NSW National Parks and Wildlife Service

WildCount

Final report on results of the WildCount program (2012 to 2021)

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Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

Artist and designer Nikita Ridgeway from Aboriginal design agency – Boss Lady Creative Designs, created the People and Community symbol.

Cover photo: Swamp wallaby image captured by WildCount camera trap. DCCEEW

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Summary

WildCount was a landscape-scale fauna monitoring program led by the NSW National Parks and Wildlife Service (NPWS). Running from 2012 to 2021, it was NSW's first large-scale, multi-species camera trap initiative. The program was developed in response to critical gaps in data for vertebrate species identified in the *State of the catchments 2010: assessing the sustainability of native fauna in NSW* report. WildCount aimed to improve understanding of native mammal populations and establish a robust, long-term framework for tracking changes in species occurrence across the eastern seaboard.

Key findings from WildCount were:

- detected 162 species across 204 monitoring sites in 146 national parks and reserves, including 143 native and 19 introduced species
- contributed valuable data on 27 threatened species, improving understanding of their distributions
- WildCount had sufficient power to detect a 30% change in species occupancy for common brushtail possum, swamp wallaby and red fox, although no significant trends were observed for these species over the 10-year period.

During the 2019–20 Black Summer bushfires, 42% of WildCount monitoring sites were impacted by fire, including 58 sites experiencing high-severity burns. Surveys at monitoring sites following the fires revealed that most species showed no significant change in occupancy. However, some species, such as the swamp wallaby, exhibited increased risk of extinction in areas affected by high-severity fires, while other species showed resilience or positive responses.

Although WildCount had limitations, particularly for monitoring small and cryptic species, the program offered valuable insights into the effectiveness of camera traps for long-term fauna monitoring. The program's findings highlight the need for methodological review and refinement to ensure that monitoring efforts are robust, statistically powerful and capable of informing meaningful conservation outcomes. Systematic, long-term monitoring remains essential for managing biodiversity and at-risk species, and for guiding the delivery of effective conservation strategies.

1. Introduction

1.1 Program aims

WildCount was initiated by the NSW National Parks and Wildlife Service (NPWS) in response to the *State of the catchments 2010: assessing the sustainability of native fauna in NSW* report (Mahon et al. 2011), which identified data gaps for a range of vertebrate species in New South Wales (NSW). The report found that there was inadequate information to assess broadscale trends in even our most common species.

WildCount aimed to improve knowledge of native mammal populations across the eastern seaboard of New South Wales and to foster a long-term commitment to monitoring trends in native fauna. The program's objective was to detect and report on distributional changes for a suite of species using annual occupancy data. Additionally, it sought to relate local-scale environmental observations with species occurrence and occupancy trends. The program set to achieve this by systematically monitoring changes in terrestrial fauna occurrence within the national parks estate of eastern New South Wales, using data acquired from remotely deployed cameras ('camera traps'). Monitoring changes in species occurrence is important for identifying changes in the distribution of animal populations and assessing a species' risk of significant decline or extinction.

Part 1 of this report summarises the findings for the 10-year WildCount program, with a focus on species occupancy trends for the program's most commonly encountered species. It includes an assessment of the program's statistical power to detect changes in species occurrence. Part 2 discusses the impacts of the 2019–20 Black Summer bushfires.

Further information is available on the *WildCount* webpage (see link in the 'More information' section).

Part 1

2. Survey design

The WildCount survey boundary was defined by the overlapping distribution of 6 medium- to large-sized species with widespread occurrence: swamp wallaby, red-necked wallaby, long-nosed bandicoot, common brushtail possum, common wombat and superb lyrebird. While these 6 species were not the sole targets for monitoring, they are highly suitable for detection using camera traps and their distributions provide broad geographic coverage that supports monitoring of a suite of similar species.

2.1 Site selection

Site selection was based on stratified random sampling to ensure unbiased sampling. A total of 204 sites were selected within 146 national parks and reserves across the eastern seaboard of NSW (Figure 1). Details on program development, site selection and survey design are detailed in Porter et al. (2013). A brief summary is provided in the following sections.

