from hibernation earlier to prepare for the breeding season (Körtner & Geiser 1998). In recent years, the breeding patterns at Mt Kosciuszko and Mt Buller have become less synchronised, possibly due to low population sizes, low food availability or early snow melt (L. Broome & D. Heinze unpubl. data.).

Higher and more frequent extreme summer temperatures may also cause heat stress, as Mountain Pygmy-possums quickly become hyperthermic at ambient temperatures above 30° C (Fleming 1985)[3]. Populations on western aspects may be particularly susceptible to heat stress during hot summers where the depth of the boulderfields provides insufficient insulation for the micro-habitat (Shi 2012). Reduced rainfall and intermittent drying of alpine streams may also directly impact Mountain Pygmy-possums, which readily drink free water.

Climate change and food resources

Other impacts on the Mountain Pygmy-possum could include changes in food availability through declines or changes in seasonality of plant production, or availability of Bogong Moths and other arthropods. Not all changes may be negative; for example, nectar and seed production of some plants may increase (McDougall & Broome 2007). However, the bio-physical effects of climate change on Bogong Moth habitat and ecology remains unclear as does the effects on the moths from land use and agricultural management practices in Bogong moth breeding habitat. Although the Bogong moth is considered abundant at present, large scale regional changes such as drought, change of land use from grazing to cropping and use of pesticides could reduce available breeding areas.

Climate change and fire regimes

South-east Australia faces a drier, warmer and extreme weather event-prone future with high risk of extreme fire days (IPCC 2007; Steffen 2009; Henessey *et al*. 2005). Extensive fires in alpine and subalpine environments generally only occur in periods of extended drought (Williams *et al.* 2008) such as the two fires experienced in the decade prior to good rainfall in 2010, in 2003 and 2006. The societal response, focusing on fire prevention through land management (e.g. reducing fuel load) is likely to increase. Surrounded by highly flammable forest, the "island effect" makes alpine and subalpine environments particularly vulnerable to fire effects at the landscape scale, and Mountain Pygmy-possum populations more so at the micro scale. The long-term demographic effects of the 2003 fire on the Victorian population was examined by Heinze and Baumgartner (2012).

Climate Change and Mountain Pygmy-possum adaptation

The essentially subterranean habitat of the Mountain Pygmy-possum may be able to provide some buffering protection from ambient temperature rises. However, the persistence of the species is likely to relate to its physiological and behavioural adaptive capacity to adapt to climate change and its indirect effects. This includes responses to bio-physical changes, such as increased temperatures, changes in rainfall and snow depth and duration (Hennessey *et al*. 2003), and their ability to tolerate any competitive advantages from potential competitors and predators, future fire regimes, weed invasion and vegetation change. The ability of the Mountain Pygmy-possum to adapt to the range of changes predicted with climate change will likely depend on how tightly the species is tied to its current highly seasonal phenology, and its physical and behavioural plasticity.

[3] Mountain Pygmy-possums have been kept in ambient temperature enclosures at Healesville Sanctuary (VIC) for several years. Here breeding was occasionally observed in all seasons and was not as synchronised as in the wild.

Decline in numbers of Bogong Moths

As Bogong Moths provide the primary and most abundant food source for Mountain Pygmy-possums, especially in spring and at high elevations, any threats or actions that substantially reduce numbers of moths in the alpine and subalpine boulderfields are also a threat to the Mountain Pygmy-possum. Potential threats to Bogong Moths include further loss of inland native grassland habitat, application of agricultural chemicals in their breeding sites and environmental variation due to climate change, especially increased drought conditions. There is also evidence that artificial UV light, building lights and storms can interfere with the moths' navigation during migration. Some buildings within ski villages seasonally attract and harbour large numbers of moths, possibly reducing the numbers congregating in boulderfields and reducing the food supply for the Mountain Pygmy-possum.

The presence of arsenic within Bogong Moths has previously been identified as a potential threat. Arsenic was detected in Bogong Moths, the scats of Mountain Pygmy-possums and other small predators that feed on the moths although any potential impact of this on the Mountain Pygmy-possum was not known (Green *et al*. 2001; Green 2008). Subsequent detailed analyses of moths sampled from a wide range of lowland and alpine locations revealed that arsenic concentrations in Bogong Moths did not differ significantly between sites or years. Additionally, these results and those presented in the above publications are consistent with the natural or background levels. Using methods of Food Standards Australia New Zealand revealed that arsenic concentrations in Bogong Moths are very low and are comparable to common food items such as sultanas and mixed-grain breakfast cereal (Love 2010), The concentrations in the scats of small mammals (Green *et al*. 2001) also indicate ingestion at levels below NOAEL toxicity levels. It is therefore advised that arsenic levels in Bogong moths be no longer considered a threat to either Mountain Pygmy-possum or human consumers (Dr Susan Lawler, LaTrobe University pers. Comm. September 2012).

In contrast, the presence of organic pesticides in Bogong Moths has been tested from only one (pooled) sample from one natural site, with negative results (Green 2008). It would be of interest to determine if pesticides were impacting on local populations of Bogong Moths in their breeding grounds and whether there was a potential for these pesticides to accumulate in moths and be transported to the mountains.

Weed invasion and competition from introduced species

Weeds affect the quality of Mountain Pygmy-possum habitat by out-competing preferred native species and reducing biodiversity. Main problem weeds in Victoria include willows (*Salix* spp.), Apple (*Malus pumila*) and Blackberry (*Rubus fruticosus*).

Climate change may increase potential for other exotic weed species to establish. Currently, introduced grasses and clover sown along roads and on ski runs attract rabbits and hares, which have the potential to sustain predator populations. Rabbits and hares appear to have increased in abundance in some areas at higher altitudes and this may be in response to drought conditions or climate change. These animals also have grazing and erosion impacts in alpine and subalpine areas. Sambar (*Cervus unicolor*) are also emerging as a potential issue in some areas.

