CAUGHT ON CAMERA

Citizen science in the Wombat State Forest

JANUARY 2019

A REPORT ON THE FIRST FIVE YEARS OF MONITORING THE EFFECTS OF FIRE ON WILDLIFE

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Victorian National Parks Association

The Victorian National Parks Association is a community-led nature conservation organisation. Our vision is to ensure Victoria is a place with a diverse and healthy natural environment that is protected, respected and enjoyed by all.

We work with all levels of government, the scientific community and the general community to achieve long term, best practice environmental outcomes and help shape the agenda for creating and managing national parks, conservation reserves and other important natural areas across land and sea in Victoria.

We are also Victoria's largest bushwalking club and provide a range of education, citizen science and activity programs that encourage Victorians to get active for nature.

NatureWatch

The Victorian National Parks Association's NatureWatch program is a citizen science program which gets community involved in collecting scientific data on Victorian native plants and animals. The program builds links between community members, scientists and land managers and develops scientifically based, practical projects which contribute to a better understanding of species and ecosystems, and the management of natural areas.

Project Partners

Wombat Forestcare

Wombat Forestcare is a community group dedicated to protecting and enhancing the natural ecosystems of the Wombat State Forest and surrounding areas.

Eco Insights

Eco Insights is a consultancy established by Richard Loyn that conducts strategic projects in Australia and Papua New Guinea. Richard is an ecologist with special interests in forests, fire, wetlands, threatened species, bird migration and conservation.

Acknowledgements

NatureWatch and the Caught on Camera project would not exist without the tremendous amount of work of many volunteers who have been involved in helping establish the project, setting up cameras, maintaining equipment, team leading, identifying wildlife in images and data management.

Over the first five years of the project, each year around 45 volunteers contributed over 1,500 hours in the field, over 1,000 hours in the office identifying images and managing equipment and countless hours on other behind the scenes tasks.

Wombat Forestcare input and support, Gayle Osborne, Eddie Schambre and several others.

DELWP input and support, Matt Chick, Robin Holmes, Kerryn McTaggart and Sarah Bellhouse.

ARI input into project development, Matt Bruce, Peter Menkhorst and Richard Loyn.

EcoInsights project scientific support, Richard Loyn.

Victorian National Parks Association volunteer team leaders, office volunteers and field volunteers.

Project supported by: Since 2012, the project has received funding from the Foundation for National Parks and Wildlife, the ANZ Staff Foundation, Lord Mayor's Charitable Foundation, Field Naturalists Club of Victoria Environment Fund, Perpetual Rowe Family Foundation.

Caught on Camera is supported by the Victorian Government.

This project is conducted with full ethics approvals and under DELWP Research Permit #10007466.

VICTORIA State Government

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Above: Christine Connelly. Photo by Deb Connelly.

Cover images: Eastern Grey Kangaroos and Brush-tailed Phascogale (inset). Photos by VNPA.

Back cover images: Common Wombat and Crimson Rosella (inset). Photos by VNPA.

Summary

Between 2012 and 2016 more than 200 volunteers contributed over 2,500 hours to monitor wildlife in Wombat State Forest as part of the Caught on Camera project. Thanks to the inspiring volunteer effort, the community amassed five years of data on 13 native mammals and 15 native birds, including threatened species. This is part of a 10 year project and this report marks our findings at the half way mark.

Back in 2012, Wombat Forestcare and the VNPA were concerned that we did not know enough about the effects of fire on wildlife. So, with the support of the Department of Environment, Land Water and Planning's Arthur Rylah institute for Environmental Research (ARI), we set about devising a method to explore the question; 'what is the impact of fire on mammals?' through the VNPA's NatureWatch program.

A project for the wider community

Caught on Camera has been a major achievement for the local and wider community.

Through the project, we've built and strengthened positive and long-lasting links between the community, scientists and the government.

The community came together to develop and deliver this project over the past five years, with volunteers from Wombat Forestcare and VNPA being involved in:

- Establishing the project science and methods
- Reviewing project progress
- Setting up and packing down cameras 100 times at 44 different monitoring sites
- Habitat assessments
- Sending in recorded data
- Maintaining equipment
- Leading teams in the field
- Identifying wildlife in many thousands of images
- Overview of final reports

The participation of the community in this project demonstrates a great passion for science and conservation in Wombat State Forest.

We're incredibly grateful to everyone that has contributed to the project to date and we look forward to working with new and old friends to complete our ambitious and valuable 10-year study.

What have we found?

The community effort on this project has amassed five years of records that document 13 native mammal species and 15 native bird species, including

Mammals:

- Echidna
- Brush-tailed Phascogale
- Agile Antechinus
- Dusky Antechinus
- Common Brushtail Possum
- Mountain Brushtail Possum
- Common Ringtail Possum
- Koala
- Common Wombat
- Black Wallaby
- Eastern Grey Kangaroo
- Bush Rat
- Swamp Rat

Birds:

- Southern Boobook
- Laughing Kookaburra
- Crimson Rosella
- Superb Fairy-wren
- White-browed Scrubwren
- Spotted Quail-thrush
- Grey Shrike-thrush
- Grey Currawong
- Pied Currawong
- Australian Magpie
- White-winged Chough
- Scarlet Robin
- Flame Robin
- Eastern Yellow Robin
- Bassian Thrush

We have also recorded nine introduced mammal species and one introduced bird species:

Common Blackbird
Black Rat
House Mouse
European Rabbit
Brown Hare
Feral Goat
Sambar Deer
Red Fox
Cat
Domestic Dog (with its human!)

Other recent studies in similar ecosystems have shown that longer-term effects of fire on flora and fauna are generally more subtle than those in the first three years. Our project appears to support this, at least for the common species. So far, there is no evidence of a dramatic response for any species, and several species have shown only subtle responses.

We don't have a lot of data on the less common species but to date our results appear to show that common ground-dwelling mammal and bird species in the two forest types remained common over the study period.

Brush-tailed Phascogales: an exciting find of a threatened species!

Capturing images of a threatened Brush-tailed Phascogale (*Phascogale tapoatafa*) is an incredibly exciting outcome for this project. They are a small marsupials with a distinctive bottle-brush tail that live in dry leafy forests and nest in tree hollows and feed on insects and nectars. Being photographed at three sites across the Wombat State Forest demonstrates this is an important habitat area for this species which is listed as threatened under the Flora and Fauna Guarantee Act (1988).

A few months before these images were taken, Wombat Forestcare picked up the species on some of their cameras – these were the first recordings of the species in this part of the Wombat State Forest since the 1970's!

Brush-tailed Phascogale.

INTRODUCTION

Caught on Camera project

Caught on Camera is an ongoing project that involves working with local community groups, land managers and scientists to establish long-term wildlife monitoring, using motion-sensing cameras. Field deployment of the cameras and management of equipment is undertaken by local community volunteers, with support of volunteers from elsewhere in Victoria, recruited through the VNPA.

In Wombat State Forest and Bunyip State Park, Caught on Camera involves looking at the long-term impact of fire on wildlife. In the Hindmarsh/ Wimmera region and at Bank Australia's conservation reserves, we explored the value of revegetation efforts for wildlife.

In other locations we are carrying out exploratory surveys, especially where contemporary survey data are lacking.

Project aims

The Caught on Camera project objectives in Wombat State Forest are:

- To provide crucial data on the long-term impacts of prescribed burning on wildlife to land managers, community groups, scientists and government.
- To create working partnerships with government, researchers and community, to carry out long-term monitoring.
- To demonstrate and promote to government the need for ongoing, strategic and comprehensive monitoring in response to fire.