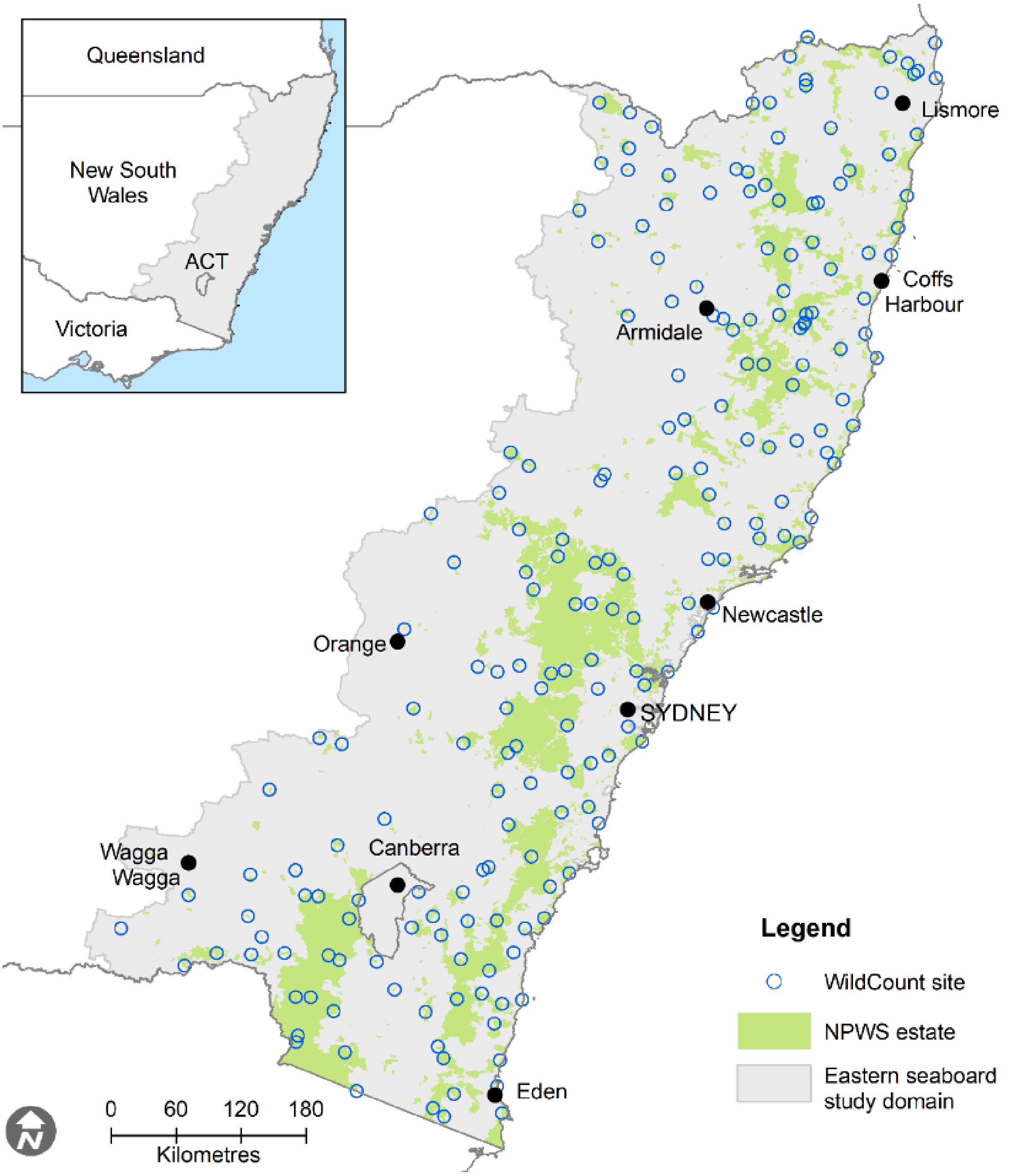


Figure 1 Location of WildCount monitoring sites in the eastern seaboard study area

2.2 Camera surveys

Within each site, 4 infra-red flash cameras (PC800, Reconyx Inc., Holmen, WI, USA) were deployed at the corners of a 500 × 500 m grid (Figure 2a). Each camera was positioned 1 m off the ground, with a lure containing peanut butter and rolled oats placed 2 m from the camera (Figure 2b). The cameras used motion sensors to detect movement and changes in ambient heat, and when both were detected the camera was triggered to take photos. WildCount cameras were set to take 3 photos per trigger and cameras remained at the sites for a minimum of 14 consecutive days.

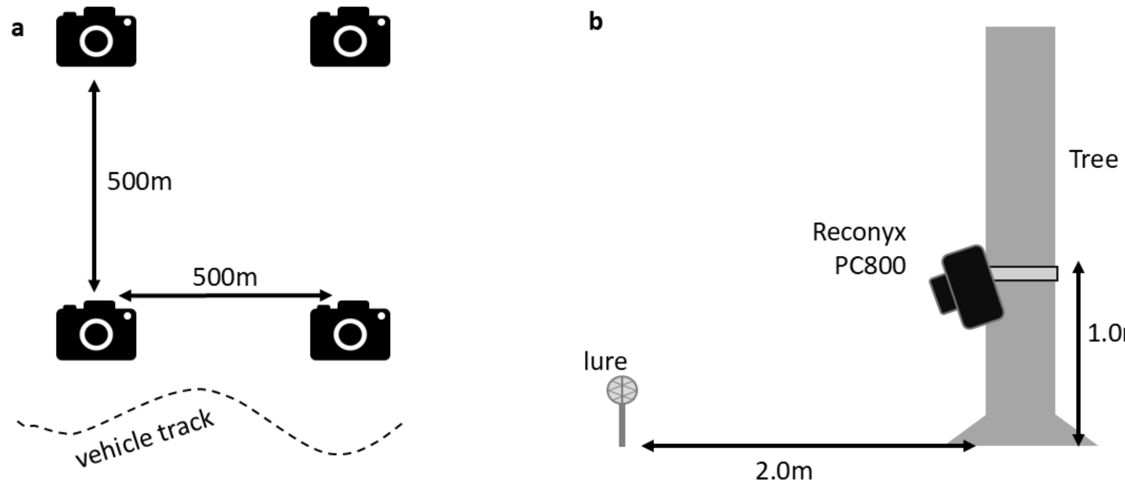


Figure 2 Diagrammatic representation of a) camera configuration at each site, and b) set-up of each camera and lure

Surveys commenced in 2012 and were conducted every year up to and including 2021. The program was operationally successful, with 198 to 204 sites surveyed each year (an average of 202 each year). From February to June each year, 5 to 6 teams of 2 people deployed cameras across eastern NSW. On average, only 12 of the 816 cameras (1.5%) deployed each year failed to operate for more than 13 days, and only 9 cameras (1.1%) operated for less than 12 days.

2.2.1 Image analysis

A small team of staff reviewed every camera image. For each year (2012 to 2021) and each site (n = 204), species were identified on camera images and the observer assigned a level of confidence – 'definite', 'probable' or 'possible' – to their species identification. Verification of species identifications was sought by recognised experts when required.

Where a species could not be identified, an 'unknown' tag was assigned under 7 classes: bird, frog, macropod, mammal, reptile, small mammal <500 g, and a generic 'unknown' where there was clear evidence an animal triggered the camera, but no further discrimination could be made.

The number of images classified as definite, probable or possible each year ranged from 165,065 to 257,789. Over the 10-year survey period, WildCount classified 1,958,849 images, with 1,913,659 (97.7%) images with a definite species classification, and 143 (<0.01%) images with a probable or possible classification. Images classified as 'unknown' comprised 2.3% (45,047 images) of all classified images. In a further 400,000 images no species were identified, usually resulting from false triggers.

A total of 162 species and 6 'species groups' were classified from camera images over the 10 years of surveys (Appendix A). The 162 species included 143 native species and 19 introduced species. Species groups were used when there was difficulty in resolving the identification of similar taxa to species level. These groups were: mouse sp., corvid sp. (crows), teal duck sp., thrush sp., rat sp. and small dasyurid.

These data are stored and managed by the department's corporate wildlife database, *NSW BioNet*.

2.3 Site ecological covariates

At each of the 4 camera locations within a site, ecological covariates were recorded at the same time as the cameras were deployed (see Appendix B). These covariates included topographic position, litter depth and various vegetation characteristics (type, height, largest tree, ground layer). Additionally, soil properties and disturbance factors (such as fire, logging, grazing, weeds, dieback and presence of feral animals) were documented. These measurements were taken annually over the 10-year duration of the program. Each covariate was assessed within a 20-m radius plot surrounding each camera location.

3. Data analysis methods

The statistical models developed for this report are primarily exploratory, aimed at identifying broad patterns in occupancy and detectability as well as detecting shifts in species distributions. To ensure analytical rigor, reduce potential biases and align with model assumptions and best practices, the analyses were conducted in close collaboration with professional statisticians.

Occupancy models were developed for species detected by camera traps that met at least one of 2 criteria over the 10-year period: presence at a minimum of 20% of all sites and/or more than 4,000 total images captured. The 4,000-image threshold was chosen to include species with low site occupancy but high detection frequency, ensuring that such species were not overlooked in the analysis.