Existing Conservation Measures and Management

There have been many conservation measures taken for the Mountain Pygmy-possum since discovery of extant populations in 1966, including public awareness campaigns, considerable research and monitoring, and habitat management. Mountain Pygmy-possum habitat is located among, or very close to the main ski resorts in Australia. Over the past decade, management boards at each of these resorts have worked closely with natural resource management agencies to assist conservation measures and reduce the impact of recreational skiing and infrastructure on the species.

VICTORIA

- Potential development of Mt Hotham initiated first systematic survey and habitat definition for Mountain Pygmy-possum (Gullan & Norris 1984).
- Active monitoring and data collection has commenced on all Victorian populations (some annually from 1981, some sub-populations every 5 years or so). This has included monitoring the abundance of Bogong Moths at Mt Buller on an annual basis.
- The Alpine National Park was extended to include important Mountain Pygmy-possum habitat on the western slopes of Mt Higginbotham (Vic) in 1983.
- From 1986, boulderfield corridors and tunnels were constructed and have successfully linked fragmented habitat areas and facilitated juvenile dispersal and movement of breeding males at Mt Hotham/Falls Creek (Mansergh & Scotts 1989; Van de Ree *et al*. 2009).
- There is active and ongoing engagement with affected interests and the broader community in conservation of the Mountain Pygmy-possum. A two-page article on the Mountain Pygmy-possum "Tunnel of Love" at Mt Hotham has been published in a variety of Australian senior high school texts on history, geography, society and environment (e.g. Bedson et al., 2010). This story has appeared in seven different titles over 10 years with a total print run of over 160,000.
- Species' requirements have been part of alpine resort planning and major development debates and decisions for over 25 years.
- An EPBC Act Conservation Agreement was made between the Commonwealth and Mt Buller Ski Lifts Pty Ltd for the rehabilitation and management of the area at the Mount Buller Ski Resort in 2005.
- The development of the Mt Buller Mountain Pygmy-possum Recovery Plan 2005, which is currently being revised with actions agreed between DELWP, the resort management board and the ski lift company.
- There are on-going integrated pest animal control programs addressing the management of foxes, cats, rabbits, deer and wild dogs in all resort areas (particularly at Mt Buller) and Alpine National Parks.
- Two large boulderfields (each 0.25 ha in size and using over 2,000 cubic metres of rock per site) were created to emulate and provide additional habitat at Mt Buller, with 35,000 plants used in revegetation works. A further six boulderfield corridors were constructed at Mt Buller to facilitate possum movement, with 50,000 plants used for revegetation works.
- Restrictions have been placed on the use of over-snow vehicles in some ski resort areas of Mountain Pygmy-possum habitat in Victoria.
- Some areas of habitat have been fenced to exclude both summer and winter recreational use.
- General protection works have been undertaken at all population and habitat sites including revegetation, weed control and sediment mitigation.
- Habitat definition, mapping and formal protection has been included in planning schemes for alpine resorts, with particular emphasis on preventing fragmentation and providing a high degree of protection for breeding areas. These maps and management zones have been incorporated as significant sites in all fire planning and implementation.
- Maps of fire severity in possum habitat during the 2003 (Bogong High Plains / Mt Hotham, Kosciuszko NP) and 2006 bushfires at Mt Buller (Harvey 2007), have identified areas requiring rehabilitation. Monitoring of fire-affected habitat and population response continues (Heinze 2005a, b, 2010).

- A captive colony was established at Healesville Sanctuary in 2006, using females and one male from Mt Buller and males from Mt Hotham. The aim is to breed animals with sufficient genetic diversity to release on Mt Buller, once habitat rehabilitation being undertaken by the Mt Buller and Mt Stirling Alpine Resorts Management Board is completed. Captive-born possums were reintroduced to Mt Buller in 2013, with ongoing monitoring of all released animals.
- In both 2010 and 2011, DSE approved the temporary translocation of six Mt Higginbotham males to Mt Buller to effect wild cross breeding and produce genetically more robust young. Two crosses from the first year successfully survived winter and bred. In Jan. 2012 - 50% (9 of 18 captured) of the cohort were cross-bred, being the first "genetic rescue" in Australia (Weeks *et al* 2011, 2012). The 2011 males remained on Mt Buller.

NSW

- Selected sites have been monitored annually for population changes in Kosciuszko National Park (KNP). They are Mt. Blue Cow (since 1986), Charlotte Pass, Summit road and The Paralyser (since 1987).
- Other selected sites in KNP have been monitored at two to five yearly intervals for population changes; they include Mt Kosciuszko, Mt Townsend, White's River, Gungartan and Gungartan Pass.
- Monitoring the abundance of Bogong Moths in Kosciuszko National Park (Mt Blue Cow and Charlotte Pass) is undertaken on an annual basis during the Spring monitoring program.
- Boulder-filled corridors and tunnels were constructed across and below ski runs at Mt Blue Cow to emulate habitat and provide links to areas of other habitat fragmented by ski runs. This has facilitated juvenile dispersal and movement of both sexes at Mt Blue Cow (Broome 2001b).
- There has been negotiated exclusion of all winter snow sports activities from an important habitat area on Mt Blue Cow in the Perisher Ski Resort.
- Mountain Pygmy-possum has been featured in KNP public brochures, posters, interpretative signage and news stories across the wider South east region of NSW.
- Maps of fire severity in possum habitat during the 2003 bushfires (Broome and Ford 2005) have identified areas requiring rehabilitation (Mt Blue Cow). Monitoring of fire-affected habitat and population response continues.
- Planting of around 1500 cuttings of Mountain Plum-pine taken from surviving plants at Mt Blue Cow following the 2003 fires has been undertaken.
- There are ongoing PhD and other research studies on Mountain Pygmy-possum ecology and biology in the KNP area.
- There is ongoing commitment to feral cat and fox control management programs through NSW National Parks and Ski resorts.
- There are preliminary negotiations underway to set up a captive colony of Mountain Pygmy-possums from KNP for further biological, ecological and husbandry research.