We specifically designed the project to explore the question:

'What mammal species are located at 'Recently Burnt', 'Medium time since burnt' and 'Long Unburnt' sites in Foothills Forest and Forby Forest in Wombat State Forest?'

This original aim remains, although we have refined our project slightly since we started. We have extended the study to look at fire response in a broader range of species, including some ground-foraging birds, and to increase the number of sites in each vegetation type and time since fire category.

This report

This report presents the results of the first five years' of monitoring, and provides recommendations for the ongoing monitoring.

Wombat

BACKGROUND

The importance of understanding the fire response

"Much monitoring of fauna is of such a small scale and short duration that the statistical likelihood of detecting a positive or negative effect of the management regime is minute. Such shortcomings will only be overcome through broad-scale and/or long-term studies of fauna." (Clarke 2008)

In Australia, we have a limited understanding of the impacts of fire on our biodiversity particularly the impacts on fauna (Clarke 2008, MacHunter *et al.* 2009). We need repeatable, ongoing monitoring or there will continue to be gaps in our understanding of the impacts of planned burning in the landscape.

For land managers to improve planned burning techniques, particularly to meet the needs of our native fauna, it is essential to understand the impact of fire on all life forms, not just the impacts on the plants. This is particularly relevant when working in a fragmented landscape, such as Victoria.

"The ability of fire planners to meaningfully implement the dual aspirations of protecting life and property and achieving ecological goals is dependent on the availability of science and evidence that informs operational processes, and monitoring that influences future management." (MacHunter et al. 2009)

Through long term community-driven projects that are developed with scientific rigour and linked to management techniques, such as planned burning, it is possible for the community to contribute to building our knowledge base on the impact of fire on fauna.

Why use motion-sensing cameras?

Monitoring of fauna using traditional survey techniques (e.g. trapping, spotlighting) can be highly labour intensive. Motion-sensing cameras provide an alternative method, and the opportunity to gather data on some animal groups (e.g. small mammals, some arboreal mammals and ground-foraging birds) with much less effort.

Cameras can be set-up at multiple locations and left to automatically detect and record species throughout the day and night. The method is also much less stressful for the fauna than trapping and can provide data on the presence of some species that are unlikely to be caught in traps.

It's important to note that motion-sensing cameras do not provide accurate data on population sizes (except in rare cases when individual animals can be recognised) but may have potential to provide data on relative abundance across different habitats.

Motion-sensing cameras also offer a terrific opportunity for community engagement — the photographs of animals 'Caught on Camera' in their natural environment can be shared throughout the community as well as to a wider audience online. This can serve as an educational tool and inform the community about the richness of their local environment, fostering a more meaningful relationship between the community and the place in which they live.

Monitoring in Wombat State Forest

Since 2012, annual monitoring took place over March to July at up to 20 sites each year. The monitoring season commences with a community training session in March, which includes deploying the cameras at the first four sites.

Throughout the monitoring season, eight cameras are rotated around the sites every three weeks, to ensure that every site is monitored once. Each deployment involves two teams of around 4-5 volunteers.

A 10-year endeavour

We established a one year trial, to test the study design and the community's capacity to carry out the study, with a view to carrying out annual monitoring over the long-term (>10 years).

At the end of the year, we reported on our results and reviewed our success and decided that the project was successful and should continue. We established a strategic plan with planning and review actions to be undertaken at four yearly intervals.

In 2015, we conducted a detailed review of the project and determined that we are tracking well; the data were of good quality and the project should continue with minor adjustments.

Specifically, we determined that we should increase our sample size by adding more sites across the site categories, to improve our likelihood of detecting responses.

Methods

Study area

The study was conducted in Wombat State Forest in central-west Victoria, approximately 80 km north-west of central Melbourne. The forest covers about 70,000 ha and extends along both sides of the Great Dividing Range, from Creswick to Mount Macedon.

Wombat forest has a long history of timber harvesting, and was extensively logged during the gold rush era of the mid-1800s. Virtually all old-growth trees have been removed from the forest. Large-scale harvesting ceased in 2002 (Macak *et al.* 2010), but the forest continues to be managed under the Forests Act, thus mining and further logging activities cannot be ruled out.

The forest comprises a mixed eucalypt foothill forest with dominant Messmate (*Eucalyptus obliqua*) overstorey, in combination with Peppermints (*E. dives* and *E. radiata*) and Candlebark Gum (*E. rubida*) (Leversha 1996). Sixty per cent of the vegetation types that occur in the Wombat forest are classified as threatened.

The Wombat forest provides habitat for over 180 native vertebrate fauna species, including 18 rare or threatened species (e.g. Greater Glider, Powerful Owl, Square-tailed Kite, White-throated Needletail and Lace Monitor). The forest is also inhabited by several key fire response species such as Mountain Brushtail Possum, Agile Antechinus and Black Wallaby (Macak et al. 2010; MacHunter *et al.* 2009).

Sites

From 2012 to 2015, 28 sites were established, a subset of 30 sites established by Wombat Forestcare and the Department of Sustainability and Environment as Community Research sites (Macak *et al.* 2010). In 2016, a further 16 sites were added to increase the statistical power of the study, providing greater capacity to detect trends in results.

The sites were selected to represent sites that have been burnt at different time intervals, which were classified into three 'time since fire' categories;

- recently burnt (RB: 0 - 10 years since the last fire),
- medium burnt (IB: 11 - 41 years since the last fire) and
- long unburnt (LU: 42+ years since the last fire).

Sites were located within two vegetation communities (ecological vegetation division categories for fire planning; EVDs); Foothills Forest and Forby Forest.

