Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Petrogale penicillata* (Brush-tailed Rock-wallaby)

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 23 November 2021.

This document provides a foundation for conservation action and further planning.

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Conservation status

Petrogale penicillata (Brush-tailed Rock-wallaby) is listed in the Vulnerable category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) effective from 16 July 2000. The species is eligible for listing because prior to the EPBC Act, it was listed as Vulnerable under the *Endangered Species Protection Act 1992* (Cwlth).

The main factor that makes the species eligible for listing in the Vulnerable category is substantial population decline, due to climate change, invasive species, habitat loss, disturbance or modification and disease.

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this species under relevant state or territory legislation, see the Species Profile and Threat Database.

Species information

Taxonomy

Conventionally accepted as *Petrogale penicillata* Gray (1827).

No subspecies have been recognised. However, three evolutionarily significant units (ESUs) with significant genetic divergence (Menkhorst & Hynes 2010) have been defined: Southern ESU (Victorian (Vic) subpopulations), Central ESU (central New South Wales (NSW) subpopulations) and Northern ESU (north-eastern NSW and south-eastern Queensland (QLD) subpopulations) (Browning et al. 2001; Paplinska et al. 2011; Hazlitt et al. 2014; Eldridge et al. 2017). Given the genetic divergence among ESUs, ESUs should be managed independently (Browning et al. 2001; Hazlitt et al. 2014).

Description

The Brush-tailed Rock-wallaby is a medium-sized marsupial. Adults weigh 6–11 kg for males and 5–8 kg for females, with a head-body length of 53–59 cm for males and 51–57 cm for females, and tail length of 51–70 cm for males and 50–63 cm for females. Colouration is generally dull brown above, tending to reddish-brown on the rump, grey on the neck and shoulders, with lighter colouration underneath and darker limbs. The head is darker, with a distinct pale stripe from the upper jaw through the cheek to the base of the ears. Juveniles are more distinctly marked than adults. The posterior third of the tail is bushy. There are slight morphological variations in northern subpopulations, which have lighter colouration and less prominent tail brush than southern subpopulations. This description is drawn from Bayne (1994), Eldridge & Close (1998) and Menkhorst & Hynes (2010).

Distribution

Historical distribution

The Brush-tailed Rock-wallaby was formerly widely distributed throughout south-eastern Australia, from south-eastern QLD through NSW and the ACT to western Vic, in the Brigalow Belt South, Cobar Peneplain, Darling Riverine Plains, Nandewar, New England Tablelands, NSW North Coast, NSW South Western Slopes, South East Corner, South Eastern Highlands, South Eastern QLD, Sydney Basin and Victorian Midlands IBRA7 Bioregion (Menkhorst & Hynes 2010). The species' distribution has declined by 50 to 90 percent (Short & Milkovits 1990) since European occupation, especially in isolated subpopulations in the southern and western parts of its range (Menkhorst 1995; Menkhorst & Hynes 2010).

Current distribution

The Brush-tailed Rock-wallaby has a disjunct range in south-eastern Australia, mostly associated with the Great Dividing Range (GDR), from the Grampians, in western Vic, to Yarraman, in south-eastern QLD (Menkhorst & Hynes 2010; Woinarski et al. 2014a). It has gone extinct in the Darling Riverine Plains and Cobar Peneplain IBRA7 Bioregions, and remnant populations are predominantly distributed on the eastern scarp of the GDR, with outlying subpopulations occurring in the Warrumbungle Ranges and Mount Kaputar in inland NSW (Menkhorst & Hynes 2010). Since 2004, many dozens of subpopulations have been extirpated (Woinarski et al. 2014a). In 2008, the total population size was estimated to be between 15 000 and 30 000 individuals, with approximately 80 percent of individuals in north-eastern NSW, 17 percent in south-eastern Qld, two percent in central and south-eastern NSW and less than one percent in Vic (DECC 2008). Over 960 sites with evidence of Brush-tailed Rock-wallaby occupation have been documented across the range of the species (DECC 2008). In 2004, 77 percent of these sites (739 sites) were occupied, 15 percent (145 sites) were unoccupied and eight percent (78 sites) had undetermined occupancy (DECC 2008). Approximately 50 percent of sites were within conservation reserves, 10 percent on other crown land, mostly state forests, and 40 percent on private land (DECC 2008).

The Brush-tailed Rock-wallaby lives in colonies, typically comprising fewer than 30 individuals, with many colonies consisting of only two to four mature individuals (Hazlitt et al. 2006; Piggott et al. 2006a; Piggott et al. 2006b). Historically, the Brush-tailed Rock-wallaby occurred as a metapopulation comprised of colonies centred on areas of high-quality rock habitat that provided adequate refuges within reach of reliable food resources (Menkhorst & Hynes 2010). However, due to the combined effects of habitat loss and fragmentation, predation and other threats, colonies are now highly fragmented and isolated from one another (Menkhorst & Hynes 2010). In this context, contemporary colonies or clusters of colonies separated by areas that are now barriers to dispersal, for example because they are cleared, can now be considered to be independent subpopulations. Decline and extirpation is likely inevitable at most smaller colonies without intensive management of threats and manipulation of genetic stocks (Woinarski et al. 2014a).

The Southern and Central ESUs are separated by approximately 320 km, between Snowy River National Park, Vic (Southern ESU) and Kangaroo Valley, NSW (central ESU; Menkhorst & Hynes 2010). The boundary between the Central and Northern ESUs is not known, but there appears to be a contact zone between Woko National Park, NSW and Broke, NSW (Eldridge & Browning 2004). In Victoria (Southern ESU) in 2020, the Brush-tailed Rock-wallaby was persisting in a small wild subpopulation in Little River Gorge, Snowy River National Park in East Gippsland and in a small, reintroduced subpopulation in Grampians National Park (Bluff et al. 2011; DELWP 2020). It is estimated that fewer than 100 individuals in the Southern ESU remain in the wild (Bluff et al. 2011; DELWP 2020; Tidbinbilla Nature Reserve 2020). Mt Rothwell and Tidbinbilla Nature Reserve (ACT Government) have captive populations of the southern ESU. The ACT Government has a captive breeding program in progress at Tidbinbilla Nature Reserve, which will create genetically robust founders for a safe haven (in development). This subpopulation will serve as an insurance subpopulation, provide a source of animals for reintroductions in Victoria, and create opportunities for research aimed at improving reintroduction success (ACT Government 2015; Tidbinbilla Nature Reserve 2020).

