



Monitoring Priority Threatened Species

A review of monitoring methods for the Brush-tailed Rock-wallaby (*Petrogale penicillata*)

September 2024

Citation

TERN Australia (2024) Monitoring Priority Threatened Species: A review of monitoring methods for the Brush-tailed Rock Wallaby (*Petrogale penicillata*) Version 1 Report to the Department of Climate Change, Energy the Environment and Water. TERN, Adelaide.

Version

Version 1.

Last updated: 2 September 2024

Acknowledgements and contributions

This work was funded by the Australian Government Department of Climate Change, Energy, the Environment and Water.

The following people contributed to this document as expert reviewers: Willow Bourke.

Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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About

This literature review collates information on one of the 110 priority threatened species identified in the *Threatened Species Action Plan 2022-2032* and has been reviewed by invited practitioners experienced in monitoring the species.

The *Survey Guidelines for Monitoring Threatened Species* project, a collaboration of the Department of Climate Change, Energy, the Environment, and Water (DCCEEW) and the Terrestrial Ecosystem Research Network (TERN), aims to improve our knowledge of threatened species by enhancing accessibility and sharing of quality scientific threatened species data. By developing best practice field survey guidelines and recommendations, practitioners will be better equipped to conduct standardised, repeatable surveys.

By identifying the monitoring methods typically implemented by practitioners, documenting and assessing the techniques known to work, and identifying opportunities to standardise the methods, we can move towards ensuring all monitoring is species-appropriate, comparable between practitioners and populations, and repeatable over time. Further, together with consistent terminology, guidelines, instructions, and data collection, we can refine efforts and resources to measure and share information. Data collected using robust, standardised methods will improve our knowledge of threatened species and underpin threatened species recovery at scale. This project is essential to establishing monitoring protocols and data repositories to enhance the accessibility and sharing of threatened species data.

TERN has prepared the literature reviews for the Department of Climate Change, Energy, the Environment, and Water. For further information, please visit the [EMSA Threatened Species Survey Guidelines](#) website. Additional information, particularly monitoring methods and techniques not included that should be considered, can be brought to the author's attention by emailing tern@adelaide.edu.au for consideration for future updates.



Contents

1	Background.....	1
1.1	Species name	1
1.2	Conservation status.....	1
1.3	Summary of data held in the Threatened Species Index.....	1
1.4	Distribution and abundance.....	1
1.5	Habitat requirements	2
1.6	Biology and behaviour	2
1.7	Threats	3
2	Existing monitoring	4
2.1	Overview of monitoring methods.....	4
2.2	Monitoring resources.....	4
2.3	Survey methods	5
2.3.1	Scat surveys	5
2.3.2	Camera trap surveys.....	6
2.3.3	Direct counts	8
2.3.4	Trapping.....	8
2.3.5	Other survey methods.....	9
3	Key agencies and organisations involved in the species research and recovery	10
4	Survey guideline recommendations gathered from the literature	12
5	References	13

Tables

Table 1.	National, international and state conservation status for the Brush-tailed Rock-wallaby. ...	1
Table 2.	Methods overview of key studies using scat surveys.....	5
Table 3.	Methods overview of key studies using camera trap surveys	6
Table 4.	Methods overview of key studies using trapping surveys	8

1 Background

1.1 Species name

Brush-tailed Rock-wallaby is the most widely used common name of the species *Petrogale penicillata*, although the species is also sometimes referred to as the Small-eared Rock-wallaby or Western rock-wallaby (Animalia 2023). The Wiradjuri names for Brush-tailed Rock-wallaby are 'Wirrang' and 'Barrbay' (Grant & Rudder 2010). The Ngunnawal name is 'Baray', which also means 'quick' (Bell & Winanggaay Ngunnawal Language Group 2021). Howitt (1886) wrote of 'Yalonga', meaning rock wallaby, and it was one of the totems of the Bidjelli of Eastern Gippsland, Victoria (DAWE 2021b). The species is hereafter referred to as the Brush-tailed Rock-wallaby.