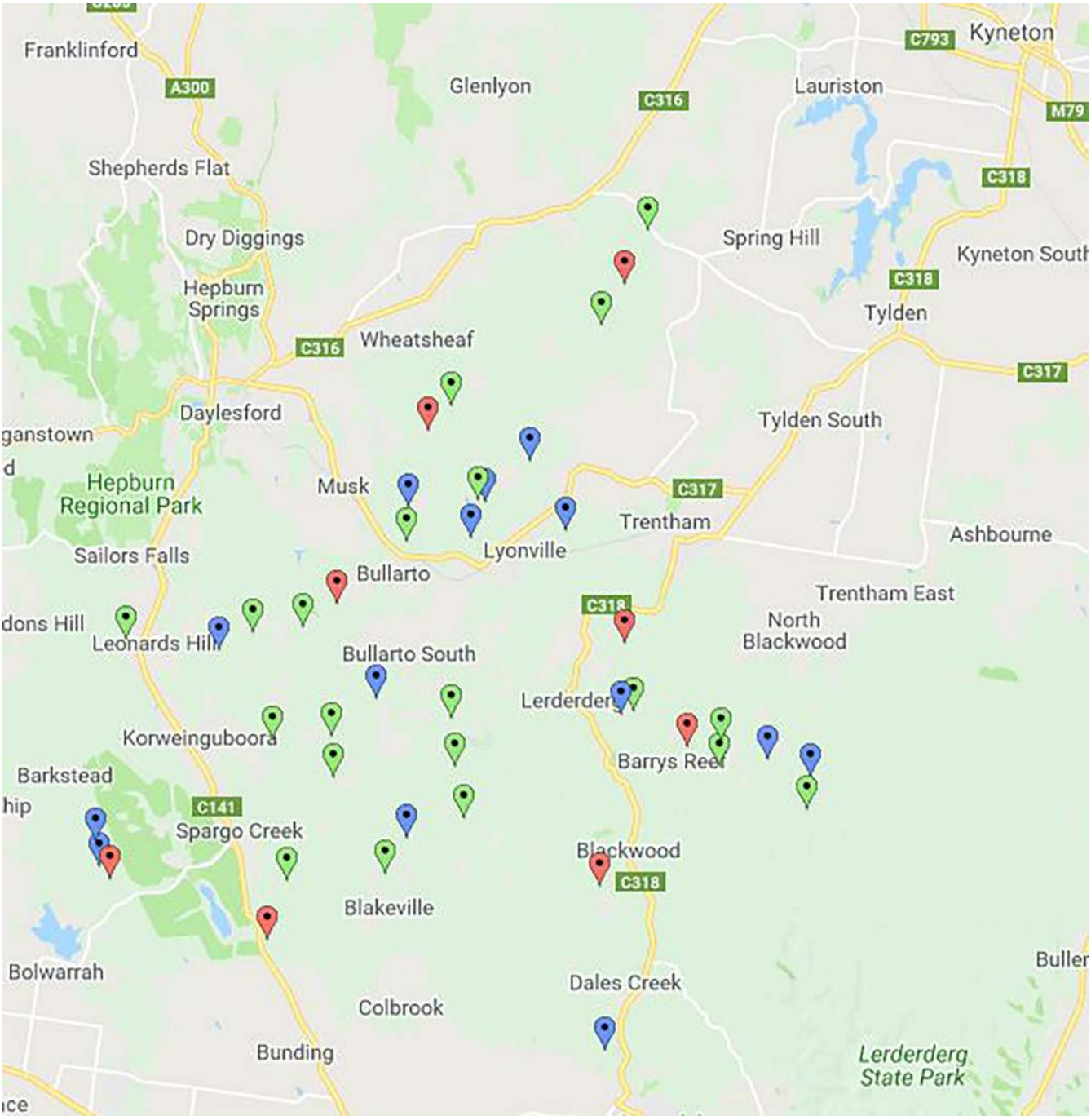
The project planning workshop provided a 10-year project plan to select 20 sites for monitoring each year. This could include some repeated sites and some new sites and result in up to 100 or more monitoring sites over the next 10 years.

Parameters for selecting monitoring sites:

- Include sites with planned burns in the subsequent 1-2 years (to collect pre-burn data and then monitor change).
- Sites in Forby Forest and Foothills Forest EVDs.
- Consider opportunities to address spatial distribution of burns in the landscape, and the patterns of burn intensity within each burn. Patchiness can be manipulated at both scales through the planning process and decisions about when to burn (weather on the day). Fine-scale patchiness can also be manipulated by decisions about ignition patterns.
- All sites are easily accessible (by 2WD vehicle and short walk).
- Sites are at least 1km apart.
- Design includes recently burnt sites (0-3 years since burn) if possible.
- If there is an interest or need identified in the future, sites in new EVCs can be included at a later stage.

So far, 44 sites have been selected and surveyed across the study area (Figure 1), with 28 monitored in the first four years and a further 16 surveyed in the fifth year covered by this report.

Figure 1. Map of the study sites within the Wombat State Forest and their time since fire category (green = long unburnt, blue= medium burnt, red= recently burnt).



Survey methods

Training

This is an ongoing community project and on-ground activities are carried out by community volunteers. Each year, coordination and training is led by the VNPA. The monitoring season starts in March and begins with a community training activity, to launch the project and train participants in how to set-up cameras.

Between 2012 and 2017, each annual training activity was attended by 25-50 eager participants , who were provided with project background, information about VNPA and Wombat Forestcare, visited several sites in Wombat forest and were trained in how to set-up bait stations and cameras.

PHOTOS: IAN KENINS

Setting up monitoring sites

Following the training activity, community volunteers from VNPA and Wombat Forestcare volunteered every three weeks to pack down, move and set-up cameras and bait stations at the 20 sites monitored each year.

A GPS and location description were used to navigate to each site. Two motion-sensing cameras (heat-in-motion type, Reconyx Hyperfire HC500) were installed at each site, approximately 100 m apart.

Each camera was attached to the nearest suitable tree at the designated location and positioned 50 cm above the ground, facing south to avoid sun glare at sunrise and sunset.

The bait station comprised six stainless steel tea strainers, which were secured inside a small rectangular cage and attached to a plastic garden stake, as shown in Figure 2.

Figure 2. Camera and bait station field set-up

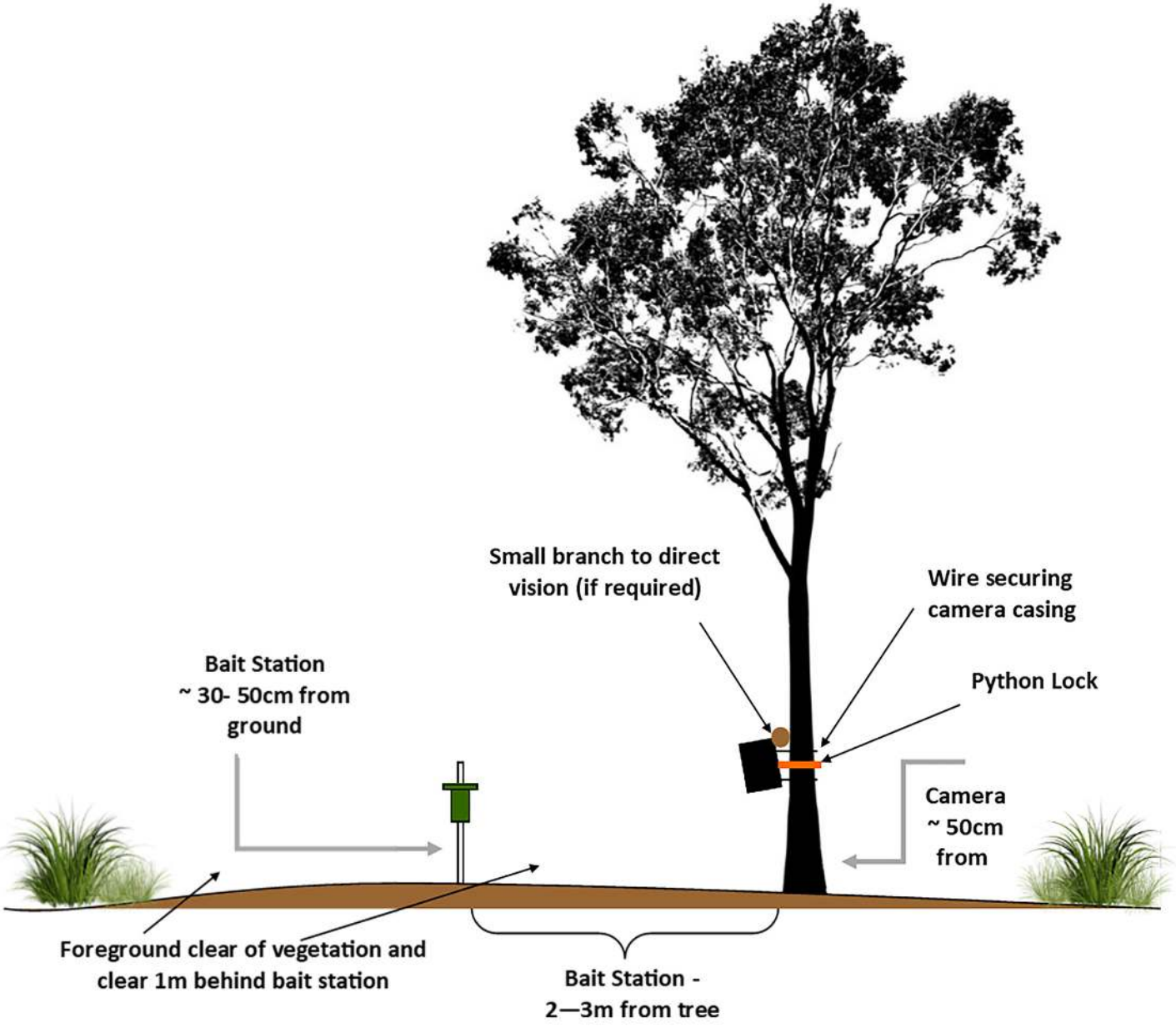


PHOTO: IAN KENINS

A bait station was placed 2-3 m in front of each camera with the base of the cage approximately 30 cm from the ground. The tea strainers were filled with a bait mixture of rolled oats, peanut butter and golden syrup, which were used to attract wildlife to the centre of the cameras' field of view.