For each species meeting either of these criteria, several analyses were conducted to:

- estimate species occupancy and identify environmental factors that influenced species distribution
- estimate species detectability and identify factors that influenced detectability
- estimate changes in occupancy over the 10-year period (trend analysis)
- identify the statistical power of the data to confidently monitor population trends.

Sections 3.1 to 3.3 outline the methodologies used to analyse occupancy and detectability, as well as to assess statistical power. A ‘season’ refers to the total period that cameras were deployed in a given year (minimum 14 days).

3.1 Occupancy

Occupancy refers to the probability or proportion of sites where a species is present during a defined survey period, based on detection data and accounting for imperfect detection.

WildCount was designed to use occupancy modelling as a statistical method to estimate the probability that a species occupies a given area, and to monitor changes in species occupancy over the program period. Occupancy modelling is used as it accounts for the possibility that a species may be present but not detected during surveys.

In performing the occupancy modelling, species presence and absence data were aggregated across all 4 cameras per site and used as a single daily presence or absence for a species. Only species’ records assigned a ‘definite’ level of identification confidence were used in the analyses.

Three types of occupancy models were run:

1. **Basic occupancy models**: These estimate the probability of species occurrence without environmental covariates (also referred to as a null model) and were used to assess change in occupancy over the 10-year duration of the study (see section 3.1.1).
2. **Occupancy models with spatial covariates**: These estimate the probability of species occurrence with respect to environmental covariates that varied spatially across sites, for example, vegetation formation and mean annual rainfall (see section 3.1.2).
3. **Occupancy models with spatio-temporal covariates**: These estimate the probability of species occurrence with environmental covariates that varied both spatially (across sites) and temporally (annually) over the duration of the study (see section 3.1.3).

3.1.1 Basic occupancy and trend analyses

For each species, a multi-season, single-species occupancy modelling approach was used (Nichols et al. 2008). To assess patterns of change in occupancy over the 10-year study period, 3 models were fitted to the data: constant (null), year-specific and linear-trend, following the approach outlined by MacKenzie (2016). Any one of these models might best represent the data for a given species dependent on the modelled results. Conceptually, these models are represented in Figure 3.

For each species, the 3 models were compared using Akaike Information Criteria (AIC) weights (see Glossary), which rank the strength of evidence of each model among the set of models. Occupancy estimates for each species were based on model averaging approaches, where parameter estimates from each of the 3 models are combined relative to their model weighting. Model averaging summarises the relative likelihood of a model compared to the other candidate models in the set; with the combined weight of all models in a set summing to 1.

3.1.2 Occupancy models with spatial covariates

Single-season, single-species occupancy models were run for each year of monitoring with the inclusion of spatial covariates for each species to:

- describe species distributions in relation to environmental factors at a large spatial scale
- identify significant environmental variables which may improve species-specific management and future monitoring designs.

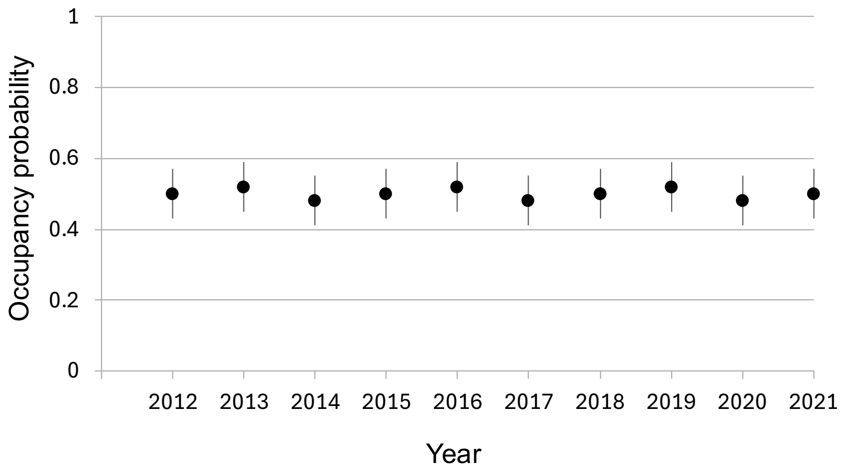
Six environmental variables, including 3 derived from BIOCLIM (Busby 1991), were used to investigate spatial patterns of occupancy:

- mean annual temperature (long-term average)
- mean annual precipitation (long-term average)
- (solar) radiation index
- vegetation formation
- distance to coast
- latitude.

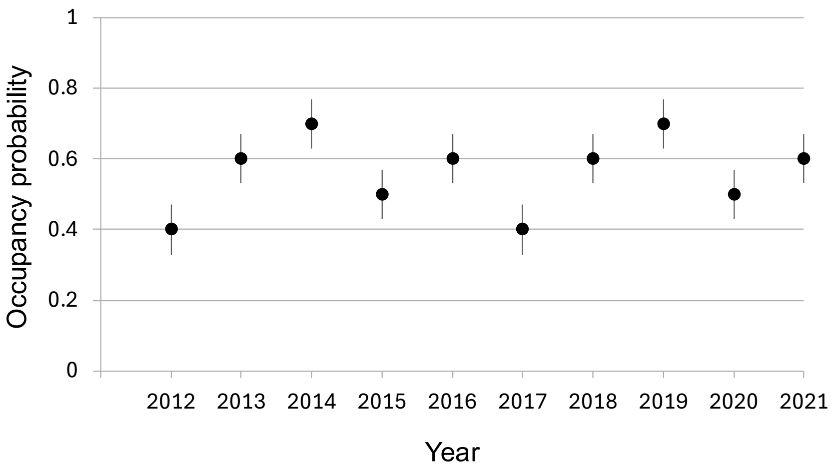
Not all combinations of the 6 variables were modelled together due to the large number of possible combinations (n = 36) and the fact that some covariates were correlated (for example, latitude and mean annual temperature). For most species, only single covariate models were tested for ease of interpretation and simplicity.