1.2 Conservation status

The Brush-tailed Rock-wallaby is currently listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) and is identified as a Priority Threatened Species under the *Threatened Species Action Plan 2022-2032*. The species has experienced substantial historical decline, continuing within most subpopulations. The rate of decline is not well resolved, but suspected to be more than 30% over a 21 year (three generation) period (Woinarski & Burbidge 2016). Table 1 identifies the species conservation status under local, national and international listings.

Table 1. National, international and state conservation status for the Brush-tailed Rock-wallaby.

Jurisdiction	Conservation status	Legislation or Listing
International	Vulnerable	The IUCN Red List of Threatened Species
Commonwealth	Vulnerable	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
Queensland	Vulnerable	<i>Nature Conservation (Animals) Regulation 2020</i>
New South Wales	Endangered	<i>Biodiversity Conservation Act 2016</i>
Australian Capital Territory	Endangered	<i>Nature Conservation Act 2014</i>
Victoria	Critically endangered	<i>Flora and Fauna Guarantee Act 1988</i>

1.3 Summary of data held in the Threatened Species Index

The Threatened Species Index (TSX) provides reliable and robust measures of change in the relative abundance of Australia's threatened and near-threatened species at national, state and regional levels. Understanding these changes in species populations is crucial for monitoring Australia's conservation progress and allows users to measure and report on the benefits of conservation investments and to justify and design targeted management responses. Currently, the index is restricted to birds, plants and mammals, with new groups to be added in the near future.

The TSX does not currently hold data on the Brush-tailed Rock Wallaby. More information on the TSX, including how to contribute threatened species monitoring data to the index, can be found on the [TSX website](#).

1.4 Distribution and abundance

The range of the Brush-tailed Rock-wallaby is believed to have contracted by 50-90% (DCCEEW 2024) with populations persisting in largely small, fragmented locations through the Great Dividing range from south-eastern Queensland down into Victoria (Botma et al. 2020; Jarman & Bayne 1996; Murray et al. 2008). Approximately 92 % of the species' resides in northern New South Wales, 7 % in south-east Queensland and <1 % in Victoria (DCCEEW 2024; DECC 2008). Known localities include Macleay River

and Clarence River gorges (DCCEEW 2024), Oxley Wild Rivers National Park (Thurtell et al. 2022), the Watagans, and Curracabundi National Park (Phillips et al. 2022), as well as two populations in western New South Wales – Warrumbungle Ranges and Mount Kaputar (Menkhorst & Hynes 2010). There are two small populations in Victoria; a remnant population in the Little River Gorge in east Gippsland (Bluff et al. 2011) and a reintroduced population in the Grampians National Park in western Victoria (Kleemann et al. 2022). Around 50 % of occupied sites are located within conservations reserves, 10% in state forests or other crown land and 40 % on private land (DCCEEW 2024; DECC 2008). The 2019/20 wildfires are thought to have burnt 80 % of known Brush-tailed Rock-wallaby habitat in New South Wales. Much of the information published prior to the fires regarding distribution and population status for the Brush-tailed Rock Wallaby is likely to be out of date. Early post fire population estimates are between 9,700 and 23,000 (DCCEEW 2024). The Victorian population is estimated at <100, with just under 50 individuals living in the Little River Gorge (Gaborov 2023). The central New South Wales population is between 1400-1500 and the northern New South Wales/south eastern Queensland population 8300-20100 (DCCEEW 2024). However, surveys are ongoing and many estimates are uncertain at this stage (DCCEEW 2024)..

1.5 Habitat requirements

The Brush-tailed Rock-wallaby inhabits rugged rocky terrain with outcrops, rock faces, scree slopes, ledges and caves important refuge areas for basking and resting during the day (DCCEEW 2024; Murray et al. 2008; Short 1982). They have also been documented sheltering in vegetation such as low limbs of trees, particularly fig trees in the New England area (Jarman & Bayne 1996), and under *Xanthorrhoea* spp. (Wong 1997). At night the Brush-tailed Rock-Wallaby will forage in grassland, dry sclerophyll woodlands and forests, near to their rocky refuges (Menkhorst & Hynes 2010; Tuft et al. 2011a; Tuft et al. 2012). Corridors of suitable habitat are important for facilitating movement between refuges and foraging habitat (DCCEEW 2024; Menkhorst & Hynes 2010; Short 1982).