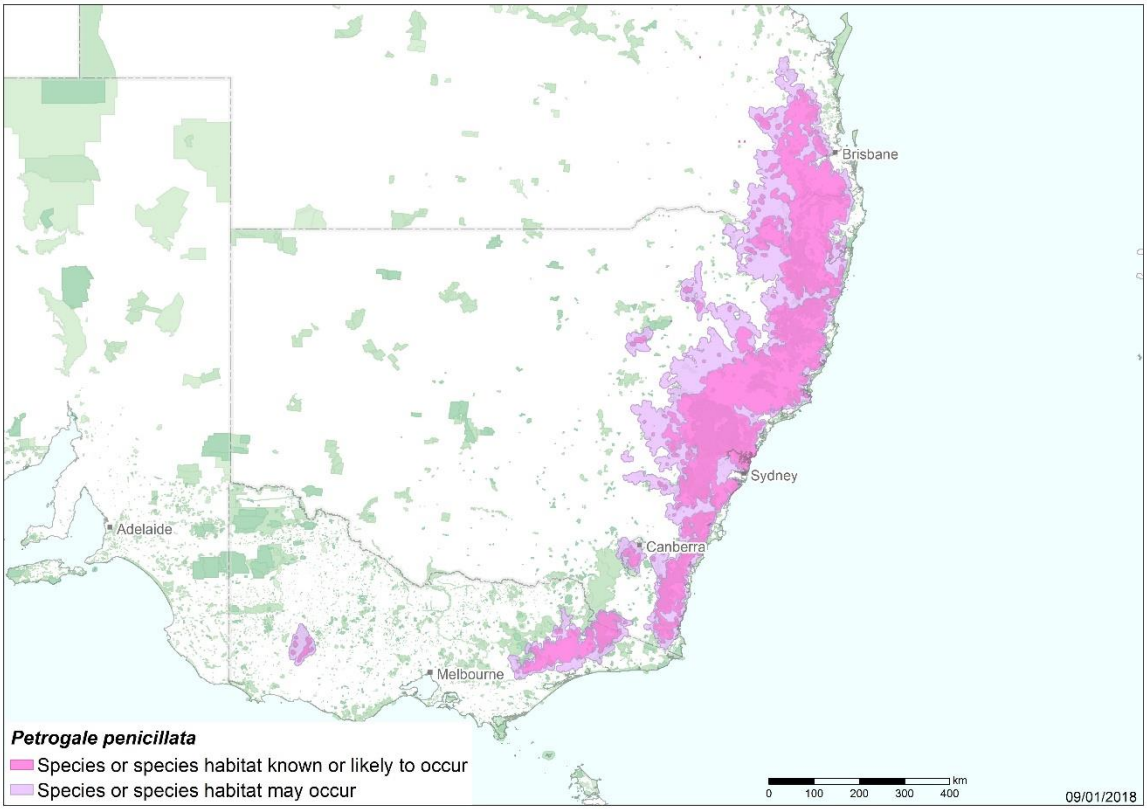
In central NSW (Central ESU), the Brush-tailed Rock-wallaby has disappeared south of Nowra/Goulburn and from virtually all sites west of the GDR, including Coombie, Gundabooka, Mount Oxley and the Weddin Mountains (Short & Milkovits 1990; Dovey et al. 1997; DECC 2008). Reintroductions to supplement declining subpopulations have been conducted in Shoalhaven, Jenolan Caves and Warrumbungle National Parks (Menkhorst & Hynes 2010). The Brush-tailed Rock-wallaby is presumed extinct in the wild in the ACT, as it has not been observed since 1959 (Ormay 1996). Skeletal material of the Brush-tailed Rock-wallaby was discovered in Namadgi National Park in the 1990s; however, it was not possible to date the remains (Ormay 1996).

In north-eastern NSW and south-eastern QLD (Northern ESU), the status of the Brush-tailed Rock-wallaby is poorly understood. The species remains locally common in gorges in the upper reaches of coastal streams, particularly the Macleay River and Clarence River gorge complexes (Hill 1991; Menkhorst & Hynes 2010). Core refuge areas in Qld are Moogerah Peaks, Main Range, Mount Barney and Crows Nest National Parks, Flinders Peak Conservation Park (Krieger 2010) and Glen Rock State Forest (Krieger and Capararo 1999).

Extralimital distribution

The Brush-tailed Rock-wallaby was introduced and became established in New Zealand and Hawaii (Lazell et al. 1984; Warburton & Sadlier 1995; Eldridge et al. 2001). The species is regarded as a pest in both countries and has now been eradicated in New Zealand (Menkhorst & Hynes 2010).

Map 1 Modelled distribution of Brush-tailed Rock-wallaby



Source: Species distribution data Species of National Environmental Significance database, base map Geoscience Australia

Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein.
Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the specific habitat type or geographic feature that represents to recent observed locations of the species (known to occur) or preferred habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

Wallabies feature in Dreaming Stories across Australia. Wallabies were an important source of food and fur for Indigenous Peoples and incorporated into the social and ceremonial fabric of Indigenous culture and tradition. The name Wallaby is derived from the Eora word, Wulaba. Wallabies have been documented in rock engravings in Eora country, dating back as far as 5000 years ago (Sydney Barani 2013). The Brush-tailed Rock-wallaby and its habitat occurs on the country of many Traditional Owner groups.

Relevant biology and ecology

Habitat ecology

During the day, the Brush-tailed Rock-wallaby rests and basks in rugged rocky areas, including rock faces and outcrops, with a preference for north-facing fissures, caves and ledges (Short 1982; Waldegrave-Knight 2002; Murray et al. 2008). The Brush-tailed Rock-wallaby forages in grassy forest and woodland habitats, as well as in artificial clearings and pastures, close to their daytime refuge areas, usually at night (Menkhorst & Hynes 2010). The home range of the Brush-tailed Rock-wallaby is approximately 15 ha and consists of refuge and foraging habitat, linked by habitually-used commuting routes (Short 1980; Menkhorst & Hynes 2010). Rock-wallabies typically move from refuge habitat to foraging habitat around dusk, returning to refuge habitat before dawn (Carter & Goldizen 2003).

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

Reproductive ecology and life history

The Brush-tailed Rock-wallaby forms matrilineal groups, usually composed of four to 10 individuals (Hazlitt et al. 2004). Groups form polygynous bonds with a single male, who has a slightly larger range than the females (Hazlitt et al. 2004). Females are highly philopatric and settle in or near their mother's range, while males disperse to other groups within the colony and less commonly between colonies (Joblin 1983; Bayne 1994; Hazlitt et al. 2004).

The Brush-tailed Rock-wallaby produces an average of 1.1 young per year (Bluff et al. 2011), with most births occurring from February to May (Joblin 1983; Wynd et al. 2006). The gestation period is approximately 30 days, with permanent pouch emergence occurring at approximately 204 days and weaning at approximately 290 days (Lee & Ward 1989). Embryonic diapause occurs in this species and females can carry a pouch young while simultaneously suckling a

young-at-foot (Wynd et al. 2006). The apparent mortality rate of individuals in their first year of life is 69 percent, suggesting predation is the strongest extrinsic factor limiting population growth (Bluff et al. 2011). Females reach sexual maturity at 18 months and males at 20 to 24 months (Lee & Ward 1989). Longevity ranges from eight to 14 years (Jones et al. 2009; Woinarski et al. 2014a), so generation length is considered to be seven to eight years (Woinarski et al. 2014a).

Diet

The Brush-tailed Rock-wallaby uses food resources on multiple spatial scales by combining a generalist feeding strategy at a broad scale (across subpopulations) with a specialised feeding strategy of particular plant species at a fine scale (within subpopulations; Tuft et al. 2011). Individual foraging ranges are small, averaging 2–3 ha, within which individuals feed in preferred patches of short grass, often of less than 0.1 ha (Laws & Goldizen 2003). The diet of the Brush-tailed Rock-wallaby mainly consists of grasses; however, *Acacia* flowers, forbs, leaves, fruit, bark and fruiting bodies of hypogeal fungi are also opportunistically consumed (Jarman & Phillips 1989; Short 1989; Fleming 2000; Carter & Goldizen 2003; Tuft et al. 2011; van Eeden et al. 2011).

Habitat critical to the survival

It is not practicable to describe habitat critical to the survival of this species. Large areas of potential habitat for this species are unsurveyed and confirmation as habitat can only be achieved through detection-based presence/absence field surveys. In the absence of confirmed occupancy, potential habitat can be identified as necessary to support the recovery of this species through verification of the presence of habitat attributes. The species eligibility for listing and key threat being the loss, degradation and fragmentation of habitat suggests that all habitat for the species either now or at some point in the near future is likely to be critical to the survival of the species.