The cameras were aligned so that the bait station appeared in the horizontal centre of the frame and the bottom of the bait cage was in the vertical centre of the frame. The vegetation between each camera and its bait station and one metre behind was cleared (within the field of view of the camera) to ensure that this did not obscure any photographs of animals.

The cameras were left to operate for a minimum of 21 days. Upon collection, cameras were checked to see if they were still operating.

Species identification

The species of wildlife in each photo taken by the cameras were identified and counted by volunteers under the supervision of the NatureWatch Coordinator. The images of wildlife which were difficult to identify were then sent to ARI or Eco Insights for further identification. Where possible, animals have been identified to species level. In cases where some doubt persisted they were assigned to a more generic category, for example "Unidentified Brushtail Possum".

Habitat assessments

At the first camera set-up at each site, habitat was assessed within a one hectare area centred on the cameras. Several habitat variables were recorded, to describe upper-, mid- and under-storey vegetation structure and to not any special features of the site. Key habitat features such as leaf litter or fallen logs were scored on a scale from 0 (absent) to 5 (very prevalent). Practice sessions helped ensure that this was estimated consistently by all assessors.

Four photographs of the habitat were taken from the locations where cameras were installed, using hand-held digital cameras. The first is a photograph of the canopy, and the rest are horizontal photographs of the vegetation immediately surrounding the site.

Analysis

We calculated the number of days on which each species was identified (using means for the two cameras) for each site and year. This measurement is called a 'site-day'. We used this as a measure of the prevalence of that species on the site at that time, or the intensity with which the species was using the site. We then assessed any relationships between this prevalence measure for each species and the following variables:

- The prevalence of other species.
- The habitat variables we recorded.
- The vegetation type (Ecological Vegetation Division; EVD).
- Fire history (number of recorded fires since 1970, and 'time since fire' as a numerical value of 'years').

We categorised the sites as recently burnt (3-14 years before the survey); medium-burnt (15-50 years before) or long-unburnt (no recorded fires for 50 years or more). This differs slightly from the original design (see pages 10-11), but it provided similar numbers of sites in each category. It happens that we did not survey any sites burnt less than three years before the survey, and we will attempt to include such very recently burnt sites in the future because some species are known to favour those early stages after fire.

We had planned to examine sites in a third EVD (Grassy/Heathy Dry Forest) but found too few sites for this to be useful. Hence, we focused mainly on Foothills Forest and Forby Forest. Two sites in Grassy/Heathy Dry Forest were analysed along with sites in Forby Forest, as some intermingling was found between those EVDs.

Table 1 shows the spread of sites across these 'time since fire' categories and the vegetation types. Because there is less Forby Forest in the Wombat forest, we located two sites within a similar EVD, 'Grassy/ Heathy Dry Forest'.

Table 1. Number of sites in each fire category and ecological vegetation division. Time since fire categories include: recently burnt (3-14 years before the survey); medium-burnt (15-50 years before) or long-unburnt (no recorded fires for 50 years or more).

Ecological Vegetation Division	Total Sites	Recently Burnt	Medium Burnt	Long Unburnt
Foothills Forest	29	7	12	10
Forby or Grassy/Healthy Dry Forest	15	4	5	6
TOTAL	**44**	**11**	**17**	**16**

Statistical analyses were run to identify significant correlations and other more complex relationships with EVD and time since fire. Further statistical models will be developed in the future for selected species.

Results

What did we observe?

Altogether we recorded 23 mammal species and 16 bird species with the motion-sensing cameras. Black Wallabies were detected on all 44 sites and were recorded on more days than any other species. In terms of numbers of sites recorded, the next most common mammal species in descending order were Common Wombat (36 sites), Agile Antechinus (31), Red Fox (28), Mountain Brushtail Possum (26), Eastern Grey Kangaroo (22), and Bush Rat (18). All were native except for the Red Fox. Details in Table 2.

The same seven species also topped the list in terms of numbers of days detected, accounting for 74.2% of mammal site-days. The two small species in the group (Agile Antechinus and Bush Rat) were recorded on more days at each site than the larger species, reflecting their small home ranges and consequently higher density.

Black Wallaby

Common Wombat

Red Fox

Bush Rat

Mountain Brushtail Possum

Eastern Yellow Robin

No other mammal species was recorded on more than 10 sites (Table 2). Black Rats appeared to be common on one of the three sites where they were recorded (WCR8, with Forby Forest last burnt in 2004) whereas other species were detected infrequently.

The species recorded were mainly ground-foragers, although Agile Antechinus also forage extensively in trees and five species feed mainly in trees (Brush-tailed Phascogale, Koala and the three possum species). No gliders or bats were recorded with the camera traps.

Agile Antechinus

Koala

Of the 22 mammal species, 13 were native and nine were introduced to Australia. Introduced mammal species contributed 7.1% of the mammal site-days, showing that introduced mammals form only a modest component of the mammal fauna detected.

The most commonly detected bird species was the Superb Fairy-wren, and it was found on 20 sites, followed by the Grey Shrike-thrush at 18 sites (Table 2).

Feral cat

Superb Fairy-wren

Table 2: Species prevalence represented by the number of sites they were recorded visiting, the percentage of total sites they visited and the mean number of days (site days) they were recorded at each site.

	Mean number of site days	Number of sites recorded (n=44)	Percentage of sites visited (n=44)
Native mammals species			
Black Wallaby	3.94	44	100.0
Common Wombat	1.49	36	81.8
Agile Antechinus	1.76	31	70.5
Any Brushtail	0.96	29	65.9
Mountain Brushtail Possum	0.77	26	59.1
Eastern Grey Kangaroo	0.45	22	50.0
Bush Rat	0.79	18	40.9
Common Ringtail Possum	0.09	10	22.7
Common Brushtail Possum	0.16	9*	20.5
Antechinus sp.	0.05	9	20.5
Echidna	0.06	9	20.5
Koala	0.08	7	15.9
Unknown Rattus sp.	0.07	6	13.6
Brushtail sp.	0.01	3	6.8
Brush-tailed Phascogale	0.04	3	6.8
Dusky Antechinus	0.01	2	4.5
Swamp Rat	0.01	1	2.3
Native bird species			
Superb Fairy-wren	0.56	20	45.5
Grey Shrike-thrush	0.49	18	40.9
White-browed Scrubwren	0.11	12	27.3
Grey Currawong	0.17	12	27.3
Australian Magpie	0.19	9	20.5
Laughing Kookaburra	0.16	7	15.9
White-winged Chough	0.13	7	15.9
Spotted Quail-thrush	0.03	4	9.1
Scarlet Robin	0.02	3	6.8
Currawong sp.	0.01	2	4.5
Southern Boobook	0.01	1	2.3
Crimson Rosella	0.01	1	2.3
Pied Currawong	0.00	1	2.3
Flame Robin	0.02	1	2.3
Eastern Yellow Robin	0.12	12	27.3
Bassian Thrush	0.06	8	18.2
Introduced species			
Red Fox	0.55	28	63.6
Cat	0.03	5	11.4
Black Rat	0.21	3	6.8
European Rabbit	0.05	3	6.8
Common Blackbird	0.02	3	6.8
Sambar or Deer sp.	0.01	2	4.5
Domestic Dog	0.01	2	4.5
House Mouse	0.01	2	4.5
Brown Hare	0.03	2	4.5
Feral Goat	0.04	1	2.3

* Identification of some Common Brushtail Possum records requires further confirmation. Local observers consider it to be unlikely to be as prevalent as these data suggest.