Complex rocky terrain is believed to be more commonly occupied as it provides increased protection from predators such as foxes, feral cats and dingoes (Jarman & Bayne 1996; Lunney et al. 1997). However, with reduced predation pressure, the Brush-tailed Rock-Wallaby may expand to include a wider range of habitat types (Jarman & Bayne 1996), as has occurred with other rock-wallaby species (de Preu & Pearce 2006; Kinnear et al. 1998).

1.6 Biology and behaviour

The Brush-tailed Rock-wallaby is a medium-sized macropod with adult males weighing 6-11 kg and adult females 5-8 kg, possessing a tail whose last third is distinctively bushy (DAWE 2021). The Brush-tailed Rock-wallaby lives in small to medium sized colonies composed of smaller matrilineal groups (DCCEEW 2024; Jarman & Bayne 1996). Home ranges vary between 6-30 ha with females generally occupying a smaller home range than males (DCCEEW 2024; Hazlitt et al. 2004). Females reach maturity at 18 months and males at 20-24 months (DCCEEW 2024). They can breed all year with females having on average one joey per year with the majority of these born between February and May (Bluff et al. 2011; DCCEEW 2024). Lifespan in the wild is between 8 and 14 years (Woinarski et al. 2014).

The diet of the Brush-tailed Rock-wallaby mainly consists of grasses (Short 1989; Tuft et al. 2011b). They have also been recorded consuming forbs, acacia flowers, leaves, fruit, bark and the fruiting bodies of hypogeous fungi (Carter & Goldizen 2003; Fleming 2000; Jarman & Phillips 1989; Short 1989; Tuft et al. 2011b; van Eeden et al. 2011).

Across its distribution three evolutionary significant units (ESUs) with significant genetic divergence have been defined (Menkhorst & Hynes 2010). The southern ESU encompasses all Victorian

subpopulations, central ESU includes subpopulations in central New South Wales and the Northern ESU includes subpopulations in northern New South Wales and south eastern Queensland (Browning et al. 2001; DAWE 2021a; Eldridge et al. 2018; Hazlitt et al. 2014; Paplinska et al. 2011). It has been proposed that given the genetic divergence among the ESUs, they should be managed independently (Browning et al. 2001; Hazlitt et al. 2014). However, survival and management of colonies, especially the reestablishment of the Grampians National Park colony, has required relaxing such rigid genetic guidelines (Taggart et al. 2016).

1.7 Threats

The most significant threats to Brush-tailed Rock-wallaby populations include predation by introduced predator species' the Red Fox (*Vulpes vulpes*) (Radford et al. 2018; Taggart et al. 2016) and Feral Cat (*Felis catus*) (Lavery et al. 2021; Read et al. 2019), competition from goats (*Capra hircus*) (Kinnear et al. 1998; Lavery et al. 2021; Lethbridge & Alexander 2008) and sympatric macropods (Tuft et al. 2011a), and changed climate and fire regimes (Lavery et al. 2021). These threats are interconnected and exacerbate the loss of genetic diversity from the rock-wallabies already small and fragmented population sizes.

Changes to rainfall patterns, temperature averages and an increase in the frequency of droughts are predicted as a consequence of climate change across the range of the Brush-tailed Rock-Wallaby (CSIRO & Bureau of Meteorology 2015). The species has shown some resilience during drought conditions, utilising alternate food resources when preferred resources are scarce, enabling them to retain body condition and continue breeding (Short 1989). However, prolonged severe drought has caused declines in the species (DECC 2008). The availability of food resources may also be significantly impacted by competitive grazing of sympatric native macropods (Botma et al. 2020; Tuft et al. 2011a), particularly during times of drought stress. Altered fire regimes are also predicted as a result of climate change and may intensify predation and competition pressures by reducing food sources and protection offered by more complex vegetation (Claridge & Barry 2000; Hradsky et al. 2017).