No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

Important populations

In this section, the word population is used to refer to subpopulation, in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

Populations important to the survival of the Brush-tailed Rock-wallaby include stronghold populations, populations at the limits of the species range, outlying populations, research populations, captive populations, and other populations where recovery actions, such as predator control or reintroductions, are being implemented (DECC 2008; Menkhorst & Hynes 2010; OEH 2020). The following list of important populations is not exhaustive:

- Grampians Range population (Vic)
- East Gippsland population (Vic)
- Warrumbungle Range/Mount Kaputar populations (NSW)
- Shoalhaven population (NSW)
- Nattai National Park population (NSW)
- Wollemi National Park and Jenolan Caves populations (NSW)
- Wolgan population (NSW)
- Watagans population (NSW)
- Big Yango population (NSW)
- Barnard River population (NSW)
- Macleay Gorges population (NSW)
- Shanno Creek population (NSW)
- Guy Fawkes River population (NSW)
- Green Gully population (NSW)
- Moogerah Peaks National Park population (Qld)
- Main Range National Park population (Qld)
- Mount Barney National Park population (Qld)
- Crows Nest National Park population (Qld)
- Flinders Peak Conservation Park population (Qld)
- Glen Rock State Forest population (Qld)

All populations in the Southern ESU and most remaining populations in the Central ESU have substantially declined and are at risk of extinction due to their small population size and fragmented distributions (Menkhorst & Hynes 2010). An associated loss of genetic diversity has been identified as a significant issue affecting the long-term survival prospects of the Southern ESU (Weeks 2014, confidential report). Accordingly, in situ populations of the Southern ESU in Vic and those in captivity (Tidbinbilla Nature Reserve and Mt Rothwell) are critical for the persistence of the Southern ESU.

Meanwhile, populations of the Northern ESU are likely to be important for the persistence of the species overall (Menkhorst & Hynes 2010). However, there are likely to be some populations, particularly in the Northern ESU, for which locality, population size and geographic extent have not been recorded (Menkhorst & Hynes 2010).

Threats

The Brush-tailed Rock-wallaby is threatened by climate change, invasive species, habitat loss, disturbance or modification and disease (Table 1). The species is threatened by several fire-related threats, including high severity fires, fire-drought interactions and fire-predator interactions. Isolated subpopulations of the Brush-tailed Rock-wallaby are highly susceptible to extinction via stochastic processes due to their small population size and fragmented distribution (Menkhorst & Hynes 2010; OEH 2019).

Table 1 Threats impacting Brush-tailed Rock-wallaby

Threat	Status and severity [a]	Evidence
Invasive species		
Predation by the European Red Fox (*Vulpes vulpes*)	• Timing: current • Confidence: known • Consequence: major • Trend: increasing • Extent: across the entire range	Predation by the European Red Fox (*Vulpes vulpes*) is listed as a Key Threatening Process under the EPBC Act (DEWHA 2008b) and has been implicated in the decline and extinction of many terrestrial, non-volant, mammal species (Ashby et al. 1990; Dickman 1996; Woinarski et al. 2014b; Radford et al. 2018). The Brush-tailed Rock-wallaby is highly susceptible to predation by the European Red Fox (Radford et al. 2018). Adults are not in the critical weight range at high risk of predation, but juveniles and sub-adults fall into this range (Burbidge & McKenzie 1989; Burbidge & Friend 1990). The restriction of Rock-Wallabies to rocky refuge habitat may be an artefact of predation by the European Red Fox (Jarman & Bayne 1997). Although this refuge habitat provides protection, it does not protect foraging and dispersing juveniles (DECC 2008). The European Red Fox preys on young Rock-wallabies and likely limits their dispersal and recruitment (Short 1980; Sharpe 1999; Woinarski et al. 2014a). Indeed, predation by the European Red Fox has been identified as the cause of at least 50 percent of Brush-tailed Rock-wallaby mortalities in Grampians National Park from 2008 to 2013 (Taggart et al. 2016). The apparent mortality rate of individuals in their first year of life is 69 percent, suggesting predation is the strongest extrinsic factor limiting population growth (Bluff et al. 2011). If the predation rate on juveniles exceeds the birth rate of the colony, the colony will die out within the lifetime of the existing adults (approximately five and ten years), unless there is recruitment from outside the colony (DECC 2008). Predation pressure by the European Red Fox is likely to have increased following the 2019-20 bushfires, as the loss of dense cover increases exposure whilst foraging (Claridge 1998; Claridge & Barry 2000; Van der Ree & McCarthy 2005; Hradsky et al. 2017).

Threat	Status and severity [a]	Evidence
Habitat degradation and competition with introduced herbivores	• Timing: current • Confidence: known • Consequence: moderate • Trend: increasing • Extent: across the entire range	Rock-wallabies frequently compete for foraging habitat with Rabbits (*Oryctolagus cuniculus*), unmanaged Goats (*Capra hircus*) and feral Horses (*Equus caballus*), and refuge habitat with unmanaged Goats (Short & Milkovits 1990; Menkhorst & Hynes 2010). Rabbits and unmanaged Goats are found in all states and territories of Australia and have been listed as a Key Threatening Process under the EPBC Act (DEWHA 2008a; DOEE 2016). Rabbits, unmanaged Goats and feral Horses can destroy and degrade native vegetation, by trampling and grazing plants, preventing plant regeneration, altering ecological communities and promoting weed invasion (DEWHA 2008a; DSEWPC 2011b; DOEE 2016). Excessive grazing by introduced herbivores may cause rock-wallabies to forage further from the rocky refuge, increasing exposure to predators (Hayward et al. 2011). Monitoring in Warrumbungle Range demonstrated a negative correlation between the density of unmanaged Goat pellets and Rock-wallaby pellets in both foraging and refuge areas (Moss et al. 1997). Additionally, unmanaged Goats are thought to be the cause of extirpation of the Dingo Creek colony in Warrumbungle National Park (Moss et al. 1999). If such species reach high densities, they could reduce foraging habitat quality and food supply for the Brush-tailed Rock-wallaby (DECC 2008). The impact of Rabbits often increases following droughts and bushfires, as food resources are scarce (DSEWPC 2011a), so the impact of this threat may be greater following the 2019-20 bushfires.
Predation by Feral Cats (*Felis catus*)	• Timing: current • Confidence: inferred • Consequence: moderate • Trend: increasing • Extent: across the entire range	Predation by feral Cats (*Felis catus*) is listed as a Key Threatening Process under the EPBC Act (DOE 2015b) and is implicated in the decline and extinction of many terrestrial, non-volant, mammal species (Ashby et al. 1990; Dickman 1996; Woinarski et al. 2014b; Radford et al. 2018). Brush-tailed Rock-wallabies, particularly juveniles, are susceptible to predation by Feral Cats (Radford et al. 2018). The impact of Feral Cats is thought to be less significant than that of European Red Foxes (Radford et al. 2018). However, control of European Red Foxes may inadvertently lead to increased abundance of Feral Cats (Risbey et al. 2000). As the Brush-tailed Rock-wallaby relies on specific refuge sites, it is susceptible to predators that can learn the location and pathway to refuge sites (Jarman & Bayne 1997). Indeed, a single Feral Cat was implicated in the death of five (46 percent) juveniles, one (14 percent) sub-adults and at least two (5 percent) adults, in a subpopulation of *Petrogale assimilis* (Allied Rock-wallaby) in northern Qld (Spencer 1991). Predation pressure by feral Cats is likely to have increased following the 2019-20 bushfires, as the loss of dense cover increases exposure whilst foraging (Claridge 1998; Van der Ree & McCarthy 2005; Arthur et al. 2012; McGregor et al. 2014; MacGregor et al. 2015; Leahy et al. 2016).