Environmental covariates that were significant in explaining a species occupancy for 7 or more years were used to model species trends (as described in section 3.1.1). Model comparisons were performed using AIC weights to determine which was the favoured model (null, year or trend).

a) Constant



b) Year



c) Trend

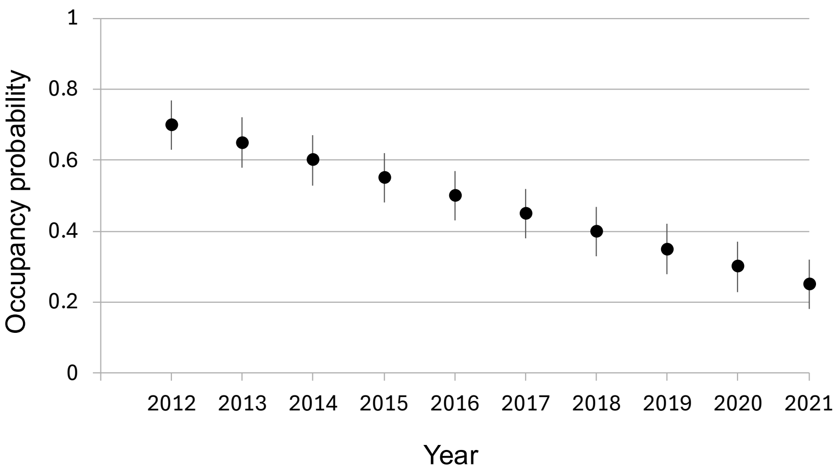


Figure 3 Conceptual illustration of the differences between a) constant, b) year and c) trend occupancy models

3.1.3 Occupancy and spatio-temporal covariates

Occupancy models using spatio-temporal covariates were run to assess their influence on trends in species occupancy. These covariates differ to those used in section 3.1.2 as variables varied year-by-year. Site ecological covariates (section 2.3) and variables derived from the *Australian Water Availability Project* (AWAP, see link in 'More information' section) (Raupach et al. 2009, 2008) were used in these analyses.

AWAP variables are derived from Bureau of Meteorology weather stations and interpolated climate surfaces, providing spatial and temporal estimates of terrestrial water balance across the entire Australian continent. These data have a spatial resolution of 0.05 degrees latitude and longitude (~5 km × 5 km) and the temporal window is monthly or annual. The following 5 AWAP variables were chosen as they were thought to most likely influence the occupancy of vertebrate fauna:

- mean spring precipitation (monthly precipitation was summed for the 3-month period, September to November, of the year preceding surveys)
- mean solar radiation
- mean minimum temperature
- mean maximum temperature
- mean evaporation.

Note, only monthly estimates of the covariates, or derivations thereof, were used in models.

Models were run using site ecological covariates and AWAP variables modelled as interactive terms with year and trend. For most species, only single covariate models were tested for ease of interpretation and simplicity. Model support was compared using AIC. Spatial and temporal variables which were significant in explaining species occupancy for 7 or more years of data are reported (Appendix C).

3.2 Detectability

Detection probabilities represent the likelihood of observing a species during a survey period, given that the species is present at the site. These probabilities are crucial for accurately estimating the true occupancy of a species and in designing effective survey protocols.

3.2.1 Daily detection

For WildCount, daily detectability was estimated from single-season, single-species occupancy models. Daily detection refers to the probability of detecting a species on any given day during the survey period, using 4 cameras per site. Mean detection estimates were calculated by averaging model-derived annual estimates across all 10 years of surveys.

3.2.2 Sampling covariates

One of the assumptions of occupancy modelling is that detectability is constant across all sites, or that variation in detection can be modelled by incorporating covariates. Given the geographic spread and range of habitats sampled by WildCount, it is unlikely that detection probabilities were constant across sites. Therefore, it is important to identify if there were site-based variations in species detectability.

To investigate factors which might influence species detectability, 3 analyses were conducted. One considered the effect of **moon phase** and **seasonality**. The second looked at the **distance a camera was to the road**. These 3 covariates are described below. The third analysis looked at **site ecological covariates** (see section 2.3) collected at the same time the cameras were deployed.

Moon phase

Moon phase, expressed as percent illumination, was calculated for each camera and each day of deployment, with 0% representing a new moon and 100% representing a full moon.

Seasonality

Seasonality was used as a surrogate for ambient temperature. It was measured as the number of days since 1 January for each camera. The limitations of using this covariate as a surrogate are acknowledged, given that the large geographic spread of sites could result in significantly different ambient temperatures across sites at the same time of year.

While ambient temperature was recorded by each camera, 50% of cameras did not record night-time temperatures (as no images were triggered at night). This resulted in substantial gaps in the temperature data necessitating the use of seasonality as a proxy. Future studies could address this issue by programming cameras to record at regular intervals (e.g. set on time-lapse).

Distance of camera from trail or road

During the design of WildCount, Barry (2011) highlighted the potential for sampling bias if cameras were placed too close to roads or trails. Specifically, that the detection of feral predators (foxes and cats) might be higher on cameras closer to roads and trails due to these species' potential preferential use of these areas. Conversely, the detection of prey species might be lower close to roads and trails, with detection rates increasing with greater distance from roads and trails. Distance was derived using all road classes (types) in GIS shapefiles. The majority of camera locations (73.5%) were within 400 m of the nearest road or trail. Models incorporating distance to roads or trails were fitted using mixed-effects models to account for the spatial dependence of cameras within a site.

Species for which one of these 3 covariates was significant in explaining detection estimates for 7 of the 10 years are reported (see Appendix D). None of the site-level ecological covariates were found to significantly explain variation in the detectability of any species.

3.3 Power analysis

In species monitoring studies, it is crucial that the design is adequate to detect changes. This involves several key considerations:

- Incorporating methods to estimate and account for detection probability, as not all species are equally detectable. This can include using multiple visits to each site, variable camera deployment lengths or employing different methods.
- Ensuring a sufficient number of sites are surveyed to capture the variability in species occupancy across different habitats and regions.

To assess the adequacy of the survey design for WildCount for each species, several approaches were used. To evaluate the efficacy of cameras and the deployment length, species detectability was assessed. To determine the adequacy of the WildCount survey design, the percent change in occupancy that could be detected over the 10 years was estimated.

3.3.1 Deployment duration

Model-estimated daily detection probabilities for each species across each year (2012–2021) were used to calculate the cumulative probability of detection based on the number of deployment days. The goal was to determine the number of survey days required to achieve 90% probability of detecting the species at least once at an occupied site. Species with low detection probabilities require a greater number of survey days to reach 90% detection probability (Figure 4).