Brush-tailed Rock-wallaby populations have become increasingly isolated due to habitat fragmentation and reduced connectivity in the landscape (Menkhorst & Hynes 2010). When combined with increased predation this can result in decreased dispersal and restricted gene flow, impacting genetic diversity within populations. Significant genetic differentiation has been recorded between colonies, likely as a result of limited breeding dispersal (Hazlitt et al. 2006). The southern ESU in particular, as well as some populations within the central New South Wales ESU, have experienced a decline in genetic diversity (Menkhorst & Hynes 2010). If this decline continues, increased inbreeding and reduced fitness will occur, increasing the risk of extinction in these populations. (DCCEE 2024). Diseases such as hydatidosis, toxoplasmosis and lumpy jaw also pose a risk to the Brush-tailed Rock-wallaby, particularly when populations are already under stress from other threats (DCCEE 2024).

2 Existing monitoring

2.1 Overview of monitoring methods

Presence and population monitoring of the Brush-tailed Rock-wallaby can be determined through direct observation of individuals (Murray et al. 2008), live trapping (Bluff et al. 2011; Taggart et al. 2016), radio-tracking (Molyneux et al. 2011; Taggart et al. 2016), identification from camera trapping (Bluff et al. 2011; Gaborov 2023; Kleemann et al. 2022), and either observation or collection and genetic analysis of wallaby scats (Bluff et al. 2011; Murray et al. 2008; Taggart et al. 2016; Tuft et al. 2011a).

Key population monitoring indices of the Brush-tailed Rock-wallaby include:

- Population abundance (estimated)
- Area of occupancy
 - Number of extant colonies (Ormay 1996; Reside & Martin 1997; Wong 1993a, 1993b) and their trajectory (e.g. Bluff et al. 2011; Kleemann et al. 2022)
- Habitat condition (e.g. impact of competitors, predators and fire) (DECC 2008; Menkhorst & Hynes 2010)

2.2 Monitoring resources

Key resources with information for monitoring the Brush-tailed Rock-wallaby include:

- DCCEEW (2024) Draft National Recovery Plan for the brush-tailed rock-wallaby *Petrogale penicillata*
 - Objectives include implementing and maintaining a national monitoring program reporting on the species population size, distribution, trends and effectiveness of management.
- Gaborov (2023) Monitoring of southern Brush-tailed Rock-Wallaby in the Upper Snowy River (Little River Gorge), Autumn 2023
 - Outlines methods for camera trap deployment and set-up (including baited lures), which has been carried out annually in Autumn since 2014.
 - Camera monitoring supplemented every 2-3 years with live trapping.
- Waldegrave-Knight and Clausen (2012) Brush-tailed Rock-wallaby trapping and monitoring protocol manual.
 - Detailed protocol summarising trapping and marking methods for the Brush-tailed Rock-wallaby. Provides information on survey timing, duration, capture, handling and marking techniques, and data and sample collection.
 - Documents methods for observations of individuals and recording and collection of scats.
- NESP Threatened Species Recovery Hub (2021) is a factsheet produced on their key directions for effectively monitoring *Petrogale* species
- Australian Museum Business Services (2004) 5 ha survey method

There are also a range of scientific papers and field survey reports that provide more information about survey methods (Biolink 2020; Bluff et al. 2011; Botma et al. 2020; Coulson et al. 2021; Jarman

& Capararo 1997; Kleemann et al. 2022; Lavery et al. 2021; Phillips et al. 2022; Piggott et al. 2018; Reside & Martin 1997; Thurtell et al. 2022).

2.3 Survey methods

The Brush-tailed Rock-wallaby is a colonial species that is now found in small groups and rugged habitats. Accessing these colonies to survey remnant populations can be difficult, however the use of camera traps and genetic information from fresh scats has enabled direct assessment of primary population parameters including movement along the escarpment, survival, abundance, population growth, breeding, and recruitment (Kleemann et al. 2022).

2.3.1 Scat surveys

Surveying for fresh wallaby scats can provide evidence of their presence in an area, or possibly former presence if only old scats can be located (Short & Milkovits 1990; Tuft et al. 2011a). As the primary habitat of this species is rugged escarpments, where possible scat collection is made at, or below, these inhabited escarpments (Phillips et al. 2022; Short 1989; Tuft et al. 2011b). In addition, DNA can be obtained from fresh scats to identify individual wallabies, determine pedigrees, recruitment, dispersal and movements (Bluff et al. 2011; Kleemann et al. 2022; Piggott et al. 2018). See Table 2 for more detail relating to scat survey methodology.