Management Practices and Policies

Management practices necessary to avoid a significant adverse impact on the Mountain Pygmy-possum include:

- protection of habitat from disturbance or destruction, including direct destruction of habitat, fragmentation of habitat (e.g. road construction through habitat), sedimentation from works away from habitat, fire protection works)
- creation of new habitat, including movement corridors between habitat patches
- effective control of feral predators such as foxes and cats

- effective control of weeds
- effective control and management of fire

Other relevant policy documents:

- Management Strategy and Guidelines for the Conservation of the Mountain Pygmy-possum (VIC) (Mansergh *et al.* 1989).
- The Victorian Department of Environment, Land, Water and Planning Flora and Fauna Guarantee Action Statement for the Mountain Pygmy-possum *Burramys parvus* (Mansergh 1991).
- Recovery Plan for the Mountain Pygmy-possum on Mt Buller, Victoria (2005) (Mount Buller and Mt Stirling Alpine Resort Management Board).
- The Alpine Resorts Planning Scheme (2000) and incorporated Environmental Significant Overlays (ESOs).
- Fire Protection Plan for the North East region: Mansfield, Ovens, Shepparton and Upper Murray Fire Districts 2003.
- Mount Buller and Mount Stirling Alpine Resorts Environmental Management Plan 2007 (Mount Buller and Mt Stirling Alpine Resort Management Board).
- Mount Buller Alpine Resort Wildfire Management Plan V.4 (2009) (Mount Buller and Mt Stirling Alpine Resort Management Board).
- Recovery Plan for the Mountain Pygmy-possum for New South Wales (NPWS, 2002).
- Kosciuszko National Park Plan of Management (2006).
- Kosciuszko National Park Fire Management Strategy (2008).
- Perisher Environmental Policy (2010).
- Perisher Range Resorts Environmental Management System (2002).
- Rehabilitation Guidelines for the Resort Areas of Kosciuszko National Park (2008).

Recovery Objectives

The long-term conservation objective for the Mountain Pygmy-possum is to ensure that the species persists across its range and maintains its potential for evolutionary development in the wild. However, with the severe threat to the species from climate change, alternative strategies for its long-term survival also need to be considered.

Within the life span of this recovery plan, the Specific Objectives for recovery are:

1. **To maintain or increase the number of Mountain Pygmy-possums in wild sub-populations that have declined and at least maintain current population levels at remaining sites**.

At present the total numbers of Mountain Pygmy-possums are critically low on Mt Buller and are still low at Mt McKay, Pretty Valley West in the Bogong High Plains and at Mt Blue Cow in Kosciuszko National Park. An increase in numbers at these sites is essential for the persistence of this species and its genetic viability at site and sub-population levels.

Sub-populations in other areas are currently relatively high following four years of high rainfall (2010-2013). This recovery, following *ca.* 10 years of drought illustrates the sensitivity of the species to climate and the long-term predictions of climate change. The objective for these sub populations is to maintain them at their current high levels. This will be achieved through control of direct threats, enhancement of habitat and population supplementation where required.

2. To maintain Victorian captive population and establish NSW captive breeding populations of Mountain Pygmy-possum.

The captive colony at Healesville Sanctuary should be maintained and enhanced to further develop captive husbandry techniques and knowledge of Mountain Pygmy-possum biology and husbandry.

A new captive breeding program focused on natural enclosures and adaptive processes is in negotiation for the NSW population as insurance against future catastrophic declines in NSW, and to investigate key questions regarding limits to Mountain Pygmy-possum distribution and its ability to respond to climate change effects.

3. To restore and prevent damage to habitat.

The availability of and access to suitable feeding, nesting and breeding habitat is the major factor affecting Mountain Pygmy Possum abundance. The availability of suitable nest and hibernation sites is a significant limiting factor in NSW. Shrubby heathland close to boulderfields is important for foraging and protection from predators and will be increasingly important if Bogong Moth numbers decline. Degradation to or loss of these areas or accessibility to them represents a major ongoing threat to the conservation of the species, and a range of actions are required to counter this threat. There is the need to restore habitat with the potential to reconnect previously fragmented sub-populations and allow for future movement corridors.

4. To investigate key aspects of the biology and ecology of the Mountain Pygmy-possum.

Knowledge of key elements of the biology and ecology of the Mountain Pygmy-possum is essential for developing the most appropriate management decisions for the survival of the species.

5. To assess the capacity of the Mountain Pygmy-possum to adapt to climate change and investigate alternate strategies to assist their long-term survival.

Most of the on-ground actions in this Recovery Plan are addressed at increasing the resilience of Mountain Pygmy-possums to climate change by reducing other direct threats such as degradation of habitat and predation. Under present climate change predictions, the probability of any of the current areas of habitat having winter snow cover by 2050 appears extremely low. A number of research actions are directed to better understand why Mountain Pygmy-possums are mostly restricted to areas above the winter snowline, and to obtain detailed measurements of microclimate and develop more accurate models of possum persistence. However, given the predictions, it is essential that the potential for Mountain Pygmy-possums to adapt to climate change is assessed. Alternative strategies to assist the long-term survival of the Mountain Pygmy-possum need to be considered.

6. To increase community awareness of and support for the conservation of the Mountain Pygmy-possum.

The Mountain Pygmy-possum is an icon species and interesting narratives have been created across a range of audiences (scientists, recreation and educationalists). Community awareness of, and support for the conservation of the Mountain Pygmy-possum is essential for enabling management actions to be undertaken. It is of particular importance to have the support of the skiing community since there is significant overlap between Mountain Pygmy-possum habitat and ski resorts.