Threat	Status and severity [a]	Evidence
Predation by wild Dogs (*Canis familiaris*)	• Timing: current • Confidence: known • Consequence: minor • Trend: increasing • Extent: across the entire range	Predation by wild Dogs (*Canis familiaris*) is listed as a Key Threatening Process under the *NSW Threatened Species Conservation Act (1995)* and can have negative impacts on some threatened species (DPI 2017). Recent anecdotal and monitoring evidence suggests that the distribution and impacts of wild Dogs are increasing in some parts of NSW (DPI 2017). Remains of the Brush-tailed Rock-wallaby have been found in wild Dog scats in Apsley and Macleay National Parks (Lunney et al. 1996). However, the impact of wild Dogs is thought to be less than that of European Red Foxes, as they are less likely to invade the refuge habitats of the Brush-tailed Rock-wallaby (Menkhorst & Hynes 2010).
Weed invasion	• Timing: current • Confidence: suspected • Consequence: minor • Trend: increasing • Extent: across the entire range	Weeds can invade, establish in and outcompete native vegetation, particularly following disturbance events, such as bushfires (Hobbs 1991; Hobbs 2002; Brown et al. 2016). In particular, grassy weeds can increase fuel load and alter fire regimes (Milberg & Lamont 1995; Setterfield et al. 2013). These altered fire regimes can create conditions that are detrimental to the maintenance of native species and favourable to the establishment and spread of weeds (D'Antonio & Vitousek 1992; Grigulis et al. 2005). Invasion of other weeds, such as Lantana (*Lantana camera*) may degrade foraging habitat for the Brush-tailed Rock-wallaby (Capararo & Beynon 1996; Wong 1997). Lantana is recognised as a Weed of National Significance (Thorp & Lynch 2000).
Climate change		
Inappropriate fire regimes	• Timing: current • Confidence: known • Consequence: major • Trend: increasing • Extent: across the entire range	Fires can cause mortality of medium-sized marsupials, including wallabies, directly via high temperatures, toxic effects of smoke and oxygen depletion (Whelan et al. 2002); or indirectly via starvation and predation, linked to loss of suitable habitat, increased predator abundance and activity (McGregor et al. 2014; Leahy et al. 2016; Hradsky et al. 2017). Fires often follow periods of drought, exacerbating any declines in small- and medium-sized marsupials already caused by drought conditions (Crowther et al. 2018). In 2019-20, following years of drought (DPI 2020b), catastrophic bushfire conditions resulted in extensive bushfires covering an unusually large area of eastern Australia. Fire intensity and severity varied across the bushfire extent, with many patches burning at extreme intensity and severity while others remained unburnt (DPIE 2020). Such catastrophic bushfires are increasingly likely to occur due to climate change (CSIRO & Bureau of Meteorology 2015). These bushfires overlapped with approximately 50 percent of the Brush-tailed Rock-wallaby's distribution (Legge et al. 2021). The Brush-tailed Rock-wallaby is considered less susceptible to direct mortality from fire than some other mammal species, because it has access to rocky shelters that can protect animals from radiant heat, however increased predation and lack of food after fires may cause additional mortality.

Threat	Status and severity [a]	Evidence
Increased temperatures and change to precipitation patterns	• Timing: current • Confidence: inferred • Consequence: moderate • Trend: increasing • Extent: across the entire range	The CSIRO & Bureau of Meteorology (2015) predict that eastern Australia will experience decreased rainfall, increased average temperatures and frequency of droughts. Drought has been implicated in the decline of *Petrogale xanthopus* (Yellow-footed Rock-wallaby) in western NSW (Lim et al. 1992; Sharpe 1999). Additionally, *Petrogale lateralis* (Black-footed Rock-wallaby) and Allied Rock-wallaby are known to significantly decline in abundance following drought (Kinnear et al. 1988; Spencer 1991). Short (1982) reported that the Brush-tailed Rock-wallaby retained body condition and continued to breed successfully during a season of 50 percent below-average rainfall. However, Brush-tailed Rock-wallaby subpopulations in the Macleay and Clarence River catchments noticeably declined in abundance, following extensive loss of vegetation during a drought (DECC 2008). These subpopulations may rely heavily on mesic vegetation for refuge and therefore may be more susceptible to predation during droughts (DECC 2008). Accordingly, the cumulative impacts of predation and drought may elevate the risk of local extinction (DECC 2008).

Threat	Status and severity [a]	Evidence
Habitat loss, disturbance or modification		
Land clearing	• Timing: historical/current • Confidence: known • Consequence: major • Trend: increasing • Extent: across the entire range	Habitat loss and fragmentation, via forestry, land clearing, road and urban development, is implicated in the decline of many small- and medium-sized mammals (Bennett 1990; Law & Dickman 1998; Lindenmayer et al. 2000; Ramalho et al. 2018). Loss of forest/woodland habitat via land clearing may alter the foraging resources available to the Brush-tailed Rock-wallaby and cause a decline in abundance (Menkhorst & Hynes 2010). Since European occupation, habitat loss and degradation has isolated many Brush-tailed Rock-wallaby colonies (Jarman & Bayne 1997; Menkhorst & Hynes 2010). Additionally, most remaining subpopulations occur in undisturbed areas (Menkhorst & Hynes 2010). In the Central and Southern ESUs, genetic diversity loss is high due to founder effects and genetic drift (Menkhorst & Hynes 2010). There is significant genetic differentiation between colonies, even when colonies are separated by only two to four km (Browning et al. 2001; Hazlitt et al. 2006; Hazlitt et al. 2010). These high levels of genetic differentiation may be due to limited breeding dispersal between colonies (Hazlitt et al. 2006; Hazlitt et al. 2010). Genetic simulation models (assuming a best-case scenario) suggest additional depletion of at least 50% of genetic diversity will occur over the next 100 years, which will have fitness consequences for the population (and increasingly higher levels of inbreeding). Management interventions, including carefully designed gene-pool mixing aimed at improving genetic diversity and increasing effective population size, may need to be maintained to improve the recovery likelihood for this ESU. Land clearing continues for residential and tourist developments near escarpments and cliffs, to maximise scenic opportunities, particularly in northern NSW (Menkhorst & Hynes 2010). Land clearing in NSW has increased by approximately 60 percent since the *Native Vegetation Act 2003* was repealed in 2017 (DPI 2020a).
Habitat degradation and competition with native herbivores	• Timing: current • Confidence: inferred • Consequence: moderate • Trend: static • Extent: across the entire range	The Brush-tailed Rock-wallaby shares foraging habitat with *Osphranter robustus* (Eastern Wallaroo), *Macropus giganteus* (Eastern Grey Kangaroo), *Macropus parryi* (Whiptail Wallaby), *Notamacropus rufogriseus* (Red-necked Wallaby), *Wallabia bicolor* (Black Wallaby), *Trichosurus cunninghami* (Mountain Brushtail Possum) and *Trichosurus vulpecula* (Common Brushtail Possum) (DECC 2008). If these species reach high densities, they could reduce foraging habitat quality and food supply for the Brush-tailed Rock-wallaby (Tuft et al. 2012). However, the level of competition between the Brush-tailed Rock-wallaby and other native herbivores is poorly understood (DECC 2008).

Threat	Status and severity [a]	Evidence
Road mortality	• Timing: current • Confidence: known • Consequence: minor • Trend: unknown • Extent: across part of its range	In Australia, kangaroos and wallabies are commonly killed on roads (Coulson 1982; Osawa 1989; Ramp et al. 2005; Klöcker et al. 2006). The Brush-tailed Rock-wallaby is a known victim of road mortality (Hazlitt et al. 2014). Wallabies regularly use underpasses and road escape ramps, which may reduce road mortality (Taylor & Goldingay 2003; Goldingay et al. 2018). However, road mortality remains a threat to individuals residing near main roads and highways (OEH 2019).
Hunting	• Timing: historical • Confidence: known • Consequence: moderate • Trend: static • Extent: across the entire range	The Brush-tailed Rock-wallaby was indiscriminately hunted for the commercial fur trade, sport and as a purported agricultural pest, from the 1880s to 1920s (Lim et al. 1987; Lunney et al. 1996). However, illegal shooting was reported until at least the 1960s (Lunney et al. 1996). As many as 144 000 Rock-wallaby skins were sold in NSW in the 1890s alone (Lunney et al. 1996). This intensive, prolonged and large-scale hunting pressure substantially reduced population numbers and led to the local extinction of many Brush-tailed Rock-wallaby colonies, particularly in the west and south of its range (Short & Milkovits 1990; Lunney et al. 1996). In 2020, hunting is no longer considered a threat to the Brush-tailed Rock-wallaby.
Disease		
Hydatid disease caused by *Echinococcus granulosis*	• Timing: current • Confidence: known • Consequence: moderate • Trend: unknown • Extent: across part of its range	Hydatid disease is caused by infection with the larval stage of *Echinococcus granulosus* (Hydatid Worm) and is spread by cats and dogs. Infection of small macropods can cause pulmonary impairment and death (Barnes et al. 2008). Hydatid disease has been implicated as an important cause of mortality in some Brush-tailed Rock-wallaby subpopulations in southern Queensland (Barnes et al. 2008). The prevalence of the disease in subpopulations across the remainder of the species range is unknown.
Toxoplasmosis caused by *Toxoplasma gondii*	• Timing: current • Confidence: known • Consequence: moderate • Trend: unknown • Extent: unknown	Toxoplasmosis is an infectious disease caused by the protozoan parasite, *T. gondii,* and is spread by cats (the only definitive host). *Toxoplasma gondii* infections can causes disease and mortality in Australian marsupials (Hollings et al. 2013). *Toxoplasma gondii* infections have been reported in the Brush-tailed Rock-wallaby (Barnes et al. 2010; Parameswaran et al. 2010). However, the prevalence of the pathogen, the incidence of disease, and its outcomes, in Brush-tailed Rock-wallabies is unknown (Hillman et al. 2015).