Table 2. Methods overview of key studies using scat surveys

Survey type	Study design	Survey effort	Location	Reference
Scat DNA	<ul style="list-style-type: none"> ▪ Fresh scats collected opportunistically from across the length of the rocky escarpment area in and around the known colony site (Moora Moora Creek Escarpment) ▪ Only one scat, selected at random, taken from locations where multiple scats were present in close proximity to one another ▪ Scats were collected in individual zip-lock bags to avoid DNA contamination among scats. Scat locations were recorded using a hand-held GPS unit ▪ Scat samples then stored in a portable cooler while travelling and on site ▪ Scat samples kept frozen at -20°C in the laboratory before DNA extraction ▪ For comparison of genetic diversity, DNA extracted from stored ear biopsies of 10 BTRWs of known sex were included in the study 	<ul style="list-style-type: none"> ▪ Surveyed ~3.6 km of escarpment ▪ Between September 2018 and February to April 2019 	Moora Moora Creek, Grampians National Park, Victoria	Kleemann et al. (2022)
Scat	<ul style="list-style-type: none"> ▪ Trialled concept of gravity-assisted transects loosely aligned along the base of cliff-lines and/or associated terraces, with series of replicated sampling points located at fixed intervals ▪ Initial transect length was arbitrarily set at 150m, with a sampling interval of 5m and associated sampling points located 3m out perpendicularly from the base of the cliff-line ▪ At each sampling point, counts of fresh and/or recent and older BTRW 	<ul style="list-style-type: none"> ▪ Survey conducted over 9 days 	Within or immediately adjoining Watagans National Park and in Curracabundi National Park, NSW	Phillips et al. (2022)

Survey type	Study design	Survey effort	Location	Reference
	scats undertaken within concentric fixed-radius circular plots of 1m, 2 m, and 3 m respectively			
Scat DNA	<ul style="list-style-type: none"> Faecal pellets collected from five monitored colonies within the Warrumbungle National Park: Square Top Mountain (Mtn), Chalkers Mtn, Black Jack Mtn, Mt Uringery and Wheoh Peak Difference in sampling occasions for each colony was due to accessibility, size of habitat to be surveyed and obtaining sufficient scat numbers for analysis Due to the small number of faecal pellets at sites, especially fresh ones, all pellets found were collected and stored dry 	<ul style="list-style-type: none"> Samples collected on 1–4 occasions for each colony: Chalkers Mtn (February 2001; April, June, August 2002), Square Top Mtn (February 2001; June 2002), Black Jack Mtn (February, April 2001; February, June 2002), Mt Uringery (April 2001; February 2002) and Wheoh Peak (June 2002) 	Warrumbungle National Park, NSW	Piggott et al. (2018)
Scat	<ul style="list-style-type: none"> On each mountain top, surveyed 200 evenly distributed plots, and at each mountain base, 200 plots every 10m along radial transects to a distance of 100m outwards from the cliff Plots were placed at a density of 7–13 per hectare Presence or absence of fresh (<1 month old) scats of rock-wallabies and sympatric macropods was recorded for each plot 	<ul style="list-style-type: none"> 400 x 1 m2 plots in total 	Chalkers Mountain and Mount Uringery, Warrumbungles National Park, NSW	Tuft et al. (2011a)
Scat	<ul style="list-style-type: none"> Study conducted at five brush-tailed rock-wallaby colonies in three populations across NSW Collected Brush-tailed Rock-wallaby scats for diet analysis from each colony in each of the eight sampling periods 	<ul style="list-style-type: none"> Eight sampling periods: Summer 2006/07, Autumn, Winter and Spring 2007, Summer 2007/08, Autumn, Winter and Spring 2008 	Chalkers Mountain and Mount Uringery, Warrumbungles National Park; Cedar Gully and Pimple Creek, Curracabundi National Park; Kangaroo Valley, NSW	Tuft et al. (2011b)
Scat DNA	<ul style="list-style-type: none"> Scats found in the field, DNA extracted from epithelial cells adhering to scats After amplification and sequencing, genotypes from scat samples were compared with those from ear biopsies and camera data 	<ul style="list-style-type: none"> Conducted as part of systematic biannual trapping program 	Little River Gorge, Snowy River National Park, Victoria	Bluff et al. (2011)
Scat	<ul style="list-style-type: none"> Presence of fresh scats used to determine presence of wallabies. 	<ul style="list-style-type: none"> 1 km transects walked, total of 200 sites 	Great Dividing Range of southeast Queensland north of the NSW border	(Murray et al. 2008)
Scat	<ul style="list-style-type: none"> Between 20 and 30 fresh faecal pellets (circa 50g dry weight) collected each season from fixed plots along escarpments 	<ul style="list-style-type: none"> 100m length of escarpment at both locations 	Kangaroo Valley and Goulburn River, NSW	Short (1989)