Performance Criteria

The Recovery plan will be considered successful if within the 5-year lifetime of the plan it can achieve the following:

1. There is an overall increase in numbers of animals in each depleted wild sub-population and elsewhere wild sub-populations are maintained.
2. The Victorian captive breeding colony has reported increased number of individuals, and a captive breeding colony has been established for the NSW population and can demonstrate successful breeding[4].
3. There is no measurable loss of occupancy of habitat.
4. Key aspects of the biology and ecology (specific Objective 4) of the Mountain Pygmy-possum are determined and incorporated into planning and management for conservation of the species.
5. Studies and strategies into the Mountain Pygmy-possum's capability to adapt to climate change in an alternative environment have commenced.
6. An increase in community support, and ski resort user behaviour shows evidence the community understands and supports conservation measures undertaken for the Mountain Pygmy-possum.

[4] **Successful breeding** for the purpose of this recovery plan can be defined as at least 50% captive-born adults having bred and produced young.

Actions

Specific Objective 1:

To maintain or increase the number of Mountain Pygmy-possums in wild sub-populations that have declined and at least maintain current population levels at remaining sites.

Action 1.1 Monitor and control introduced mammal species.

Predation by the Red Fox and feral Cat is a major threat to the survival of the Mountain Pygmy-possum, and a reduction in predator numbers is essential. Rabbit and fox/cat control needs to coincide because rabbits can sustain high predator numbers (Lunney *et al*. 2002). Rabbits and hares also pose a threat to the Mountain Pygmy-possum through grazing pressure.

Tasks:

- Continue fox monitoring and control programs.
- Increase cat monitoring and control programs particularly within ski resort areas.
- Continue rabbit monitoring and control programs.
- Assess whether deer browsing and trampling is having an adverse effect on habitat

Integrated pest management strategies will continue or be implemented over the entire range of the Mountain Pygmy-possum and these will be progressively assessed and adapted to achieve better outcomes.

Responsibility: Vic Department of Environment, Land, Water and Planning (DELWP), NSW Office of Environment and Heritage (OEH), Parks Victoria, Alpine Resorts

Action 1.2 Assess the success of wild bred crosses (Higginbotham x Buller) at Mt. Buller.

A proposal for temporary release of Mt Higginbotham males to Mt Buller was implemented in 2010 and 2011 with the objective of increasing the genetic heterozygosity of the Mt Buller population, and to increase the breeding success and overall abundance of the Mt Buller population (Mansergh *et al*. 2010), while decreasing adverse observed genetic effects and inbreeding. The translocation program successfully bred genetically more robust young in the wild at Mt Buller (50% of the 2012 cohort monitored), producing a total of 11 cross-bred animals.

Tasks:

- Monitor the ecological fitness of the wild bred cross-breeds at Mt Buller.
- Assess the population to determine genetic composition, relative survival, fecundity and key demographic parameters (abundance, sex ratios etc.).
- Review success, risks and any impacts to Mt. Buller population, and examine future management options.

Responsibility: Vic DELWP.

Action 1.3 Undertake extensive surveys across potential habitat areas in Vic, NSW and the ACT to determine any extant yet undiscovered populations.

Discovery of new colonies of Mountain Pygmy-possum at three sites in the northern section of Kosciuszko National Park has raised questions of whether all potential areas of boulderfield habitat for the species have been thoroughly investigated. This discovery also suggests that Mountain Pygmy-possums may persist in areas of habitat at slightly lower elevations and slightly higher latitudes than previously recognised (Broome *et al.* 2013, L. Broome, unpubl. data).

Tasks:

- Add northern sites in Kosciuszko National Park to monitoring program.
- Assess and trap other potential habitat sites in Victoria, Kosciuszko National Park in NSW and the Brindabella Ranges region of NSW and ACT.
- Review surveys to determine whether future periodic trapping of these sites is warranted.

Responsibility: Vic DELWP, NSW OEH, ACT

Specific Objective 2:

To maintain Victorian captive colony and establish NSW captive breeding colonies of Mountain Pygmy-possum

Action 2.1 Maintain captive colony in Victoria for potential population supplementation at Mt Buller.

Tasks:

- Maintain the current captive colony.
- Monitor hibernation, reproductive behaviour and nutrition in-situ to increase knowledge of biology and improve husbandry.
- Define aims of genetic restoration for potential augmentation to Mt Buller population.

Responsibility: Vic DELWP, Healesville Sanctuary

Action 2.2 Establish a captive colony of Kosciuszko animals.

Individuals for captive breeding colonies will be selected to prevent loss of genetic variation and may include crossing between subpopulations to provide genetic restoration. Additional research questions concerning what is limiting Mountain Pygmy-possum populations will be addressed in future if surplus, captive-bred animals can be raised.

Tasks:

- Secure funding and establish an initial breeding colony at Secret Creek Sanctuary[5] .
- Investigate the feasibility of a further captive colony at Tidbinbilla Nature Reserve (as a joint project between NSW and ACT) or other suitable location.
- Investigate the feasibility of these colonies as supplementation for wild NSW populations.

Responsibility: NSW OEH, Foundation for National Parks and Wildlife (NSW), Secret Creek Sanctuary, UNSW.

[5] Secret Creek Sanctuary near Lithgow has been selected to house the first captive breeding colony of NSW animals due to its elevation and its ability to undertake this action.

Specific Objective 3:

To restore and prevent damage to habitat

Action 3.1 Create new boulderfield habitat.

Boulderfield habitat above 1,400 m (Vic) and 1,200 m (NSW) elevation is a critical component for Mountain Pygmy-possums as it provides shelter, hibernacula and aestivation sites for Bogong Moths.

Tasks:

- Identify areas for further boulderfield augmentation and habitat expansion in both NSW and Vic. This includes identifying specific locations for manually creating boulder areas and crossings that emulate boulderfield habitat.
- Undertake boulderfield augmentation and habitat expansion in suitable identified locations to assist breeding and movement near developments and provide protective islands between smaller colonies.
- Monitor boulderfield augmentation sites for Mountain Pygmy-possum and Bogong Moth use.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.2 Increase and restore native vegetation, to create and maintain feeding areas and movement corridors between disjunct populations or populations fragmented by human actions.