All of the birds observed forage extensively from the ground or low vegetation, and most were classed as members of two guilds that take invertebrates from open ground or damp shady ground respectively.

Another common species (Grey Shrike-thrush) is classed as a general insectivore, which takes invertebrates and other food from a wide range of situations.

The only seed-eating bird recorded (Crimson Rosella) feeds mainly in the tree canopy but also from the ground or low plants.

Two carnivorous species (Laughing Kookaburra and Southern Boobook) feed mainly by pouncing on ground-dwelling prey though they may take prey from a range of situations.

Laughing Kookaburra

Many bird species that feed from tall shrubs, tree trunks or the eucalypt canopy are known to be common in the forest, but were not detected with camera traps.

All bird species recorded, except Common Blackbird, were native species. Introduced species contributed 0.7% of the bird site-days, showing that introduced birds form a very small component of the bird fauna detected.

Associations between animal species

We found positive correlations between species that favour similar habitats, including Black Wallaby and Common Wombat; Agile Antechinus and Echidna; and Grey Shrike-thrush and Eastern Yellow Robin. These species all occupy a wide range of habitats but the first pair favours reasonably dense shrub cover and the other two pairs become most common where shrub cover is interspersed with areas of open ground. Dusky Antechinus were identified at two sites where Bassian Thrush was detected (WCR13 & 28), and both species have a general preference for forest gullies, damp or wet forest.

Birds that favour drier situations (e.g. White-winged Chough, Scarlet Robin and Spotted Quail-thrush) also showed positive correlations with each other, showing that they tended to favour similar sets of sites. Few negative correlations were found, suggesting that competition between species was not a major force in shaping the bird community in this forest.

Associations with habitat features

In terms of the designated EVD, two native species (Echidna and Spotted Quail-thrush) appeared to favour Grassy/Heathy Dry Forest or Forby Forest over Foothills Forest. Two introduced species (European Rabbit and Feral Cat) were also found more often in those EVDs.

Three of the uncommon native mammal species recorded were only found in Foothills Forest: these were Brush-tailed Phascogale, Swamp Rat and Dusky Antechinus. Fewer birds were recorded in the two sites containing Grassy/ Heathy Dry Forest than in sites containing Forby Forest or Foothills Forest.

In general, the designated EVD explained only a small part of the variation in mammal and bird communities between sites. Mean numbers of site-days for each species in each EVD are shown in Table 3.

Table 3: Mean number of site days of each species by Ecological Vegetation Division.

Site EVD	Foothills Forest	Forby Forest or Grassy/Heathy
Number of sites	29	15
Native mammal species		
Echidna	0.04	0.10
Brush-tailed Phascogale	0.05	0.00
Agile Antechinus	1.97	1.33
Dusky Antechinus	0.01	0.00
Common Brushtail Possum	0.19	0.11
Mountain Brushtail Possum	0.90	0.53
Any Brushtail	1.11	0.65
Common Ringtail Possum	0.11	0.04
Koala	0.08	0.09
Common Wombat	1.70	1.07
Black Wallaby	3.91	4.01
Eastern Grey Kangaroo	0.48	0.41
Bush Rat	1.03	0.32
Swamp Rat	0.01	0.00
Native bird species		
Southern Boobook	0.02	0.00
Crimson Rosella	0.02	0.00
Laughing Kookaburra	0.16	0.15
Superb fairy wren	0.66	0.37
White-browed Scrubwren	0.11	0.10
Spotted Quail-thrush	0.02	0.06
Grey Shrike-thrush	0.50	0.46
Australian Magpie	0.16	0.26
Pied Currawong	0.00	0.00
Grey Currawong	0.17	0.17
Currawong sp.	0.00	0.01
White-winged Chough	0.17	0.04
Scarlet Robin	0.03	0.00
Flame Robin	0.00	0.05
Eastern Yellow Robin	0.15	0.05
Bassian Thrush	0.08	0.03
Introduced species		
Black Rat	0.08	0.47
House Mouse	0.02	0.00
European Rabbit	0.03	0.08
Brown Hare	0.02	0.07
Feral Goat	0.00	0.12
Sambar or Deer sp.	0.01	0.01
Red Fox	0.63	0.41
Cat	0.01	0.06
Domestic Dog	0.00	0.02
Common Blackbird	0.00	0.04

Correlations were evident with some of the measured habitat characteristics. For example, the abundance of tree-ferns was positively associated with Dusky Antechinus and Bassian Thrush. Sedges and Blackwood wattles were positively associated with Common Wombat and insectivorous birds that feed from damp ground (including White-browed Scrubwren and Eastern Yellow Robin).

The proportion of smooth-barked eucalypts (gums, mainly Candlebark) was positively correlated with Koala (which feeds preferentially from these species) and Mountain Brushtail Possum (which favours the damp habitats occupied by gums). The proportion of stringybarks (mainly Messmate) was negatively correlated with Mountain Brushtail Possum but positively with Agile Antechinus.

Numbers of Agile Antechinus correlated positively with the number of trees with dead tops, and negatively with the number of trees lacking that feature. Tree size and number of hollows correlated positively with total birds and several bird species.

Relationships with fire history

No species showed strong relationships with fire history, showing that most species can tolerate a range of fire regimes. However, weak relationships were found for some species (Table 4).

Four native species showed weak positive relationships with time since fire, suggesting a long process of recovery after an initial negative impact of fire. These were Echidna, Bush Rat, Grey Shrike-thrush and Superb Fairy-wren[1].

Two uncommon species were found mainly on sites that had not been burned for a long time: these were Dusky Antechinus and (more surprisingly) the introduced European Rabbit. Introduced House Mouse was only found in two sites (WCR4 and 19), both of which were long-unburnt.

The three records of Brush-tailed Phascogale were in Foothills Forest in each of the three time since fire categories (recently burnt, medium burnt, long unburnt).

Short-beaked Echidna

1 Statistical significance for all tests: $p < 0.1$

Table 4: Mean number of site days for each species by fire history category.