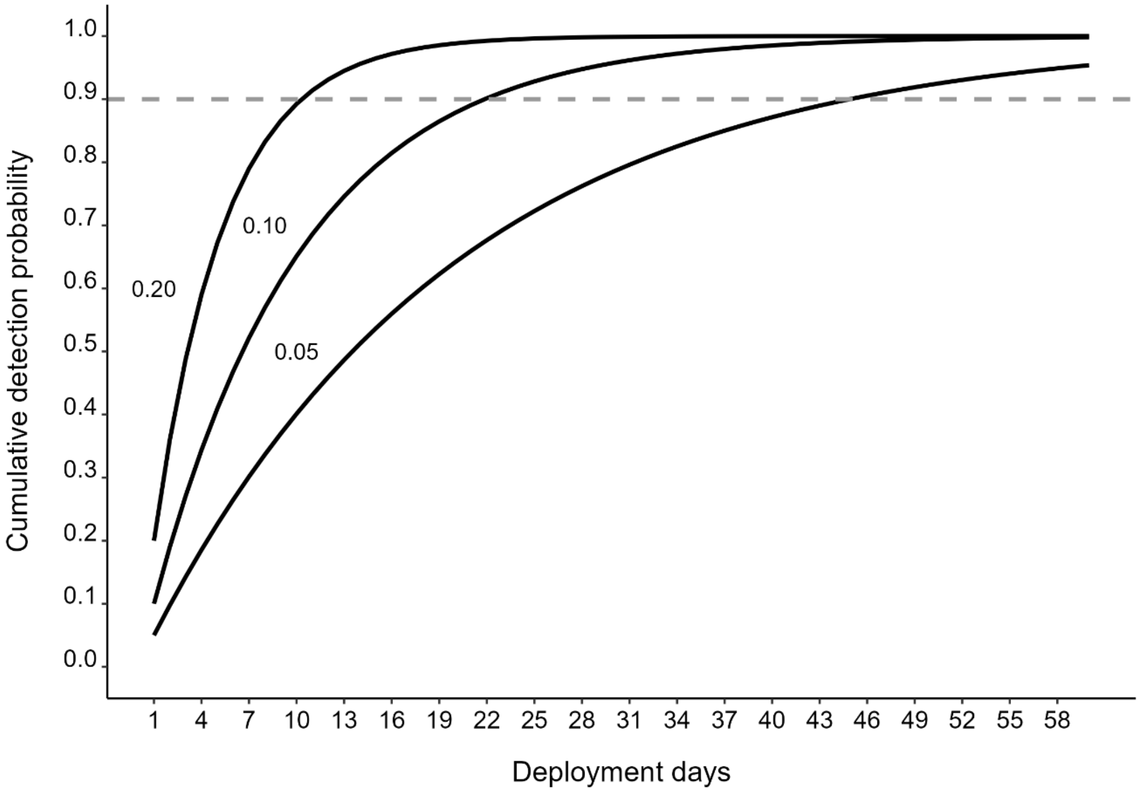


Figure 4 Cumulative detection probabilities based on daily detection estimates

Grey dash line represents a cumulative detection probability of 90% (0.90). The number of deployment days required to reach this threshold varies depending on the daily detection probability (0.20 versus 0.10 versus 0.05).

3.3.2 Detectable change

Power calculations were performed for each species based on average modelled occupancy and detection probabilities over 10 years using the methods outlined by Guillera-Aroita and Lahoz-Monfort (2012). A power level of 0.80 was used, as is convention, meaning that there is an 80% probability of detecting an effect if one exists. A significance level (alpha) of 0.1 was preferred over the more commonly used 0.05, as it represents a more conservative error rate – meaning the probability of incorrectly identifying an effect is lower. The minimum percent change detectable for the species after 10 years, assuming a constant and incremental change over that period, is reported.

4. Results

4.1 Native mammals

WildCount detected 143 native mammals, including 27 threatened species (Appendix A).

The WildCount monitoring technique proved most effective for large- and medium-sized mammals. Among the large- and medium-sized species detected, 11 species had a 90% cumulative probability of being detected within 14 days if they occupied the site (Table 1). However, some species required much longer camera deployments to achieve a 90% chance of detecting the species at a site if it is present. Three threatened species (black-striped wallaby, long-nosed potoroo and Parma wallaby) recorded by the program had high detection probabilities given the survey effort.

There was high annual variability in detection probabilities for certain species, possibly due to identification difficulties. For instance, the long-nosed bandicoot's detection probabilities varied yearly, potentially due to confusion with northern and southern brown bandicoots as indicated by many images being tagged as 'probable' by observers.

Seasonality influenced detectability for some species. For example, echidnas were more detectable in February than in April or May, indicating higher activity in summer (Appendix D). This suggests that deploying cameras during warmer months could enhance detectability.

The impact of camera distance from roads on detectability varied among species. It was a significant predictor for bare-nosed wombats, common brushtail possums and swamp wallabies (Appendix D), with detectability increasing the further a camera was from a road. However, over 80% of cameras were placed within 350 m of a road or trail, resulting in limitations on this assessment.

Climatic variables significantly influenced the occupancy of several species (Appendix C). Specifically, site occupancy for eastern grey kangaroos, euros, red-necked wallabies and swamp wallabies decreased as mean annual precipitation increased (Figure 5, Figure 6), reflecting the climatic preferences for these species. Conversely, long-nosed potoroo only occupied sites with mean annual rainfall greater than 1,500 mm.

None of the site-level ecological covariates collected during camera deployment were found to significantly explain variation in the detectability of any species. The selected covariates may have been too general to reveal species-specific patterns.

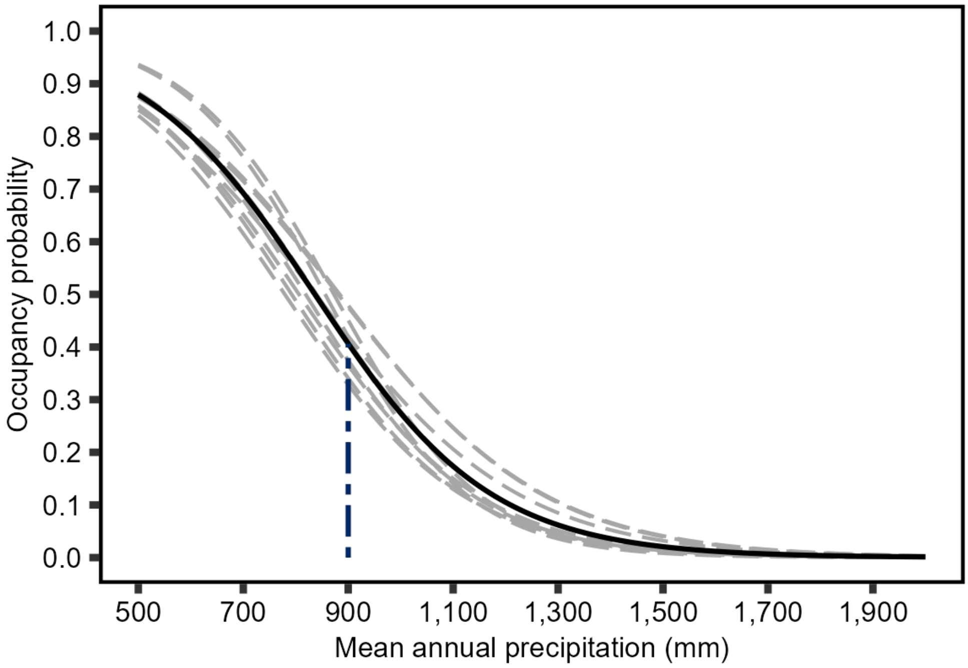
The WildCount camera set-up was less effective for monitoring small mammals. Observers had difficulty reliably identifying species in images due to the 2-m focal distance and the use of an infra-red flash, which did not capture diagnostic features such as fur colour. Consequently, many small mammals were identified only at a species group level (for example, rodent and small dasyurid), making the data insufficient for deriving meaningful models.