Native vegetation provides food for Mountain Pygmy-possums and shelter from predators. Damage to the Mountain Plum-pine is of particular concern due to its slow growth rate and long period required for recovery from damage. Some areas already identified as critical areas for revegetation include sites that were burnt by both the 2003 and 2006 fires, and areas damaged during construction or maintenance of ski runs.

Movement corridors will be maintained and created to assist foraging and enable gene flow through populations, movement of males into breeding areas and dispersal of juveniles.

Tasks

- Native vegetation regeneration and revegetation will be undertaken on selected modified ski slopes to assist movement of animals, particularly Zali's Ski Run at Mt Blue Cow in consultation with Perisher Ski Resort.
- Undertake revegetation of lost or previously damaged habitat caused by fire, snow-sport activities and clearing for roads and tracks.
- Monitor recovery and recruitment rate of Mountain Plum-pine in burnt areas and undertake revegetation where required.
- Construct corridors in priority areas including under the Great Alpine Road to link the upper and lower sections of boulderfield habitat located at Cherokee Corner at Mt Little Higginbotham.
- Monitor these movement corridors for use by Mountain Pygmy-possums.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.3 Determine and map habitat critical to the survival of the Mountain Pygmy-possum.

Identifying and mapping habitat critical to survival of the species is a key component required to protect the species and its habitat, especially in the context of ongoing development in alpine resorts.

Tasks:

- Identify current habitat maps available and consider their current utility and any information gaps.
- Identify and map potential movement corridors including broader dispersal areas to assist action 3.4.
- Identify habitat used by male and female Mountain Pygmy-possums for feeding, nesting and hibernation, movement corridors between male and female habitat, and dispersal corridors between habitat patches that constitute the minimum habitat critical to survival of the species.
- Identify and map habitat quality for all locations.

Responsibility: Vic DELWP, NSW OEH, Alpine Resorts.

Action 3.4 Reduce pressures and risks from ski slope activities.

Prime areas of Mountain Pygmy-possum habitat overlap with ski resorts, and many activities both in winter and summer have potentially harmful effects on the species and its habitat.

Tasks:

- Develop protocols with ski industry interests with the aim to reduce impacts and increase protection of habitat from activities such as snow grooming, snow farming, snow fencing, snow-making and summer slope grooming.
- Identify the limiting depth of snow cover to determine areas where the activities above should not occur under any circumstance.
- Ensure that protocols are followed to ensure protection to Mountain Pygmy-possum populations and habitat.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts, Ski Lift Companies.

Action 3.5 Reduce sedimentation impacts on habitat.

It is important to ensure appropriate methods for preventing soil disturbance within the vicinity of, or within any catchments upstream of Mountain Pygmy-possum habitat.

Tasks:

- Develop the most appropriate sediment mitigation design.
- Ensure appropriate drainage works and sediment traps are constructed before any disturbance occurs.
- Ensure sediment pits are appropriately designed, constructed and cleared regularly with the sediment transported away from the catchment.
- Ensure any areas of exposed soil are stabilised.
- Ensure activities that disturb vegetation or soil and may interact with Mountain Pygmy-possum habitat are limited to December–March whenever possible.

Responsibility: NSW OEH, Parks Victoria, Alpine Resorts, Ski Lift Companies.

Action 3.6 Monitor and control weeds if they threaten habitat.

Invasive weeds can threaten habitat in some areas. Early intervention and control of weeds affecting, or likely to affect Mountain Pygmy-possum habitat needs to be undertaken.

Tasks:

- Control woody weeds including willows, Apple and Blackberry where they threaten habitat.
- Monitor and control the spread of exotic grasses.

Responsibility: NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.7 Manage walking tracks and roads to avoid impact on habitat.

Construction and modification of walking tracks and roads adversely affect the Mountain Pygmy-possum through habitat modification or increased sediment input.

Tasks:

- Investigate and implement mechanisms to prevent widening, modification or re-alignment of roads.
- Realign walking and vehicle tracks away from the edges of boulderfields.

Responsibility: NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.8 Protect habitat from fire and fire suppression activities.

Extensive areas of Mountain Pygmy-possum habitat were burnt in bushfires in 2003 and 2006. In NSW and the ACT, all fire protection and response plans and databases must identify key areas of Mountain Pygmy-possum habitat with surrounding buffer areas to receive the highest priority protection from wildfire and fire suppression activities. In Victoria, mechanisms should be developed and implemented to enable fire suppression activities to take into consideration areas of important habitat, including boulderfields, surrounding heathland and corridors linking these.

Tasks:

- Develop and implement mechanisms that seek to ensure that all fire suppression activities occur outside areas of important habitat, including boulderfields, surrounding heathland and corridors linking these.
- Collaborate with ski resorts to assist local fire suppression using available infrastructure, such as water storage reservoirs and snow making equipment.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.9 Develop a site-specific management plan for each location for management of the Mountain Pygmy-possum.

The Mountain Pygmy-possum occurs in small, discrete areas, with each site varying slightly in its management requirements. Since each of the three major populations overlap with areas that are used intensively for recreation, detailed site management plans are required for each of the relevant alpine resorts. These plans should cater for all aspects of Mountain Pygmy-possum management specific to their respective locations, including additional measures to protect Mountain Pygmy-possum habitat.

Tasks:

- Develop or revise management plans specific to each relevant alpine resort area in collaboration with land managers and alpine resort management boards.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 3.10 Develop or amend planning scheme overlays or schedules for Mountain Pygmy-possum habitat and ensure currency in all planning processes.