Site	Long unburnt	Medium burnt	Recently burnt
Native mammals species			
Echidna	0.11	0.05	0.00
Brush-tailed Phascogale	0.02	0.06	0.02
Agile Antechinus	2.00	2.13	0.82
Dusky Antechinus	0.02	0.00	0.00
Common Brushtail Possum	0.09	0.22	0.17
Mountain Brushtail Possum	0.96	0.69	0.61
Any Brushtail	1.06	0.95	0.81
Common Ringtail Possum	0.14	0.08	0.03
Koala	0.12	0.04	0.09
Common Wombat	1.67	1.46	1.26
Black Wallaby	3.73	4.02	4.13
Eastern Grey Kangaroo	0.45	0.35	0.63
Bush Rat	1.37	0.61	0.22
Swamp Rat	0.02	0.00	0.00
Native bird species			
Southern Boobook	0.00	0.00	0.05
Crimson Rosella	0.00	0.00	0.05
Laughing Kookaburra	0.02	0.23	0.25
Superb fairy wren	1.00	0.36	0.23
White-browed Scrubwren	0.13	0.07	0.13
Spotted Quail-thrush	0.03	0.06	0.00
Grey Shrike-thrush	0.78	0.36	0.25
Australian Magpie	0.21	0.16	0.22
Pied Currawong	0.01	0.00	0.00
Grey Currawong	0.13	0.21	0.16
Currawong sp	0.01	0.01	0.00
White-winged Chough	0.09	0.22	0.05
Scarlet Robin	0.04	0.02	0.00
Flame Robin	0.05	0.00	0.00
Eastern Yellow Robin	0.17	0.11	0.06
Bassian Thrush	0.08	0.07	0.02
Introduced species			
Black Rat	0.00	0.01	0.84
House Mouse	0.04	0.00	0.00
European Rabbit	0.13	0.00	0.00
Brown Hare	0.00	0.06	0.05
Feral Goat	0.00	0.00	0.16
Sambar or Deer sp.	0.01	0.00	0.02
Red Fox	0.48	0.60	0.60
Cat	0.05	0.02	0.01
Domestic Dog	0.01	0.00	0.01
Common Blackbird	0.02	0.00	0.05

Trends over time

We surveyed 11 of the 44 sites every year from 2012 to 2015, which enables us to examine trends over time at these sites. Data from those sites are graphed in Figures 3-6 for four common native mammal species: along with most species, these were expected to demonstrate a response to fire.

Two of the 11 sites were classed as recently burnt: site WCR30 was burnt in 2009 (three years before our study began), and site WCR18 in 2005 (7 years). Three of the sites were classed as medium time since fire, having been burnt 10-50 years previously (WCR5, 14 & 23), and six were classed as long-unburnt (WCR3, 12, 19, 26, 28 & 29). It was expected that the recently burnt sites (especially WCR30) might show more evidence of successional change than the sites burnt longer ago. However, little support for that idea was found for these four species (Figures 3-6).

Nevertheless, some differences in response were evident[2]:

- Black Wallabies appeared to increase over time on the most recently burnt site (WCR30) but remained more stable on the set of other sites (Figure 3).
- Common Wombats were initially more common on WCR30 than on other sets of sites, but decreased to average levels in the fourth year of the survey (Figure 4).
- Bush Rats were not recorded on WCR30 except in the third year of the survey (2014), and numbers fluctuated greatly in the other sets of sites (Figure 5).

2 Further analysis is needed to assess the statistical significance of these results.

Figure 3: Black Wallaby relationship with fire history.

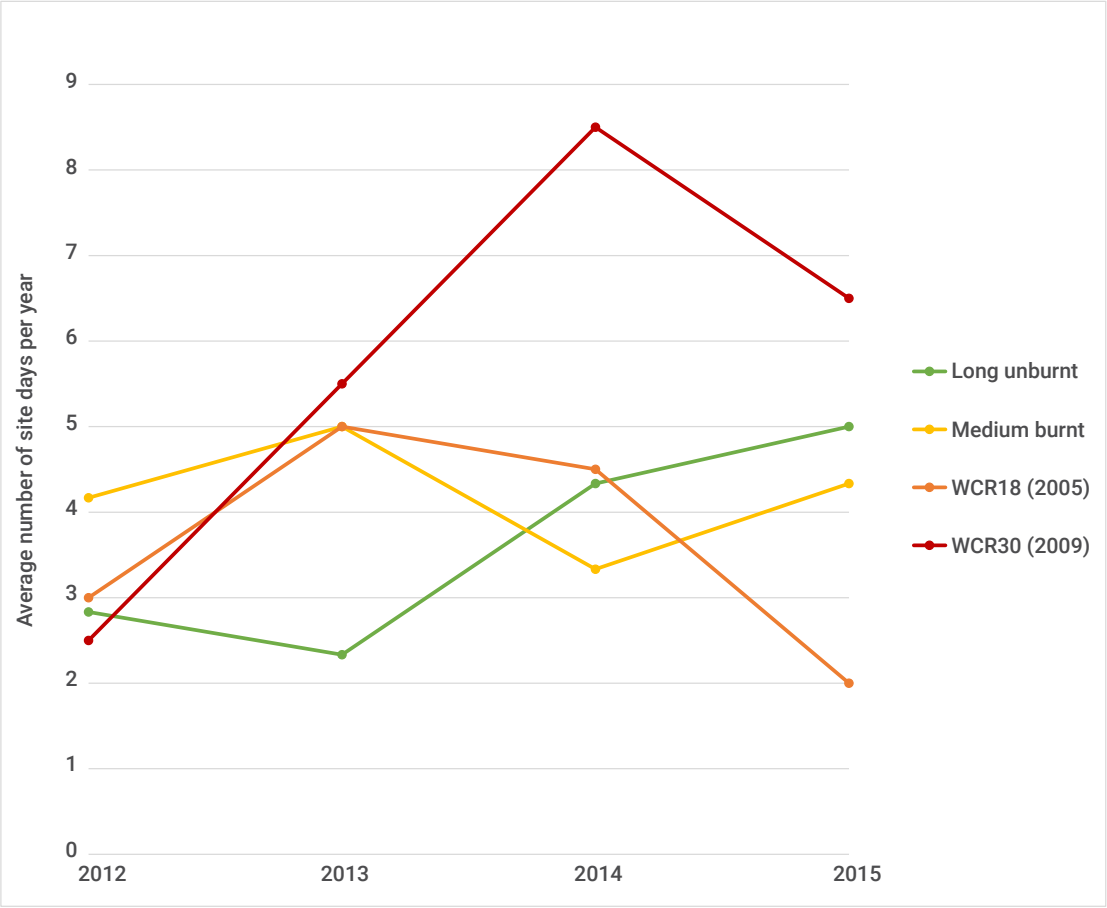


Figure 4. Common Wombat relationship with fire history.