Timing—identify the temporal nature of the threat;

Confidence—identify the extent to which we have confidence about the impact of the threat on the species;

Consequence—identify the severity of the threat;

Trend—identify the extent to which it will continue to operate on the species;

Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 1 in terms of the extent that it is operating on the species. The risk matrix (

Table 2) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with experts and using available literature.

Table 2 Brush-tailed Rock-wallaby risk matrix

Likelihood	**Consequences**				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Moderate risk **Predation by wild Dogs**	Very high risk **Increased temperature and change to precipitation patterns** **Predation by feral Cats**	Very high risk **Inappropriate fire regimes** **Predation by the European Red Fox** **Habitat degradation and competition introduced herbivores**	Very high risk
Likely	Low risk	Moderate risk **Weed invasion**	High risk **Habitat degradation and competition with native herbivores**	Very high risk	Very high risk
Possible	Low risk	Moderate risk **Road mortality**	High risk **Hydatid disease caused by *E. granulosis*** **Toxoplasmosis caused by *T. gondii***	Very high risk **Land clearing**	Very high risk
Unlikely	Low risk	Low risk	Moderate risk **Hunting**	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

Priority actions have then been developed to manage the threat particularly where the risk was deemed to be 'very high' or 'high'.

Conservation and recovery actions

Primary conservation objective

By 2030, the population of Brush-tailed Rock-wallaby will have increased in abundance and distribution, and genetic diversity of isolated subpopulations will be maintained or enhanced, especially in the southern and central ESUs.

Conservation and management priorities

Habitat loss disturbance and modifications

- Avoid further loss and fragmentation of habitat: avoid the loss of vegetation connecting areas of habitat for the Brush-tailed Rock-wallaby; avoid creating or enhancing barriers to movement between colonies.
- Promote the restoration and enhancement of habitat between colonies to allow safe movement of individuals, where feasible.
- Promote the conservation and management of Brush-tailed Rock-wallaby habitat, outside of National Parks, through voluntary conservation agreements, council open space habitat areas and management of covenanted areas.
- Implement measures to reduce road mortality, such as underpasses, road escape ramps and devices to slow vehicles, e.g., signs.

Invasive species (including threats from grazing, trampling, predation)

- Develop and implement long-term strategies to control predation by the European Red Fox, Feral Cats and wild Dogs, as detailed in the relevant Threat Abatement Plans (TAPs) or management strategies (DEWHA 2008b; DOE 2015; DPI 2017). Predator control after fire, or in areas that provide dispersal pathways for the Brush-tailed Rock-wallaby, are examples of specific management priorities that may apply in some areas.
- Develop and implement long-term strategies to control introduced herbivores, including Rabbits and unmanaged Goats, as detailed in the relevant TAPs (DEWHA 2008a; DOEE 2016). Control in buffer areas around Brush-tailed Rock-wallaby colonies may be a specific priority.
- Develop and implement long-term strategies to manage weeds, as detailed in the relevant management strategies.
- Promote the registration and responsible management of domestic Dogs.
- Manage native herbivores where competition with the Brush-tailed Rock-wallaby for limited resources is apparent, to reduce their impact on habitat and foraging resources required by the Brush-tailed Rock-wallaby.

Fire

- Ensure immediate and ongoing post-fire predator control within the habitat of the Brush-tailed Rock-wallaby.
- Develop and implement a fire management strategy that optimises the survival of the Brush-tailed Rock-wallaby. Protect habitat from fire and any proposal for prescribed burns in the vicinity must consider potential impacts on food availability and predator activity relative to the likelihood that prescribed burns will provide protection from bush fires.
- Provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigation measures in bushfire risk management plan/s, risk register and/or operation maps.

Disease

- Determine the prevalence of *T. gondii* and *E. granulosus* across subpopulations of the Brush-tailed Rock-wallaby, and the frequency and outcomes of disease.

Breeding, seed collection, propagation and other ex situ recovery action

- To manage the risk of losing genetic diversity, continue to support captive breeding and reintroduction programs, where feasible. Increase genetic diversity for highly inbred ESUs and populations.

Stakeholder engagement/community engagement

- Engage and involve Traditional Owners in conservation actions, for example by incorporating Indigenous fire management actions near Brush-tailed Rock-wallaby colonies, as well as involving Traditional Owners in survey, monitoring and management actions.
- Liaise with the local community and relevant state government agencies to ensure that up-to-date population data and scientific knowledge inform the implementation of conservation actions for this species.
- Increase the recognition and support for the recovery of the species. Educate landowners and managers of the importance of maintaining native vegetation, and the integration of habitat protection into land management regulations.
- Prevent mortality of the Brush-tailed Rock-wallaby due to illegal hunting by educating hunters about the species and the importance of its recovery.

Survey and monitoring priorities

- Conduct ongoing strategic surveys of known or potential Brush-tailed Rock-wallaby sites, identified via habitat suitability models. Assess population size (or relative abundance) and viability of subpopulations across its' range, identify important subpopulations and conduct long-term monitoring to assess its' status and assess further declines or re-establishment/recovery of populations.
- Monitor and record the incidence of fire and vegetation responses across the species range, including any changes in response to fire management.
- Monitor the abundance of introduced predators across the species range and assess the efficacy of management interventions, particularly responses to control of the European Red Fox and the consequent potential increase in feral Cats; responses to post-fire predator control; and post-fire food provision.

Information and research priorities

- Undertake connectivity analysis to prioritise important areas for connectivity conservation between fragmented subpopulations.
- Monitor and evaluate the effectiveness of breeding programs to improve genetic diversity of Brush-tailed Rock-wallaby ESUs.
- Continue to explore the potential impacts of climate change on the long-term survival prospects of the species, due to altered temperatures, rainfall patterns, bushfires, environmental stressors and diseases.
- Assess the efficacy and impacts of management options to reduce the incidence, extent and intensity of fire affecting the species' habitat.
- Identify an optimal fire regime for the species' habitat by assessing population-level responses to a range of fire regimes, and modelling habitat viability across all fire scenarios.
- Investigate the level of competition between the Brush-tailed Rock-wallaby and other native herbivores.

Links to relevant implementation documents

Brush-tailed rock-wallaby (*Petrogale penicillata*) saving our species strategy

National Recovery Plan for the Brush-tailed Rock-wallaby *Petrogale penicillata* (2010)

Threat abatement plan for competition and land degradation by rabbits (2016)

Threat abatement plan for competition and land degradation by unmanaged goats (2008)

Threat abatement plan for predation by the European red fox (2008)

Threat abatement plan for predation by feral cats (2015)

Conservation Advice references

ACT Government (2015). *Brush-tailed rock-wallaby (*Petrogale penicillata*): an endangered species. Action plan no 22 (version 2)*. Environment ACT, Canberra.

Arthur AD, Catling PC & Reid A (2012). Relative influence of habitat structure, species interactions and rainfall on the post-fire population dynamics of ground-dwelling vertebrates. *Austral Ecology* 37, 958-970.