Areas inhabited by the Mountain Pygmy-possum have been incorporated into the Victorian Alpine Resorts Planning Scheme as Environmental Significance Overlays, but these are in need of revision to more accurately map and protect habitat. In NSW, the Department of Planning and Environment is responsible for approvals for any development in the Kosciuszko National Park ski resorts guided by OEH's advice.

Tasks:

- Develop or amend Environmental Significance Overlays where required to include Mountain Pygmy-possum habitat and appropriate buffers at the alpine resorts at a scale useful for detailed planning decisions.

Responsibility: Vic DELWP, NSW OEH.

Specific Objective 4:

To investigate key aspects of the biology and ecology of the Mountain Pygmy-possum.

Action 4.1 Continue to undertake detailed population monitoring and collect demographic information.

Close monitoring of population size, change and dynamics such as survival, sex-ratio, body weight and breeding condition is essential for implementing effective site-specific management strategies, especially detecting the response of populations to management actions for conservation, and any disturbance.

Tasks:

- Determine adequacy of current monitoring programs and protocols and adjust if necessary.
- Review data to estimate and detect changes in population sizes and demographics and, where possible, determine if any factors are affecting their recovery.
- Conduct annual population monitoring in November/December for all populations at appropriate sites.

Responsibility: Vic DELWP, NSW OEH.

Action 4.2 Monitor Mountain Pygmy-possum diet and key food sources.

The composition of Mountain Pygmy-possum diet is highly variable between locations, seasons and years. Monitoring of diet and the availability of key food resources (Bogong Moths, Mountain Plum-pine seeds and fruits) can help explain fluctuations in population numbers and inform strategies for management.

Tasks:

- Collect and analyse scat samples from all annual monitoring sites.
- Monitor timing, presence and relative abundance of Bogong Moths.
- Monitor Mountain Plum-pine seeds and fruits.

Responsibility: Vic DELWP, NSW OEH.

Action 4.3 Investigate genetic composition, relatedness and undertake regular genetic monitoring of populations.

Mountain Pygmy-possum genetics has been documented for Victorian and NSW populations and most sub-populations. Maintaining the genetic diversity of all three regional populations is important for retaining the evolutionary potential of the Mountain Pygmy-possum for this species to be able to adapt to the predicted changes in environmental conditions resulting from climate change.

Tasks:

- Assess future annual monitoring results of the key threatened population at Mt Buller, and sub-populations at Mt McKay, Pretty Valley West and other Victorian sub-populations (each 5 years) against Victorian genetic baseline work to date.
- Continue collecting NSW genetic samples to provide a framework for future monitoring, and identify key sub-populations under threat from any loss of genetic diversity, or increase in inbreeding and genetic load.
- Collect genetic materials for study in any monitoring or translocations to be conducted *in situ* (either wild to wild or captive colony to wild translocations).
- Accurately determine the genetic relatedness and health within sub-populations and overall genetic robustness of each regional population.
- Investigate gene flow between populations after habitat rehabilitation or other disturbances.

Responsibility: Vic DELWP, NSW OEH.

Action 4.4 Investigate the source and availability of Bogong Moths.

Although varying by season and by site Bogong Moths are considered the single most important food item for the Mountain Pygmy-possum, and their availability probably underpins the survival and density of many sub-populations of Mountain Pygmy-possums. However, little is known of conditions that affect Bogong Moth abundance in the Australian Alps.

Tasks:

- Monitor Bogong Moth arrival times and relative abundance in Mountain Pygmy-possum habitat at ski resorts and where possible at other key sites in the Alps.
- Collect relevant information on Bogong Moth ecology and encourage studies into Bogong Moth:
    - population response to changes in environmental conditions and agricultural practices including the use of pesticides in winter breeding grounds.
    - whether there is any potential for transfer of organic pesticides via fat accumulation in Bogong Moths to summer aestivation sites
    - population sources in different aestivation sites in the Alps through genetic analysis or other methods.
    - likely effects of climate change and light pollution on Bogong Moth populations and migration patterns

Responsibility: Vic DELWP, NSW OEH.

Action 4.5 Monitor snow duration at each long-term monitoring site.

The yearly duration of snow cover and snow depth are likely to affect hibernation and survival of the Mountain Pygmy-possum. The effects of snow duration and depth on Mountain Pygmy-possum population dynamics at key sites and the effects of ski slope activities on snow dynamics need to be understood in order to better predict population responses to climate change, the effects of ski slope activities on Pygmy-possums and the future possibility of using snow farming or snow fencing to enhance snow cover on Mountain Pygmy-possum habitat.

Tasks:

- Monitor the presence of snow cover and if possible measure snow depth at long-term population monitoring sites, and sites enhanced by snow making or snow farming.
- Investigate and review the appropriateness of snow ski slope maintenance activities over and adjacent to areas of Mountain Pygmy-possum habitat.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 4.6 Monitor microclimate and develop population, snow dynamics and climate change models.

It has been predicted that a 1° C rise in mean temperature will result in the loss of the bioclimate of the Mountain Pygmy-possum (Brereton *et al*. 1995). However, it is not known to what extent the possum boulderfield habitat is able to buffer changes in temperature or temperature extremes. Data loggers have been deployed in areas of possum habitat over a range of elevations and aspects.

Tasks:

- Measure the microclimate within possum habitat.
- Develop population, snow dynamics and climate change models to better predict the likely persistence of Mountain Pygmy-possums.
- Using this information, identify sites most at risk from climate change and sites likely to be refugia under predicted environmental conditions.
- Use models to identify the most appropriate management strategies to mitigate adverse effects.

Responsibility: Vic DELWP, NSW OEH.

Action 4.7 Investigate interactions with potential competitors and predators.

The distribution and population size of Mountain Pygmy-possums may be influenced by competition and predation from co-occurring native and invasive species, in addition to feral predators.