Table 1 Native mammal model estimated occupancy and detection probabilities

Naive and modelled occupancy, detection probabilities, and the number of days cameras would need to be deployed at a site to reach a 90% chance that the species will be detected if it is there. Species listed alphabetically by common name. * Data was insufficient to model.

Species	Naïve occupancy	Modelled occupancy	Daily detectability	Days to 90% detectability
Bare-nosed wombat	0.35	0.36	0.24	9
Black-striped wallaby	0.02	0.32	0.14	14
Brush-tailed rock-wallaby	0.09	0.35	0.10	18
Common brushtail possum	0.57	0.58	0.35	5
Common ringtail possum	0.04	0.07	0.04	47
Dingo/wild dog	0.07	0.25	0.04	47
Eastern grey kangaroo	0.33	0.34	0.22	10
Euro	0.10	0.12	0.14	22
Koala*	0.03	–	–	–
Long-nosed bandicoot	0.22	0.27	0.11	21
Long-nosed potoroo	0.04	0.04	0.27	8
Mountain brushtail possum	0.08	0.08	0.21	10
Northern brown bandicoot	0.12	0.14	0.14	15
Parma wallaby	0.03	0.23	0.13	15
Red-legged pademelon	0.03	0.33	0.33	11
Red-necked pademelon	0.06	0.07	0.19	8
Red-necked wallaby	0.29	0.30	0.25	7
Short-beaked echidna	0.26	0.48	0.06	41
Short-eared brushtail Possum	0.15	0.15	0.22	9
Small dasyurid	0.18	0.23	0.11	19
Spotted-tailed quoll	0.06	0.12	0.06	45
Swamp wallaby	0.84	0.84	0.48	4

a) Eastern grey kangaroo



b) Euro

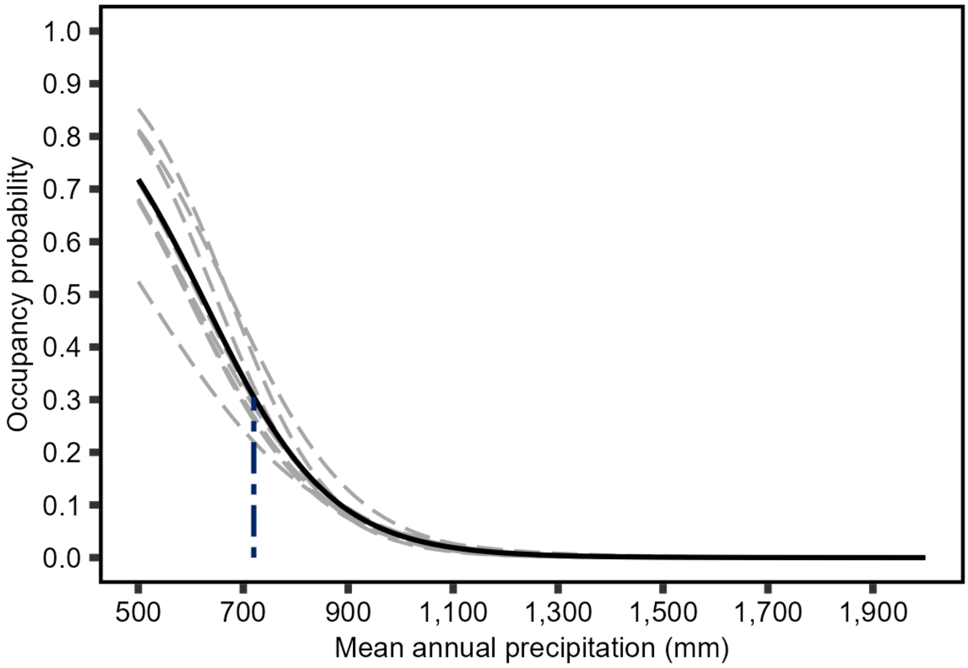
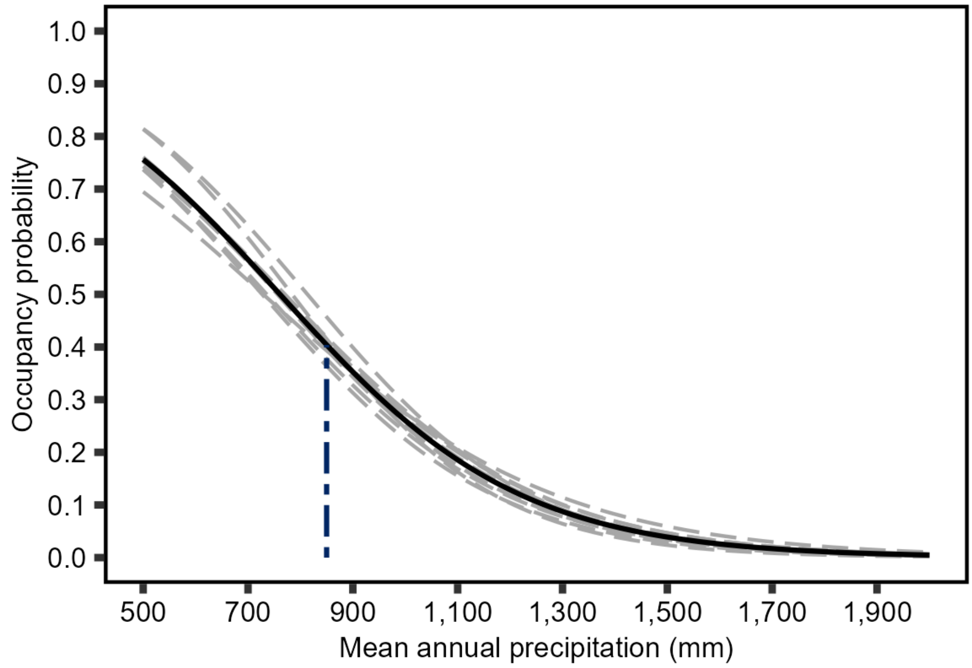


Figure 5 Modelled occupancy as a function of mean annual precipitation for a) eastern grey kangaroo and b) euro

The black solid line is the mean occupancy estimate based on 10 years of surveys, dashed grey lines are individual years. Dot-dashed vertical line indicates the mean annual precipitation at the species' 10-year averaged occupancy.