Ashby E, Lunney D, Robertshaw J & Harden R (1990). Distribution and status of bandicoots in NSW. In: Seebeek JH, PR Brown, RL Wallis, CM Kemper (eds) *Bandicoots and Bilbies*. Surrey Beatty and Sons, Sydney. pp 43-50.

Barnes TS, Goldizen AW, Morton JM & Coleman GT (2008). Cystic echinococcosis in a wild population of the brush-tailed rock-wallaby (*Petrogale penicillata*), a threatened macropodid. *Parasitology* 135, 715-723.

Barnes TS, Goldizen AW, Morton JM & Coleman GT (2010). Parasites of the brush-tailed rock-wallaby (*Petrogale penicillata*). *Journal of Wildlife Diseases* 46, 218-228.

Bayne P (1994). Behaviour of the brush-tailed rock-wallaby, *Petrogale penicillata*, and the recognition of individuals. . Thesis. University of New England.

Bennett AF (1990). Habitat corridors and the conservation of small mammals in a fragmented forest environment. *Landscape Ecology* 4, 109-122.

Bluff LA, Clausen L, Hill A & Bramwell MD (2011). A decade of monitoring the remnant Victorian population of the brush-tailed rock-wallaby (*Petrogale penicillata*). *Australian Mammalogy* 33, 195-201.

Brown K, Paczkowska G & Gibson N (2016). Mitigating impacts of weeds and kangaroo grazing following prescribed fire in a *Banksia* woodland. *Ecological Management & Restoration* 17, 133-139.

Browning TL, Taggart DA, Rummery C, Close RL & Eldridge MDB (2001). Multifaceted genetic analysis of the “critically endangered” brush-tailed rock-wallaby *Petrogale penicillata* in Victoria, Australia: implications for management. *Conservation Genetics* 2, 145-156.

Burbidge A & Friend T (1990). The disappearing mammals. *Landscope* 6, 28-34.

Burbidge AA & McKenzie NL (1989). Patterns in the modern decline of western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50, 143-198.

Capararo SM & Beynon F (1996). *Ground surveys of brush-tailed rock-wallaby (*Petrogale penicillata*) colonies in southern NSW*. Unpublished report to National Parks and Wildlife Service (NSW).

Carter K & Goldizen AW (2003). Habitat choice and vigilance behaviour of brush-tailed rock-wallabies (*Petrogale penicillata*) within their nocturnal foraging ranges. *Wildlife Research* 30, 355-364.

Claridge AW (1998). Use of tracks and trails by introduced predators: an important consideration in the study of nativeground-dwelling mammals. *Victorian Naturalist* 115, 79-83.

Claridge AW & Barry SC (2000). Factors influencing the distribution of medium-sized ground-dwelling mammals in southeastern mainland Australia. *Austral Ecology* 25, 676-688.

Coulson GM (1982). Road-kills of macropods on a section of highway in central Victoria. *Wildlife Research* 9, 21-26.

Crowther MS, Tulloch AI, Letnic M, Greenville AC & Dickman CR (2018). Interactions between wildfire and drought drive population responses of mammals in coastal woodlands. *Journal of Mammalogy* 99, 416-427.

CSIRO & Bureau of Meteorology (2015). *Climate change in Australia information for Australia's natural resource management regions: technical report*. CSIRO and Bureau of Meteorology, Australia.

D'Antonio CM & Vitousek PM (1992). Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics* 23, 63-87.

DECC (Department of Environment and Climate Change) (2008). *Approved NSW recovery plan for the brush-tailed rock-wallaby* Petrogale penicillata. Department of Environment and Climate Change (NSW), Sydney.

DELWP (Department of Environment, Land, Water and Planning) (2020). Brush-tailed rock-wallaby (southern ESU) *Petrogale penicillata*. Accessed: 1 December 2020 Available at: https://www.environment.vic.gov.au/conserving-threatened-species/threatened-species/brush-tailed-rock-wallaby

DEWHA (Department of Environment, Heritage, Water and Arts) (2008a). *Threat abatement plan for competition and land degradation by unmanaged goats*. Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (Department of Environment, Heritage, Water and Arts) (2008b). *Threat abatement plan for predation by the European red fox*. Department of the Environment, Water, Heritage and the Arts, Canberra.

Dickman CR (1996). Impact of exotic generalist predators on the native fauna of Australia. *Wildlife Biology* 2, 185-195.

DOE (Department of the Environment) (2015). *Threat abatement plan for predation by feral cats*. Department of the Environment, Canberra.

DOEE (Department of the Environment and Energy) (2016). *Threat abatement plan for competition and land degradation by rabbits*. Department of the Environment and Energy, Canberra.

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

DPI (Department of Primary Industries) (2017). *NSW wild dog management strategy 2017-2021*. Department of Primary Industries (NSW), Sydney.

DPI (Department of Primary Industries) (2020a). 2018 landcover change reporting. Accessed: 9 December 2020 Available at: https://www.environment.nsw.gov.au/topics/animals-and-plants/native-vegetation/landcover-monitoring-and-reporting/2018-landcover-change-reporting

DPI (Department of Primary Industries) (2020b). Drought in NSW. Accessed: 14 Spetember 2020 Available at: https://www.dpi.nsw.gov.au/climate-and-emergencies/droughthub/drought-in-nsw

DPIE (Department of Planning, Industry and Environment) (2020). *DPIE fire extent and severity mapping* Department of Planning, Industry and Environment (NSW), Sydney.

DSEWPC (Department of Sustainability, Environment, Water, Population and Communities) (2011a). *Feral european rabbit (Oryctolagus cuniculus)*. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

DSEWPC (Department of Sustainability, Environment, Water, Population and Communities) (2011b). *Feral horse (*Equus caballus*) and feral donkey (*Equus asinus*)*. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Eldridge MDB & Browning TL (2004). *Genetic analysis of brush-tailed rock-wallabies in Woko national park*. Unpublished report to the Department of Environment and Sustainability (NSW), Hurstville.

Eldridge MDB, Browning TL & Close RL (2001). Provenance of a New Zealand brush-tailed rock-wallaby (*Petrogale penicillata*) population determined by mitochondrial DNA sequence analysis. *Molecular Ecology* 10, 2561–2567.

Eldridge MDB & Close RL (1998). Brush-tailed rock-wallaby, *Petrogale penicillata*. In: Strahan R (ed) *The Mammals of Australia*. New Holland Publishers Pty Ltd, NSW.

Eldridge MDB, Neaves LE, Faris J & Soderquist T (2017). Genetic affinities of a remnant population of the brush-tailed rock-wallaby (*Petrogale penicillata*) in Mt Kaputar National Park, northern New South Wales. *Australian Mammalogy* 40, 112-117.

Fleming PJS (2000). Brush-tailed rock-wallaby, *Petrogale penicillata* (marsupialia: macropodidae), observed feeding on fallen *Acacia* inflorescences. *Australian Mammalogy* 22, 63-63.

Goldingay RL, Taylor BD, Parkyn JL & Lindsay JM (2018). Are wildlife escape ramps needed along Australian highways? *Ecological Management & Restoration* 19, 198-203.

Grigulis K, Lavorel S, Davies ID, Dossantos A, Lloret F & Vilà M (2005). Landscape-scale positive feedbacks between fire and expansion of the large tussock grass, *Ampelodesmos mauritanica* in Catalan shrublands. *Global Change Biology* 11, 1042-1053.

Hayward, M., Bellchambers, K., Herman, K., Bentley, J., and Legge, S. (2011). Spatial and activity patterns of yellow-footed rock-wallabies Petrogale xanthopus in Buckaringa Sanctuary, central Flinders Ranges, South Australia. Australian Journal of Zoology 59, 1-8.

Hazlitt SL, Eldridge MD & Goldizen AW (2004). Fine-scale spatial genetic correlation analyses reveal strong female philopatry within a brush-tailed rock-wallaby colony in southeast Queensland. *Molecular Ecology* 13, 3621-3632.