Tasks:

- Examine interactions between possums and native and invasive small mammals.
- Assess predation risk from feral predators in relation to the distribution and availability of food resources, including Bogong Moths.
- Use this information to inform future management actions if possum populations continue to decline with climate change or due to a decrease in critical food resources.

Responsibility: NSW OEH, University of New South Wales.

Specific Objective 5.

To assess the capacity of the Mountain Pygmy-possum to adapt to climate change and investigate alternative strategies to assist its long-term survival

Action 5.1 Assess the capacity of the Mountain Pygmy-possum to breed and survive at higher temperatures and investigate the possibility of future translocations to alternative environments.

It is not known why the Mountain Pygmy-possum is restricted to areas above the winter snowline as its ancestors were widespread in the cool temperate climate of the Tertiary rainforests 12–24 million years ago. One possibility is that the environment at the edge of the snowline is simply too extreme and the Mountain Pygmy-possum has become isolated over evolutionary time in alpine areas that have insulating winter snow cover. If it can be demonstrated that Mountain Pygmy-possums can survive and breed in temperate environments without snow, this opens up the possibility of future translocations to alternative habitats.

Tasks

- Initiate and direct research projects into aspects of this question, including Mountain Pygmy-possum tolerance and adaptation to climate extremes, food supply and interactions with other species.
- Trial as part of the breeding program for the NSW Mountain Pygmy-possum, the ability of animals to sustain breeding and survival in an outdoor temperate environment.

Responsibility: NSW OEH, University of NSW, Secret Creek Sanctuary.

Specific Objective 6:

To increase community awareness of and support for the conservation of the Mountain Pygmy-possum.

Action 6.1 Develop, publish and distribute informative material on the conservation status of Mountain Pygmy-possum and its habitat protection to a range of audiences.

Tasks:

- Produce information brochures and other material on Alps and Mountain Pygmy-possum conservation issues and distribute or display at the alpine resorts, National Park Offices, at field days and on the web.
- Report progress on the recovery of the Mountain Pygmy-possum.

Responsibility: Vic DELWP, NSW OEH, Parks Victoria, Alpine Resorts.

Action 6.2 Encourage Indigenous and broader community engagement in the conservation of the Mountain Pygmy-possum.

Tasks:

- Advertise survey, monitoring and habitat rehabilitation work opportunities for community participation in recovery activities for the Mountain Pygmy-possum.
- Encourage the reporting of sightings of Mountain Pygmy-possums.
- Encourage the reporting of sightings of feral animals.
- Document skier incursions into restricted habitat areas of ski resorts

Responsibility: Vic DELWP, NSW OEH, Parks Victoria.

Program Implementation and Evaluation

This Recovery Plan guides recovery actions for the Mountain Pygmy-possum and will be implemented and managed by DELWP for Victorian populations and OEH for the NSW population (subject to available resources), supported by other agencies, educational institutions, regional natural resource management authorities and community groups as appropriate. Implementation of individual actions will remain the responsibility of the relevant agencies and organisations identified in the Recovery Plan (subject to available resources), who will be responsible for preparing work plans and monitoring progress toward recovery within their own jurisdiction. Technical, scientific, habitat management or education components of the Recovery Plan will be referred to specialist groups on research, *in situ* management, community education and cultivation as required. Contact will be maintained between the state agencies on recovery issues concerning the Mountain Pygmy-possum. The Recovery Plan will run for five years from the date of its adoption under the EPBC Act, and will be reviewed by DELWP and OEH and revised within five years of the date of its adoption.

Interests Affected by the Plan

Interests that may be affected by implementation of the Mountain Pygmy-possum Recovery Plan include:

- Department of Environment, Land, Water and Planning (Victoria)
- NSW Office of the Environment and Heritage
- Department of the Environment (Australian Government)
- Parks Victoria
- Mt Hotham Alpine Resort Management Board
- Falls Creek Alpine Resort Management Board
- Mt Buller and Mt Stirling Alpine Resort Management Board
- Mt Buller Ski Lift Company
- Private landowner at Mt Hotham
- Perisher Blue Pty Ltd
- Charlotte Pass Village Pty Ltd
- Kosciuszko Thredbo Pty Ltd
- Snowy Hydro Ltd
- Country Fire Association (VIC) and Rural Fire Service (NSW)

Role and Interests of Indigenous People

Indigenous peoples on whose traditional lands the Mountain Pygmy-possum occurs have been advised, through the relevant regional indigenous facilitator, of this Recovery Plan, and invited to comment and be involved in the implementation of the Recovery Plan.

Indigenous peoples in NSW with a potential interest in the plan include the Ngarigo, Walgalu, Bidawal, Djilamatang, Ngunnawal, Duduroa (Young *et.al* 2000) and possibly Wiradjuri (Flood 1980). There appears to be little historic, environmental or cultural evidence that aboriginal people had any direct connection with the Mountain Pygmy-possum as such (Flood 1980), but more importantly with its habitat, the boulderfields, and its primary food source, the Bogong Moth. Aboriginal peoples travelled from many directions to the alpine and subalpine areas in summer to feast on this major seasonal food source (Flood 1980).

Social and Economic Impacts

The implementation of this Recovery Plan will have some social and economic impacts, although these are unlikely to be significant. A large proportion of all three populations occur within national parks. A large extent of the Mountain Pygmy-possum habitat occurs within or very close to the major ski resorts. Over the past decade, resort managers have worked closely with natural resource management agencies to reduce the impact of recreational skiing and infrastructure on the Mountain Pygmy-possum. There will be ongoing costs associated with prevention of damage to habitat, protection of habitat, control of feral predators and weeds and creation of new habitat. The only site (0.2 ha) where the species occurs on private property is steep, rocky and unsuitable for development, so there are unlikely to be any lost opportunity costs through prohibition of development of this site.

The recovery plan does not consider the economic effects of any remedial action that might be undertaken to counter the effects of climate change. As a key species that is likely to be one of the first to be measurably affected by climate change, survival of the Mountain Pygmy-possum will ultimately depend on effective action to reduce the extent of climate change.