a) Red-necked wallaby



b) Swamp wallaby

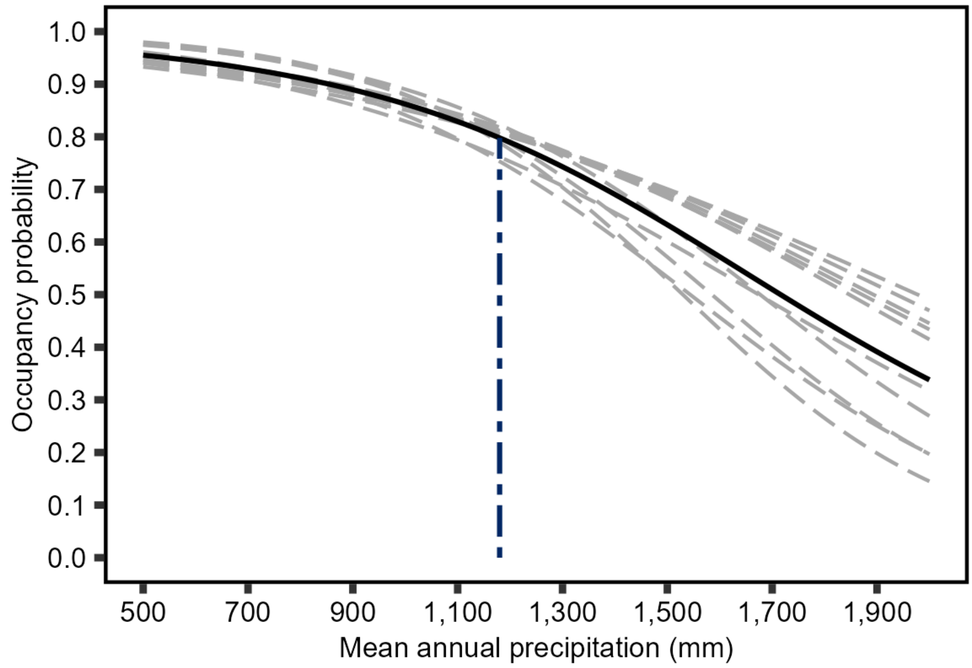


Figure 6 Modelled occupancy as a function of mean annual precipitation for a) red-necked wallaby and b) swamp wallaby

The black solid line is the mean occupancy estimate based on 10 years of surveys, dashed grey lines are individual years. Dot-dashed vertical line indicates the mean annual precipitation at the species' 10-year averaged occupancy.

4.2 Feral animals

WildCount detected 19 feral animal species and was reasonably effective for detecting fallow deer, goat, red fox and rabbits (Table 2, Appendix A). However, much longer camera deployments were required to achieve a 90% chance of detecting other feral species at a site if they are present, given the WildCount camera deployment technique.

Mean annual precipitation was a significant variable influencing the occupancy of goats and red foxes (Appendix C) with occupancy decreasing as mean annual precipitation increased (Figure 7), reflecting the climatic limitations for these species.

There was no influence of camera distance from roads on the detectability of any of the feral animal species. This is counter to the prevailing belief that feral predators, such as foxes and cats, are more likely to be detected by cameras placed near roads and trails (Wysong et al. 2020), due to their preferential use of these areas.

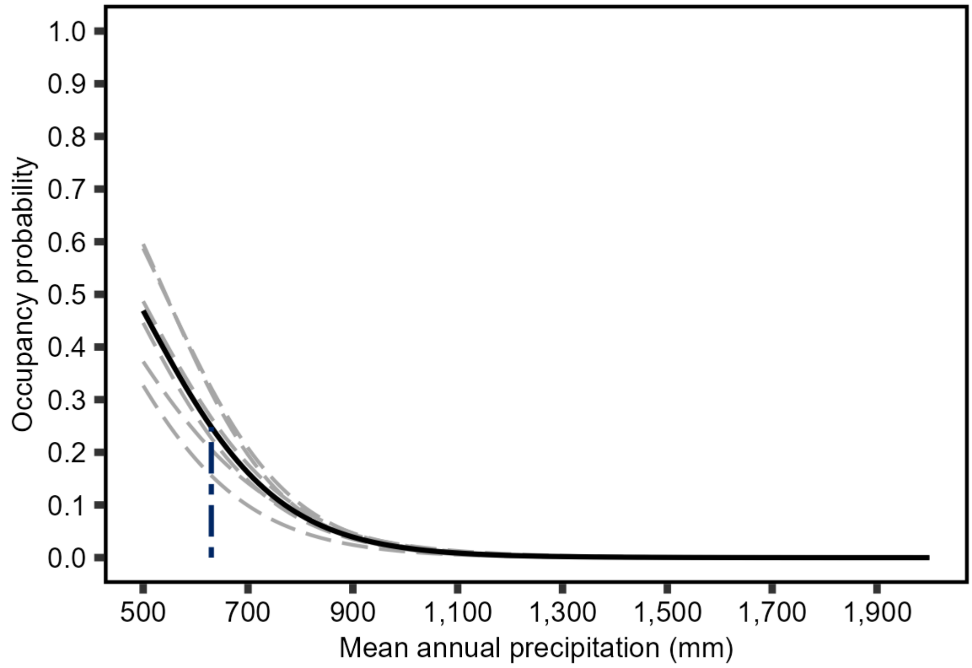
The effectiveness of a camera in triggering when an animal moves in front of it can be influenced by its micro-habitat placement but also orientation, including factors such as camera height, lure distance and the angle relative to the ground (Moore et al. 2020). The orientation of the WildCount cameras was not optimal for several feral species, such as feral cat, horse and black rat, and the low detection rates indicate that cameras need to be deployed for longer periods of time, as has been observed for cats in other studies (Stokeld et al. 2015).

Table 2 Model estimated occupancy and detection probabilities for feral animals

Naïve and modelled occupancy, detection probabilities, and the number of days cameras would need to be deployed at a site to reach a 90% chance that the species will be detected if it is there. Species listed alphabetically by common name.