Hazlitt SL, Eldridge MDB & Goldizen AW (2006). Significant patterns of population genetic structure and limited gene flow in a threatened macropodid marsupial despite continuous habitat in southeast Queensland, Australia. *Conservation Genetics* 7, 675-689.

Hazlitt SL, Eldridge MDB & Goldizen AW (2010). Strong matrilineal structuring in the brush-tailed rock-wallaby confirmed by spatial patterns of mitochondrial DNA. In: Coulson GM, MDB

Eldridge (eds) *Macropods: the biology of kangaroos, wallabies and rat-kangaroos*. CSIRO Publishing, Melbourne.

Hazlitt SL, Goldizen AW, Nicholls JA & Eldridge MDB (2014). Three divergent lineages within an Australian marsupial (*Petrogale penicillata*) suggest multiple major refugia for mesic taxa in southeast Australia. *Ecology and Evolution* 4, 1102-1116.

Hill FAR (1991). *A research recovery plan for the Brush-tailed rock-wallaby* Petrogale penicillata *(Gray 1825) in south-eastern Australia*. Unpublished report to Department of Conservation and Environment (VIC), Melbourne.

Hillman AE, Lymbery AJ & Thompson RCA (2015). Is *Toxoplasma gondii* a threat to the conservation of free-ranging Australian marsupial populations? *International Journal for Parasitology. Parasites and Wildlife* 5, 17-27.

Hobbs R (1991). Disturbance a precursor to weed invasion in native vegetation. *Plant Protection Quarterly* 6, 99-104.

Hobbs R (2002). Fire regimes and their effects in Australian temperate woodlands. In: Bradstock R, J Williams, A Gill (eds) *Flammable Australia: the fire regimes and biodiversity of a continent*. Cambridge University Press, UK. pp 305-326.

Hollings T, Jones M, Mooney N & McCallum H (2013). Wildlife disease ecology in changing landscapes: mesopredator release and toxoplasmosis. *International Journal for Parasitology. Parasites and Wildlife* 2, 110-118.

Hradsky BA, Mildwaters C, Ritchie EG, Christie F & Di Stefano J (2017). Responses of invasive predators and native prey to a prescribed forest fire. *Journal of Mammalogy* 98, 835-847.

Jarman PJ & Bayne P (1997). Behavioural ecology of *Petrogale penicillata* in relation to conservation. *Australian Mammalogy* 19, 219-228.

Jarman PJ & Phillips CM (1989). Diets in a community of macropod species. In: Grigg G, PJ Jarman, I Hume (eds) *Kangaroos, Wallabies and Rat-kangaroos*. Surrey Beatty and Sons, Chipping Norton. pp 143-149.

Joblin KPW (1983). Behaviour and ecology of the brush-tailed rock-wallaby, *Petrogale penicillata*, in the New England region. Thesis. University of New England.

Jones KE, Bielby J, Cardillo M, Fritz SA, O'Dell J, Orme CDL, Safi K, Sechrest W, Boakes EH, Carbone C, Connolly C, Cutts MJ, Foster JK, Grenyer R, Habib M, Plaster CA, Price SA, Rigby EA, Rist J, Teacher A, Bininda-Emonds ORP, Gittleman JL, Mace GM & Purvis A (2009). PanTHERIA: a species-level database of life history, ecology, and geography of extant and recently extinct mammals. *Ecology* 90, 2648-2648.

Kinnear JE, Onus ML & Bromilow RN (1988). Fox control and rock-wallaby population dynamics. *Wildlife Research* 15, 435-450.

Klöcker U, Croft DB & Ramp D (2006). Frequency and causes of kangaroo vehicle collisions on an Australian outback highway. *Wildlife Research* 33, 5-15.

Krieger G & Caparraro S (1999). *An assessment of the Brush-tailed Rock-wallaby population in the Mount Machar and Cooks Tableland areas of Glen Rock.* Internal report for Parks and Wildlife Service (Qld).

Krieger G (2010). *Habitat assessment and monitoring of the Brush-tailed Rock-wallaby (*Petrogale penicillata*) in south-east Queensland.* Internal report for Parks and Wildlife Service (Qld).

Law BS & Dickman CR (1998). The use of habitat mosaics by terrestrial vertebrate fauna: implications for conservation and management. *Biodiversity & Conservation* 7, 323-333.

Laws R & Goldizen A (2003). Nocturnal home ranges and social interactions of the brush-tailed rock-wallaby *Petrogale penicillata* at Hurdle Creek, Queensland. *Australian Mammalogy* 25, 169-176.

Lazell JD, Sutterfield TW & Giezentanner WD (1984). The population of rock wallabies (genus *Petrogale*) on Oahu, Hawaii. *Biological Conservation* 30, 99-108.

Leahy L, Legge SM, Tuft K, McGregor HW, Barmuta LA, Jones ME & Johnson CN (2016). Amplified predation after fire suppresses rodent populations in Australia's tropical savannas. *Wildlife Research* 42, 705-716.

Lee AK & Ward S (1989). Life histories of macropoid marsupials. In: Grigg G, P Jarman, I Hume (eds) *Kangaroos, Wallabies and Rat-kangaroos*. Surrey Beatty and Sons, Chipping Norton. pp 105-115.

Legge S, Woinarski JCZ, Garnett ST, Geyle H, Lintermans M, Nimmo DG, Rumpff L, Scheele BC, Southwell DG, Ward M et al. (2021). *Estimates of the impacts of the 2019-2020 fires on populations of native animal species.* Report by the NESP Threatened Species Recovery Hub. Brisbane, Australia.

Legge S, Woinarski J, Garnett S, Nimmo D, Scheele B, Lintermans M, Mitchell N, Whiterod N & Ferris J (2020). *Revised provisional list of animals requiring urgent management intervention*. Department of Agriculture, Water and the Environment, Canberra.

Lim L, Robinson A, Copley P, Gordon G, Canty P & Reimer D (1987). *The conservation and management of the yellow-footed rock-wallaby,* Petrogale xanthopus*, special publication no. 4*. Department of Environment and Planning (SA).

Lim L, Sheppard N, Smith P & Smith J (1992). *The biology and management of the yellow-footed rock-wallaby (*Petrogale xanthopus*) in NSW. Species management report number 10*. National Parks and Wildlife Service (NSW), Hurstville.

Lindenmayer DB, McCarthy MA, Parris KM & Pope ML (2000). Habitat fragmentation, landscape context, and mammalian assemblages in south-eastern Australia. *Journal of Mammalogy* 81, 787-797.

Lunney D, Law B & Rummery C (1996). Contrast between the visible abundance of the brush-tailed rock-wallaby, *Petrogale penicillata*, and its rarity in fox and dog scats in the gorges east of Armidale, New South Wales. *Wildlife Research* 23, 373-379.

MacGregor CI, Cunningham RB & Lindenmayer DB (2015). Nest-site selection of the long-nosed bandicoot (*Perameles nasuta*) in a postfire environment. *Australian Journal of Zoology* 63, 324-330.

McGregor HW, Legge S, Jones ME & Johnson CN (2014). Landscape management of fire and grazing regimes alters the fine-scale habitat utilisation by feral cats. *PLOS ONE* 9, e109097.

Menkhorst P & Hynes E (2010). *National recovery plan for the brush-tailed rock-wallaby* Petrogale penicillata. Department of Sustainability and Environment (VIC), East Melbourne.

Menkhorst PW (1995). Brush-tailed rock-wallaby species account. In: Menkhorst PW (ed) *Mammals of Victoria: distribution, ecology and conservation*. Oxford University Press, Melbourne. pp 149-151.

Milberg P & Lamont BB (1995). Fire enhances weed invasion of roadside vegetation in southwestern Australia. *Biological Conservation* 73, 45-49.

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

Moss GL, Taylor D & Miller A (1997). *Implementation of a monitoring program for the brush-tailed rock-wallaby at the Warrumbungle National Park*. Unpublished report to the National Parks and Wildlife Service (NSW).