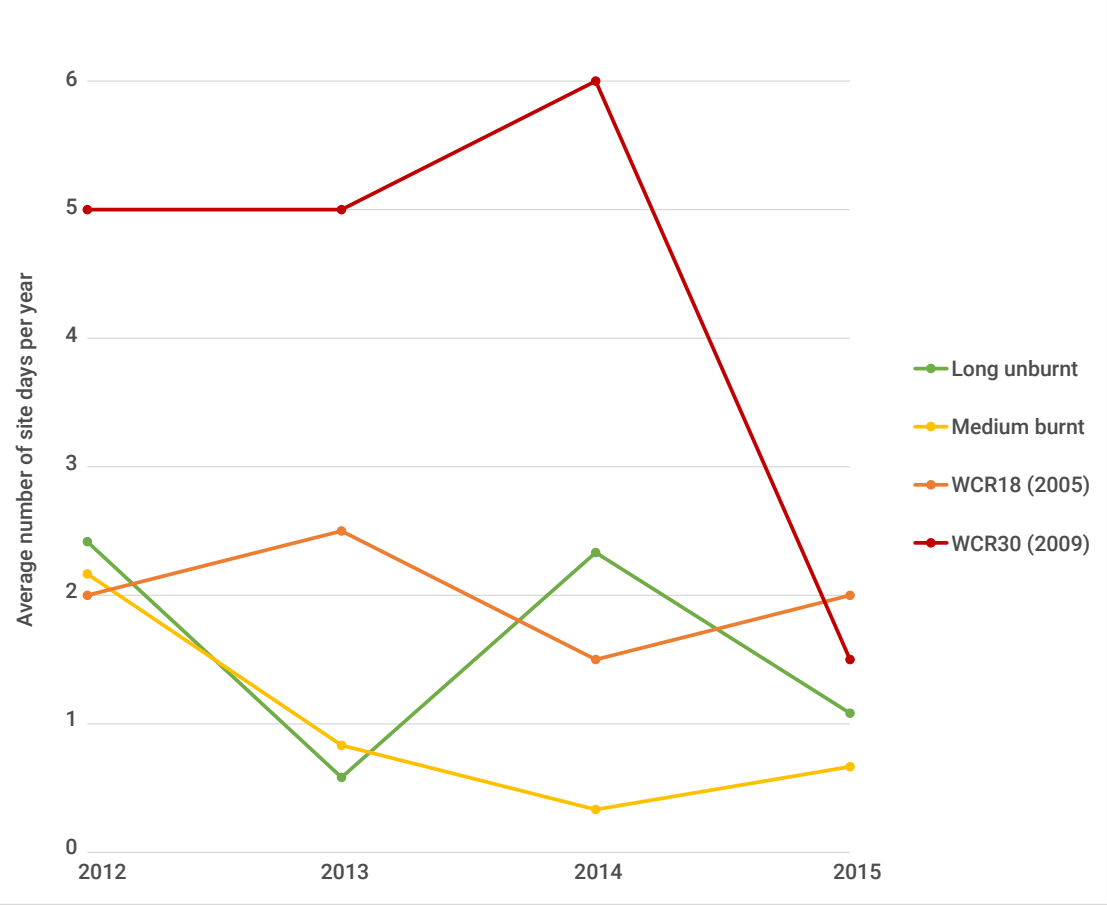


Figure 5: Bush Rat relationship with fire history.

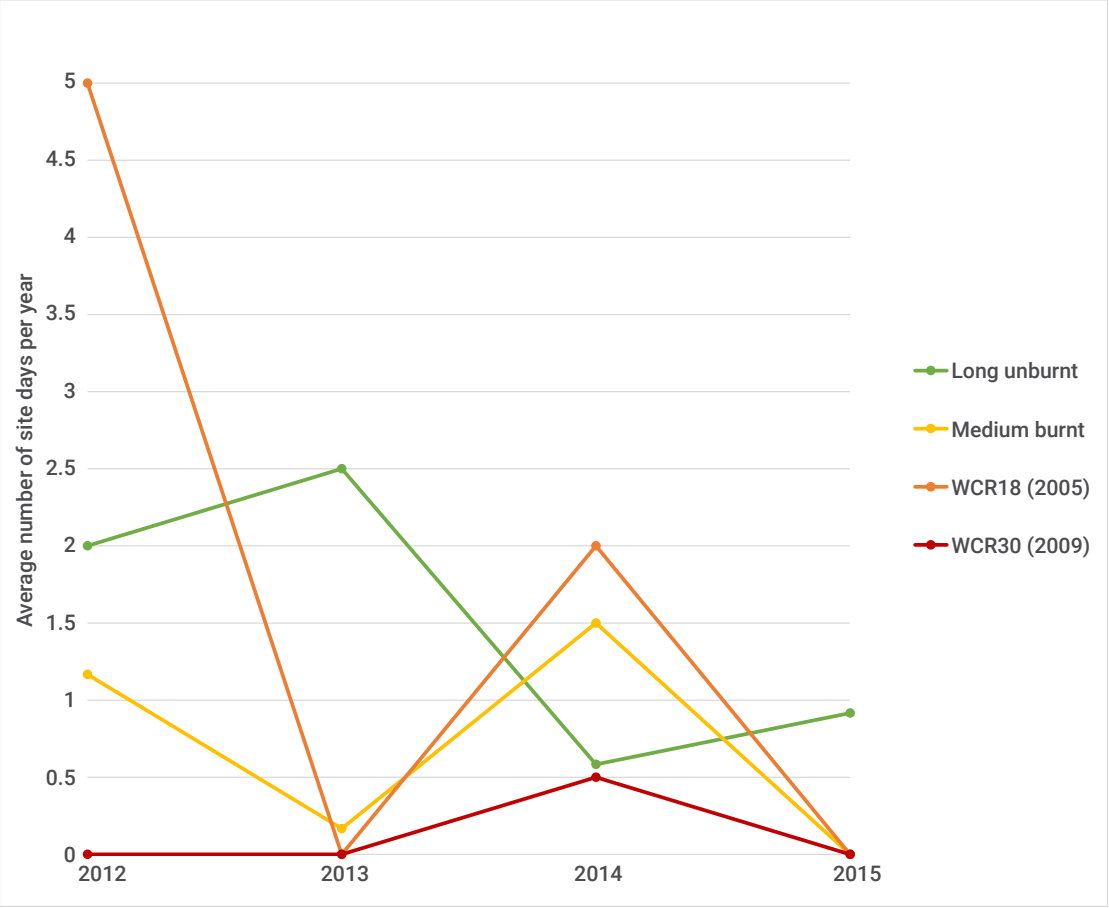
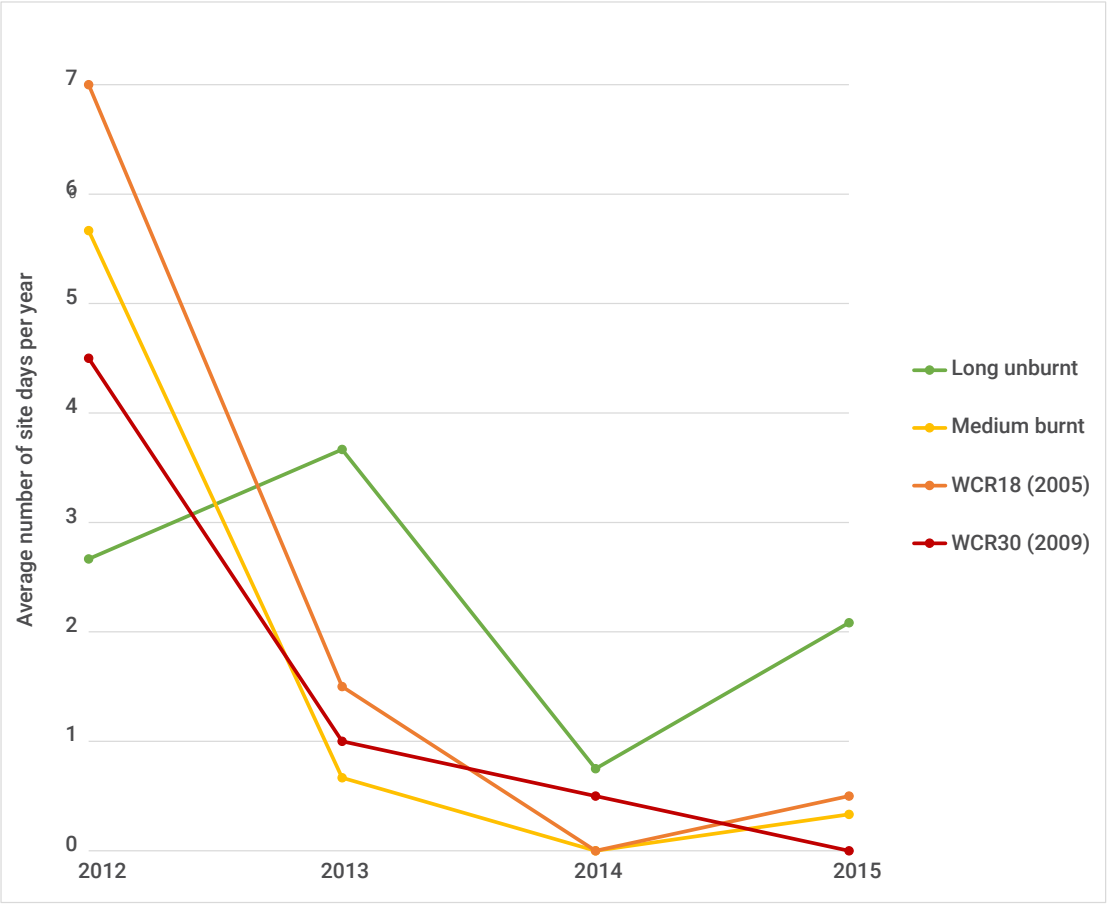


Figure 6: Agile Antechinus relationship with fire history.