2.3.2 Camera trap surveys

Camera surveys for the Brush-tailed Rock-wallaby can provide non-invasive monitoring of an area to try and detect the species (Lavery et al. 2021), or can be used to directly monitor a population, including localised movements and broader dispersal, survival, abundance, population growth, breeding, and recruitment (Bluff et al. 2011; Gaborov 2023; Kleemann et al. 2022). See Table 3 for more detail relating to camera trap survey methodology.

Table 3. Methods overview of key studies using camera trap surveys

Survey type	Study design	Survey effort	Location	Reference
Camera	<ul style="list-style-type: none"> Reconyx PC850 white flash cameras deployed at 45 locations and Reconyx HP2W white flash at 2 locations. Cameras generally 100-200 m apart. Cameras set on a tree or rock 1.5-2.5 m from and facing a hay containing net ~0.7 m above the ground or PVC bait holder 0.5-0.8 m above the ground. Lures filled with lucerne. Individuals identified from images based on which ear is tagged and tag colour combination 	<ul style="list-style-type: none"> 47 cameras across 8 sites, 21-31 night deployment Annual monitoring 	Little River Gorge, Victoria	(Gaborov 2023)
Camera	<ul style="list-style-type: none"> New cameras set up ~250 m apart, along a 1.2 km length of the Moora Moora Creek escarpment where BTRWs had been released, and which formed the main colony site Cameras uploaded photos, via a cellular base station, directly to an office computer on weekdays Recorded sightings of BTRWs on cameras from the 19 January 2019 to the 3 August 2019 obtained from Parks Victoria staff Identity of the BTRW based on clear visualisation of an identifying ear tag or definite absence of an ear tag was provided with the date and camera location of the sighting 	<ul style="list-style-type: none"> Six new motion-triggered remote cameras (BuckEye X80; BuckEye Cam Australia) were installed at Moora Moora Creek in January 2019 Surveyed a 1.2 km length of escarpment 	Moora Moora Creek, Grampians National Park, Victoria	Kleemann et al. (2022)
Camera	<ul style="list-style-type: none"> In 2016, total of 10 camera traps, comprising eight Reconyx Hyperfire HC600 covert cameras (Reconyx USA) and two UWay VH200HD cameras (Uway Canada) deployed to monitor <i>P. penicillata</i>, dingoes and other species In 2017, number of camera traps deployed increased to 27, comprising 21 Reconyx Hyperfire HC600 covert cameras, three Reconyx Ultrafire covert (Reconyx USA) and three UWay VH200HD cameras (Uway Canada) Nine cameras used at each site with similar settings, e.g. per trigger five images were taken with no time delay between images Cameras set up 20m apart around the perimeter of the <i>P. penicillata</i> colonies, focusing along the top and bottom of ridges, gullies, cliffs and gorges Camera traps strapped to trees between 50 and 75cm above the ground and aimed towards rocks or well used animal tracks where <i>P. penicillata</i> scats had been recorded and activity expected to be high 	<ul style="list-style-type: none"> Across all study sites at Aroona Station there were 728 trap-days during the pilot study in 2016 and 2318 trap-days during 2017 	Aroona Station, within the Little Liverpool Range, Queensland	Botma et al. (2020)
Camera	<ul style="list-style-type: none"> Compared daylight time lapse images collected by remote cameras with photographs taken of individual rock wallabies (photographing defining marks) at eight discrete colonies using a single lens reflex camera A total of 2190 minutes (36.5 hours) of observations made with length of each visit to a colony varying between 10 and 100 minutes Between August and September 2011, eight weatherproof time-lapse cameras deployed at four discrete BTRW colonies Four cameras set at each of the locations around the perimeter of each colony so that images did not overlap Cameras captured data every 10 minutes between 0600 and 1740 hours each day 	<ul style="list-style-type: none"> Eight discrete colonies visited over 10 days between 2 June and 22 July 2011 Still photographs taken during ~45 minutes of survey time at each of eight wallaby colonies Time lapse imagery was collected for 15 or 20 consecutive days at four of these same colonies 	Green Gully, Oxley Wild Rivers National Park, NSW	Gowen and Vernes (2014)