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

Murray JV, Low Choy S, McAlpine CA, Possingham HP & Goldizen AW (2008). The importance of ecological scale for wildlife conservation in naturally fragmented environments: a case study of the brush-tailed rock-wallaby (*Petrogale penicillata*). *Biological Conservation* 141, 7-22.

OEH (Office of Environment and Heritage) (2019). Brush-tailed rock-wallaby - profile. Accessed: 2 December 2020 Available at: https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10605

OEH (Office of Environment and Heritage) (2020). Brush-tailed rock-wallaby (*Petrogale penicillata*) saving our species strategy. Accessed: 2 December 2020 Available at: https://www.environment.nsw.gov.au/savingourspeciesapp/project.aspx?ProfileID=10605

Ormay P (1996). *Status of the brush-tailed rock-wallaby,* Petrogale penicillata*, in the Australian Capital Territory. Technical report no 1*. ACT Parks and Conservation Service, Canberra.

Osawa R (1989). Road-kills of the swamp wallaby, *Wallabia bicolor*, on north Stradbroke Island, southeast Queensland. *Wildlife Research* 16, 95-104.

Paplinska JZ, Taggart DA, Corrigan T, Eldridge MDB & Austin JJ (2011). Using DNA from museum specimens to preserve the integrity of evolutionarily significant unit boundaries in threatened species. *Biological Conservation* 144, 290-297.

Parameswaran N, Thompson RCA, Sundar N, Pan S, Johnson M, Smith NC & Grigg ME (2010). Non-archetypal type II-like and atypical strains of *Toxoplasma gondii* infecting marsupials of Australia. *International Journal for Parasitology* 40, 635-640.

Piggott MP, Banks SC, Stone N, Banffy C & Taylor AC (2006a). Estimating population size of endangered brush-tailed rock-wallaby (*Petrogale penicillata*) colonies using faecal DNA. *Molecular Ecology* 15, 81-91.

Piggott MP, Banks SC & Taylor AC (2006b). Population structure of brush-tailed rock-wallaby (*Petrogale penicillata*) colonies inferred from analysis of faecal DNA. *Molecular Ecology* 15, 93-105.

Radford JQ, Woinarski JCZ, Legge S, Baseler M, Bentley J, Burbidge AA, Bode M, Copley P, Dexter N, Dickman CR, Gillespie G, Hill B, Johnson CN, Kanowski J, Latch P, Letnic M, Manning A,

Menkhorst P, Mitchell N, Morris K, Moseby K, Page M & Ringma J (2018). Degrees of population-level susceptibility of Australian terrestrial non-volant mammal species to predation by the introduced red fox (*Vulpes vulpes*) and feral cat (*Felis catus*). *Wildlife Research* 45, 645-657.

Ramalho CE, Ottewell KM, Chambers BK, Yates CJ, Wilson BA, Bencini R & Barrett G (2018). Demographic and genetic viability of a medium-sized ground-dwelling mammal in a fire prone, rapidly urbanizing landscape. *PLOS ONE* 13, e0191190.

Ramp D, Caldwell J, Edwards KA, Warton D & Croft DB (2005). Modelling of wildlife fatality hotspots along the Snowy Mountain Highway in New South Wales, Australia. *Biological Conservation* 126, 474-490.

Risbey DA, Calver MC, Short J, Bradley JS & Wright IW (2000). The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. a field experiment. *Wildlife Research* 27, 223-235.

Setterfield SA, Rossiter-Rachor NA, Douglas MM, Wainger L, Petty AM, Barrow P, Shepherd IJ & Ferdinands KB (2013). Adding fuel to the fire: the impacts of non-native grass invasion on fire management at a regional scale. *PLOS ONE* 8, e59144.

Sharpe A (1999). *The NSW yellow-footed rock-wallaby recovery program; i background and history of the project*. Unpublished report to the National Parks and Wildlife Service (NSW)

Short J (1980). Ecology of the brush-tailed rock-wallaby (*Petrogale penicillata* Griffith, Smith and Pidgeon). Thesis. University of Sydney.

Short J (1982). Habitat requirements of the brush-tailed rock-wallaby, *Petrogale penicillata*, in New South Wales. *Wildlife Research* 9, 239-246.

Short J (1989). The diet of the brush-tailed rock-wallaby in New South Wales. *Wildlife Research* 16, 11-18.

Short J & Milkovits G (1990). Distribution and status of the brush-tailed rock-wallaby in southeastern Australia. *Australian Wildlife Research* 17, 169-179.

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

Sydney Barani (2013). Barani Sydney's Aboriginal history: Moore park engraving. Accessed: 30 November 2020 Available at: https://www.sydneybarani.com.au/sites/moore-park-engraving/

Taggart DA, Schultz DJ, Corrigan TC, Schultz TJ, Stevens M, Panther D & White CR (2016). Reintroduction methods and a review of mortality in the brush-tailed rock-wallaby, Grampians National Park, Australia. *Australian Journal of Zoology* 63, 383-397.

Taylor BD & Goldingay RL (2003). Cutting the carnage: wildlife usage of road culverts in north-eastern New South Wales. *Wildlife Research* 30, 529-537.

Thorp JR & Lynch R (2000). *The determination of weeds of national significance*. National Weeds Strategy Executive Committee, Launceston.

Tidbinbilla Nature Reserve (2020). Southern brush-tailed rock wallaby. Accessed: 1 December 2020 Available at: https://www.tidbinbilla.act.gov.au/wildlife/southern-brush-tailed-rock-wallaby

Tuft KD, Crowther MS & McArthur C (2011). Multiple scales of diet selection by brush-tailed rock-wallabies (*Petrogale penicillata*). *Australian Mammalogy* 33, 169-180.

Tuft KD, Crowther MS & McArthur C (2012). Fire and grazing influence food resources of an endangered rock-wallaby. *Wildlife Research* 39, 436-445, 410.

Van der Ree R & McCarthy MA (2005). Inferring persistence of indigenous mammals in response to urbanisation. *Animal Conservation* 8, 309-319.

van Eeden L, Di Stefano J & Coulson G (2011). Diet selection by the brush-tailed rock-wallaby (*Petrogale penicillata*) in East Gippsland, Victoria. *Australian Mammalogy* 33, 162-168.

Waldegrave-Knight L (2002). History, habitat and management: consideration in the selection of reintroduction and translocation sites for the brush-tailed rock-wallaby *Petrogale penicillata*, in East Gippsland, Victoria. Thesis. University of Melbourne.

Warburton BW & Sadlier RMF (1995). Brush-tailed rock-wallaby. In: King C (ed) *The handbook of New Zealand mammals*. Oxford University Press, Auckland. pp 58-64.

Weeks, A (2014). *The Genetic Status of the southern Brush-tailed Rock-wallaby in East Gippsland*. CONFIDENTIAL REPORT. Cesar pty ltd.

Whelan RJ, Rodgerson L, Dickman CR & Sutherland EF (2002). Critical life processes of plants and animals: developing a process-based understanding of population changes in fire-prone landscapes. In: Bradstock RA, JE Williams, MA Gill (eds) *Flammable Australia: the fire regimes and biodiversity of a continent*. Cambridge University Press, Cambridge. pp 94-124.

Woinarski J, Burbidge A & Harrison P (2014a). Brush-tailed rock-wallaby. In: *Action plan for Australian mammals 2012*. CSIRO Publishing, Melbourne, pp 422-425.

Woinarski JCZ, Burbidge AA & Harrison PL (2014b). Threats. In: *The action plan for Australian mammals 2012*. CSIRO Publishing, Melbourne, pp 867-879.

Wong V (1997). *The Shoalhaven brush-tailed rock-wallabies; surveys and monitoring, Jan-Mar 1997*. Unpublished report to the NSW National Parks and Wildlife Service.

Wynd NM, Sigg DP, Pople AR, Hazlitt SL & Goldizen AW (2006). Factors affecting female reproductive success and the survival of pouch young in the threatened brush-tailed rock-wallaby, *Petrogale penicillata*. *Australian Journal of Zoology* 54, 61-70.

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