- Agile Antechinus declined dramatically after the first year of the survey on both recently burnt sites, and on the set of three medium-burnt sites, but not on the set of six long-unburnt sites (Figure 6). A similar decline occurred on the long-unburnt sites the following year, with a partial recovery in 2015.

Discussion

A community achievement

This important study on the impacts of fire on wildlife in the Wombat State Forest is carried out almost entirely by volunteers. More than 45 volunteers each year contributed over 2,500 hours of work to amass five years of highly valuable data on mammals in Wombat State Forest.

The project has opened a new window on the ground-dwelling mammal fauna in the Wombat State Forest, and helps to improve our understanding of how different species may change over time, and respond to habitat and the way the habitat is managed.

Without this study we would have no contemporary data about the ground-dwelling mammal fauna in these forests in the decade following one of the longest droughts in recent history (1997-2009) and subsequent changes in policy relating to management of fire and logging.

The project has seen passionate community members, scientists and managers working together to increase our understanding of mammals in Wombat State Forest. The project has expanded the skills and knowledge of everyone involved.

Some of our participants, volunteers and community group leaders reflected on their learnings through an anonymous survey:

"Participation has broadened my knowledge and appreciation of local plants and animals and the habitats in which they live."

"Community members have a desire for ecological knowledge and their participation allows for the sharing of this knowledge."

We've also had some exciting and unexpected outcomes. Caught on Camera in Wombat State Forest was featured in French documentary, 'Nature's Keepers'. Representatives from VNPA and Wombat Forestcare were interviewed and the field deployment of the project was filmed to provide an international audience with an understanding of the project and our aims.

'Nature in the Dark' was a creative arts project that arose from the images we collected. Artists were provided with our wildlife images and re-worked and interpreted the original footage in their own way, with several artists' interpretations curated into a single piece that was projected at various venues. According to the curators;

"Looking at the photos there is something incredibly intimate and unguarded about them. It's as if wildlife social-realism meets the monochromatic aesthetic of night vision surveillance and we are becoming voyeurs of another intelligence at work -- which we would not have encountered otherwise." (Brüggemeier and Miranda 2012)

Understanding our results

Wombat State Forest has been subject to a long history of gold-mining, logging, wildfire and planned burns. Most of the 44 sites surveyed had been subject to some or all of these disturbances.

Fire causes substantial changes to fauna habitat, which are most marked in the first three years. Influxes of native species associated with open habitats are often seen after wildfire, and these may include introduced species such as House Mouse (Friend 1993) and native species such as Superb Fairy-wren, Scarlet Robin and White-browed Woodswallow (Loyn 1997; Loyn and McNabb 2015).

Smaller influxes may also occur after planned burns, as shown in various studies including some in the Wombat State Forest (Humphries 1994; Loyn *et al.* 2003; Loyn and McNabb 2015). The current study focused on longer-term effects, and we did not examine sites burnt less than three years before the surveys.

Some of the species that prosper in the first three years after fire (e.g. House Mouse, Superb Fairy-wren and Scarlet Robin) turned out to be more prevalent in long-unburnt forest than in younger age-classes. Other studies have shown that some of the mammals and birds that favour open stands in early stages after fire or logging may avoid the later stages where shrub cover may be dense, but become more prevalent as those stands open up again after many years (Loyn 1997, 2004, 2012).

Recent studies in Victorian foothill forests have shown that longer-term effects of fire on flora and fauna are generally subtler than those in the first three years (Muir *et al.* 2015; Leonard *et al.* 2016; Kelly *et al.* 2017). The current project supports this conclusion, showing the response of the common ground-dwelling mammal and bird fauna in these forests.

The project has also shown that these forests continue to support some less common species, including the Brush-tailed Phascogale, which was formerly only known from the drier northern parts of Wombat State Forest. It is much harder to determine how they may be affected by current or future management of fire or anything else because of the low numbers we detected. However, it is reassuring that they can still be found in Wombat State Forest and continue to make use of widely distributed and less-threatened habitats including Foothills Forest.

Limitations and recommendations

Camera trapping has become a popular and valuable survey method, and refinements will continue to be made to the technology and the different ways of analysing data (e.g. Swann *et al.* 2004; Nelson and Scroggie 2009; Meek *et al.* 2014).

At present, the number of photographs does not provide a robust measure of species abundance, as individual animals may spend long and variable periods at the bait station on a single visit. Some ecologists have argued that quantitative conclusions cannot be made with camera-trap data unless individual animals are identified, but we believe that approach is too limited, and quantitative analyses of the sort we have undertaken can provide important information about the relative abundance of mammal species in different types of habitat. Analysis based on presence-absence would clearly be inadequate for common species such as Black Wallaby, which was recorded on every site but exhibited marked variation in prevalence between sites (different numbers of site-days).

As with any project, our study does not provide a complete picture, and there are some limitations with the field methods and with the exploratory analysis presented here. But, despite the limitations, this project has progressed our knowledge of fauna in Wombat State Forest. More complex statistical analyses will be needed to unlock the potential of this study to inform us about effects of habitat and fire management. The analyses reported here are exploratory, and more sophisticated approaches are possible (Robley *et al.* 2010; Gillespie *et al.* 2016) which we look forward to exploring in the future.

With the present data, it is clear that some species were detected much more often on some sites than others, in terms of numbers of photographs taken and numbers of days on which they were photographed. The number of days on which the species is detected is highly likely to reflect the relative abundance of that species on the site (for species with small home ranges), or the intensity of use that site (for species with large home ranges).

What's next

At a workshop to develop our long-term project plan, attended by the project partners, we decided the best way to progress was to increase the number of sites by monitoring new sites each year. The benefits of this approach were identified as:

- Increase the statistical power of the project and capacity to answer the research question.
- Easily make it possible to include several of the following options:
    1. Adding monitoring of birds at existing sites.
    2. Adding monitoring in other vegetation types
    3. Setting up monitoring sites to monitor burn patterns at specific sites.
    4. Setting up monitoring at sites before and after fire.
    5. Gather more detailed habitat data.
    6. Include more 'recently burnt' sites (0-4 years since fire).
- Make it possible to analyse the data against different variables.

The following reporting will be undertaken:

1. Regular reporting back to community via social media and emails.
2. Reporting all feral and threatened species records to DELWP within a week of downloading data.
3. Reports every five years prepared for a mixed audience (scientists, land managers, community and volunteers) and published by VNPA.
4. Article for peer-reviewed science journal by around 2022 (including up to 10 years of data).

We're committed to continue this project for at least ten years. We're looking forward to a continued and lasting relationship between the community, scientists and government representatives involved in Caught on Camera in Wombat State Forest.

Black Wallaby

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Red Fox

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