Survey type	Study design	Survey effort	Location	Reference
Camera	<ul style="list-style-type: none"> ▪ Several camera models used over this period (predominantly FaunaFocus FF-120 by Faunatech), with key requirements being white-light illumination and sufficient resolution to distinguish ear tags ▪ Cameras typically located in or near trap lines, either during or outside of trapping efforts ▪ Camera sites baited with lucerne in a hay-net, suspended at height of ~50cm 	<ul style="list-style-type: none"> ▪ Motion-triggered remote cameras deployed from 2005 onwards ▪ Up to six cameras deployed simultaneously 	Little River Gorge, Snowy River National Park, Victoria	Bluff et al. (2011)

2.3.3 Direct counts

Brush-tailed rock-wallabies can be directly recorded through both ground and aerial observations.

Ground observations

Colonies of brush-tailed rock-wallabies have been surveyed by direct ground observations, both in observing and counting individuals (Murray et al. 2008; Tuft et al. 2011b; Wong 1993a, 1993b), and also by observing and taking photographs to be used for the identification of individuals (Gowen & Vernes 2014). Observation time at colonies has been largely for unspecified periods of time, while the observations and photographs taken at Green Gully, Oxley Wild Rivers National Park (NSW) were during ~45 minutes of survey time at each of the eight wallaby colonies (Gowen & Vernes 2014).

Aerial observations

Helicopter-based aerial surveys have been undertaken for the Brush-tailed Rock-wallaby in southeastern Queensland (Murray et al. 2008), and in Oxley Wild Rivers National Park in NSW since 2004 (Gowen 2015; Thurtell et al. 2022).

2.3.4 Trapping

Brush-tailed rock-wallabies can be directly captured, tagged and counted using treadle-release soft-walled cage traps (Bluff et al. 2011). Capture-mark-recapture methodologies can then be used to assess key demographic parameters, as used for the yellow-footed rock-wallaby, *P. xanthopus xanthopus* (de Preu & Pearce 2006). See Table 4 for more detail relating to trapping methodology.

Table 4. Methods overview of key studies using trapping surveys

Survey type	Study design	Survey effort	Location	Reference
Trapping	<p>Treadle-release soft-walled cage traps (34 x 37 x 63cm) baited with a variety of fruit, vegetable and peanut butter-based baits until 2005, from which date lucerne hay was used</p> <p>The establishment and positioning of additional trap lines followed the detection of rock-wallaby presence during targeted searches</p> <p>The resulting distances between neighbouring trap lines were ~1km, while typical distances between traps within lines were 5–100m</p> <p>Trapping sessions were typically a week in duration, and in most cases were restricted to a single trap line Biannual trapping periods thus involved a series of trips conducted over several weeks</p>	<p>Number of trap lines increased from one in 2000, to three in 2003, and four in 2009</p> <p>Lines nominally contained 20 traps, but in practice this varied from 8 to 30, reflecting logistical constraints of individual sites and fieldwork teams</p>	Little River Gorge, Snowy River National Park, Victoria	Bluff et al. (2011)
Trapping	<p>Traps baited with peanut butter, passionfruit pulp and oat mix</p> <p>Aerial baiting for foxes has occurred throughout the timeline of this project.</p>	Monitoring of the population has occurred every two years since 2003	Jenolan Caves, Blue Mountains, NSW	(DCCEEW 2024; DPIE 2021)

Survey type	Study design	Survey effort	Location	Reference
	Resulting in a steady increase in population size.			