Biodiversity Benefits

The Mountain Pygmy-possum is the only Australian mammal endemic to the alpine area. Because it persists in very restricted habitat and specific climatic parameters, it is an indicator species for the health of some alpine ecosystems, particularly with respect to projected effects of climate change. Protection of habitat for the Mountain Pygmy-possum will protect boulderfield heath vegetation communities.

Feral predator control programs and climate modelling will also benefit the endangered Southern and Northern Corroboree Frogs (*Pseudophryne* spp.), Broad-toothed Rat (*Mastacomys fuscus*) and other native species in alpine and subalpine environments. The protection of Mountain Pygmy-possum habitat will benefit many alpine and subalpine vegetation species, particularly the Mountain Plum-pine which is also an alpine endemic, slow growing and easily damaged.

The Mountain Pygmy-possum occurs in small, fragmented sub-populations. These sub-populations are proving to be excellent subjects for studies of genetic partitioning and heterozygosity within and between populations, providing real-life models against which to test conservation genetics theory. This information will assist in designing management plans to conserve species in artificially fragmented environments and under climate change.

Studies of the physiological, behavioural and evolutionary ability of the Mountain Pygmy-possum to adapt to alternate, warmer environments will have benefits to a suite of species that are likely to face similar threats from climate change in the future.

The raising of community awareness that will accompany the recovery actions for the Mountain Pygmy-possum will contribute to better appreciation of, and behaviours toward Australia's fragile alpine and subalpine environments. It is also one of the fauna species most obviously threatened by climate change and could be used as a flagship species in promoting the control of carbon emissions.

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Priority, Feasibility and Indicative Costs of Recovery Actions

Action	*Description*	*Priority*	*Feasibility*	*Responsibility*	*Cost estimate*					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total
1	**Maintain/Increase numbers**									
1.1	Control introd. mammals	1	75%	DELWP, OEH, PV, AR	$250,000	$250,000	$250,000	$250,000	$250,000	$1,250,000
1.2	Wild cross breeding Victoria	1	75%	DELWP	$0	$0	$25,000	$50,000	$50,000	$125,000
1.3	Surveys NSW, VIC ACT	1	75%	DELWP, OEH, ACT	$0	$100,00	$40,000	$40,000	$40,000	$220,000
2	**Captive colonies**									
2.1	Maintain captive colony (VIC)	2	50%	DELWP, HS	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
2.2	Establish KNP captive colony	1	75%	OEH, FNPW, SCS, UNSW	$0	$633,000	$106,000	$117,500	$118,500	$975,000
3	**Habitat**									
3.1	Create boulderfields	1	100%	DELWP, OEH, PV, AR	$10,000	$200,000	$200,000	$200,000	$200,000	$810,000
3.2	Restore/create corridors	1	100%	DELWP, OEH, PV, AR	$10,000	$200,000	$200,000	$200,000	$200,000	$810,000
3.3	Determine critical habitat	1	100%	DELWP, OEH, AR	$50,000	$50,000	$50,000	$0	$0	$150,000
3.4	Reduce skiing impacts	1	85%	DELWP, OEH, PV, AR, SLC	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
3.5	Reduce sedimentation	1	85%	OEH, PV, AR, SLC	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
3.6	Control weeds	2	75%	OEH, PV, AR	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000
3.7	Manage tracks, roads	1	100%	OEH, PV, AR	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
3.8	Protect habitat from fire	2	75%	DELWP, OEH, PV, AR	$25,000	$25,000	$25,000	$25,000	$25,000	$125,000
3.9	Develop mgt plans	2	100%	DELWP, OEH, PV, AR	$0	$10,000	$0	$0	$0	$10,000
3.10	Amend planning schemes	2	100%	DELWP, DPCD, OEH	$0	$10,000	$0	$0	$0	$10,000
4	**Investigate biology**									
4.1	Undertake monitoring	1	100%	DELWP, OEH	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
4.2	Monitor diet and food	2	100%	DELWP, OEH	$10,000	$10,000	$10,000	$10,000	$10,000	$50,000

4.3	Investigate genetics	2	100%	DELWP, OEH	$0	$20,000	$20,000	$0	$0	$40,000
4.4	Bogong Moth research	2	85%	DELWP, OEH	$0	$100,000	$100,000	$100,000	$100,000	$400,000
4.5	Monitor snow duration & depth	2	100%	DELWP, OEH, PV, AR	$10,000	$10,000	$10,000	$10,000	$10,000	$50,000
4.6	Microclimate and modelling	2	85%	DELWP, OEH	$50,000	$50,000	$50,000	$2,500	$2,500	$155,000
4.7	Species interactions	2	85%	OEH, UNSW	$50,000	$50,000	$50,000	$50,000	$0	$200,000
5	**Climate change adaptation**									
5.1	Assess capacity for CC adaptation	2	85%	OEH, UNSW, SCS	$0	$180,00	$30,000	$270,000	$30,000	$510,000
6	**Community support**									
6.1	Produce education material	3	100%	DELWP, OEH, PV, AR	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
6.2	Community engagement	3	75%	DELWP, OEH, PV	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
				TOTALS	$919,000	$2,352,000	$1,620,000	$1,779,000	$1,490,000	$8,160,000

Abbreviations:

AR = Alpine Resorts (Mt Buller, Mt Stirling, Mt Hotham, Falls Ck);

DELWP = Dept. of Environment, Land, Water and Planning;

FNPW = Foundation for National Parks and Wildlife (NSW);

HS = Healesville Sanctuary;

OEH = Office of Environment and Heritage, Dept. of Planning and Environment;

PV = Parks Victoria;

SCS = Secret Creek Sanctuary;

SLC = Ski Lift Companies (Mt Buller, Mt Stirling, Mt Hotham, Falls Ck);

UNSW = University of New South Wales.