2.3.5 Other survey methods

Home ranges of Brush-tailed rock-wallabies can be assessed using very high frequency (VHF) or global positioning system (GPS) telemetry, as done for the reintroduced population in the Grampians National Park, Victoria (Molyneux et al. 2011; Taggart et al. 2016).

Helicopter or drone surveys of current and potential Brush-tailed Rock-wallaby habitats utilising thermal cameras could provide valuable detections of possible unknown colonies. Though there is a lack of specificity with thermal detections of macropods, combining it with specifically surveying habitats that replicate the rugged cliffs and escarpments on which most colonies now reside, and then following up with primary survey methods, could locate additional unknown colonies.

3 Key agencies and organisations involved in the species research and recovery

Key agencies, organisations or individuals identified as having been previously or currently actively involved in monitoring Brush-tailed Rock-wallabies include:

- Brush-tailed Rock-wallaby National Recovery Team Department of Environment, Land, Water and Planning (DELWP, Victoria)
- Environment, Planning and Sustainable Development (ACT government)
- Department of Planning and Environment (DPE, NSW)
 - NSW National Parks and Wildlife Service
- Department of Environment and Science (DES, Qld)
 - Queensland Parks and Wildlife Service
- Hunter Local Land Services
- Dr David Taggart, University of Adelaide
- Dr Katherine Tuft, Arid Recovery - PhD on the Brush-tailed Rock-wallaby in the Warrumbungles, NSW
- Dr Jeff Short, Wildlife Research and Management Pty Ltd - PhD on the Brush-tailed Rock-wallaby in NSW
- Dr Deborah Ashworth, NSW Office of Environment & Heritage, coordinates the NSW recovery program for the endangered Brush-tailed Rock-wallaby
- Friends of the Brush-tailed Rock-wallaby
- Friends of Grampians National Park
- The Schultz Foundation Ltd
- Aussie Ark
- Australia Walkabout Wildlife Park
- Australia Zoo
- Currumbin Wildlife Sanctuary
- Featherdale Wildlife Park
- Hunter Valley Zoo
- Taronga Conservation Society
- Waterfall Springs Wildlife Sanctuary
- Wildlife HQ Zoo
- Wildlife Habitat Port Douglas
- Zoo and Aquarium Association Australasia (ZAA)
- Zoos Victoria
- Jenolan Caves Reserve Trust
- Tidbinbilla National Reserve
- Ipswich Nature Centre
- Mid Coast Council
- Cesar Australia
- Dunkeld Pastoral Company

- Mt Rothwell Conservation and Research Reserve
- The Schultz Foundation Ltd
- Wildlife Unlimited Ptd Ltd
- World Wide Fund for Nature

4 Survey guideline recommendations gathered from the literature

This literature review of monitoring methods for the Brush-tailed Rock-wallaby has identified some key points that must be addressed when developing species-specific guidelines. These points include:

- Brush-tailed Rock-wallabies can be directly captured, tagged and counted using treadle-release soft-walled cage traps (Bluff et al. 2011; Waldegrave-Knight & Clausen 2012). Capture-mark-recapture methodologies can then be used to assess key demographic parameters (Waldegrave-Knight & Clausen 2012). Trapping is however more costly, involves a higher input of time and energy, and can be difficult due to the rugged terrain.
- Scat collection provides an effective alternative monitoring technique which is not as laborious as trapping (Kleemann et al. 2022; Phillips et al. 2022; Tuft et al. 2011a; Tuft et al. 2011b).
- DNA can be obtained from fresh scats to identify individual wallabies, determine pedigrees, recruitment, dispersal and movements (Bluff et al. 2011; Kleemann et al. 2022; Piggott et al. 2018).
- Camera surveys for the Brush-tailed Rock-wallaby can also provide a relatively cheaper, non-invasive monitoring method for detecting (Lavery et al. 2021), or monitoring Brush-tailed Rock-Wallabies (Bluff et al. 2011; Gaborov 2023).
- Home ranges of Brush-tailed Rock-wallabies can be assessed using very high frequency (VHF) or GPS telemetry, as done for the reintroduced population in the Grampains National Park, Victoria (Molyneux et al. 2011).

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