Species	Naïve occupancy	Modelled occupancy	Daily detectability	Days to 90% detectability
Cat	0.16	0.38	0.04	62
Fallow deer	0.05	0.05	0.17	15
Goat	0.05	0.05	0.20	11
Pig	0.10	0.13	0.12	20
Rabbit	0.10	0.10	0.22	9
Red fox	0.38	0.41	0.18	13

a) Goat



b) Red fox

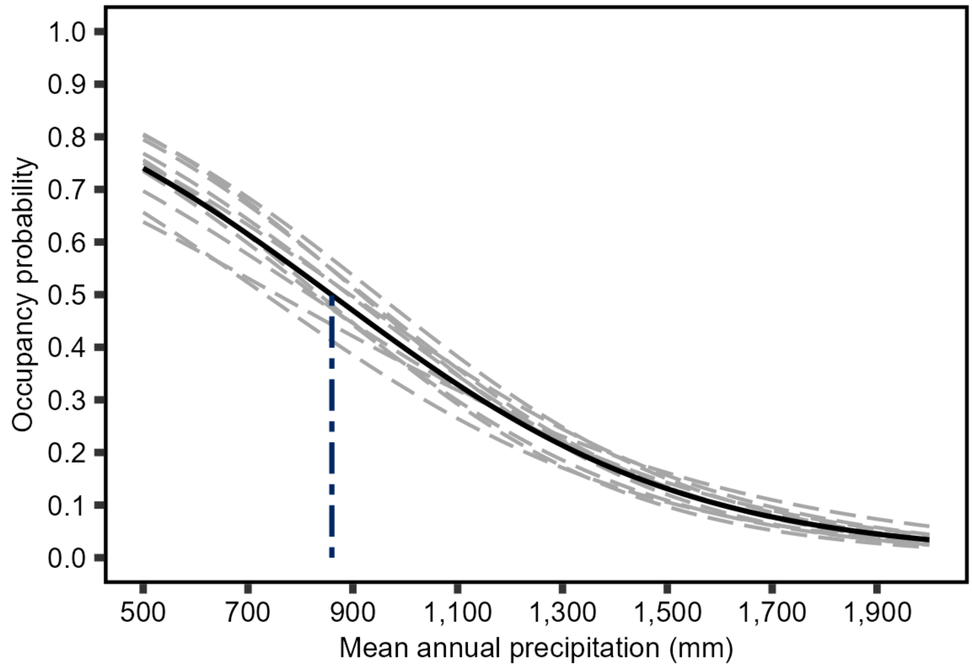


Figure 7 Modelled occupancy as a function of mean annual precipitation for a) goat and b) red fox

The black solid line is the mean occupancy estimate based on 10 years of surveys, dashed grey lines are individual years. Dot-dashed vertical line indicates the mean annual precipitation at the species' 10-year averaged occupancy.

4.3 Birds and reptiles

Camera traps are not typically used for surveying birds and reptiles. The detectability of most bird species in WildCount was generally low (<0.10). However, the superb lyrebird and Australian brush-turkey had higher detection rates (>0.22) (Table 3), making camera traps a viable method for monitoring these ground-dwelling birds.

Most bird species captured in images are widespread and commonly encountered, but are most often recorded as incidental records. For many bird species and the lace monitor, the total number of sites where they were recorded over the 10 years was much higher than their average annual occupancy. For example, the Australian magpie was recorded at an average of 13% of sites annually, but over 10 years it was recorded at 43% of all sites. Similarly, the lace monitor was recorded at an average of 0.08% of sites annually, but over 10 years it was recorded at 41% of all sites (Table 3, Appendix A).

While WildCount was not highly effective for monitoring changes in the distribution of most birds or reptiles, camera traps can still be a useful supplement to more suitable techniques such as acoustic recording or diurnal surveys. Using both direct and remote methods simultaneously can enhance species inventories and provide more complete data.

Table 3 Model estimated occupancy and detection probabilities for birds and lace monitor

Naïve and modelled occupancy, detection probabilities, and the number of days cameras would need to be deployed at a site to reach a 90% chance that the species will be detected if it is there. Species listed alphabetically by common name.

Species	Naïve occupancy	Modelled occupancy	Daily detectability
Australian brush-turkey	0.14	0.15	0.24
Australian magpie	0.13	0.15	0.13
Grey shrike-thrush	0.24	0.39	0.07
Lace monitor	0.08	0.22	0.05
Pied currawong	0.12	0.19	0.07
Superb lyrebird	0.36	0.37	0.22
White-winged chough	0.15	0.16	0.18
Wonga pigeon	0.13	0.18	0.11

4.4 Monitoring effectiveness

The effectiveness of a monitoring program is influenced by the number of sampling sites and the methods used. Larger sample sizes typically increase statistical power, making it easier to detect changes in species occupancy. Employing the most suitable sampling techniques for each species enhances the likelihood of recording it and increases detection probabilities.

A 30% decline in species occupancy is used as a benchmark for assessing the effectiveness of WildCount in detecting significant changes, in line with the IUCN definition of a significant decline (IUCN 2020). The IUCN Red List criteria have been developed for assessing the extinction risk of species. According to these criteria, a species is classified as ‘vulnerable’ if it has experienced a population decline of at least 30% over the last 10 years, or 3 generations, whichever is longer (IUCN 2020). This classification helps identify species at risk of extinction and highlights the need for conservation efforts to prevent further decline.

WildCount had adequate power to reliably detect up to a 30% change in species occupancy over the 10-year period for 3 species: common brushtail possum, swamp wallaby and red fox (Table 4). However, none of these species showed any evidence of change during the monitoring period. Each of these species had occupancy estimates greater than 0.40 and daily detectability greater than 0.15. Smaller changes in occupancy (such as a 12% change) could be reliably detected for species with higher occupancy rates. For instance, this would be equivalent to an increase in occupancy from 0.50 to 0.56, or a decline from 0.50 to 0.44.

Table 4 Species that could be reliably monitored for a 30% change in occupancy

Species occupancy and detectability estimates averaged over 10 years. The detectable change in occupancy is based on the average number of WildCount sites surveyed each year (sites = 202, number of days = 14, α = 0.1, power = 0.80). Species listed alphabetically by common name.

Species	Occupancy	Detectability	Detectable change
Common brushtail possum	0.59	0.35	21%
Red fox	0.46	0.17	28%
Swamp wallaby	0.84	0.49	12%

For 11 species, there was adequate power to reliably detect a 30% to 50% change in occupancy over the 10-year period (Table 5), however none showed any evidence of change during the monitoring period.

Table 5 Species that could be reliably monitored for a 30% to 50% change in occupancy

Species occupancy and detectability estimates averaged over 10 years. The detectable change in occupancy is based on the average number of WildCount sites surveyed each year (sites = 202, number of days = 14, α = 0.1, power = 0.80). Species listed alphabetically by common name.

Species	Occupancy	Detectability	Detectable change
Bare-nosed wombat	0.36	0.24	32%
Brush-tailed rock-wallaby	0.29	0.09	44%
Eastern grey kangaroo	0.35	0.23	32%
Grey shrike-thrush	0.39	0.08	39%
Long-nosed bandicoot	0.3	0.14	38%
Parma wallaby	0.23	0.13	45%
Red-necked wallaby	0.31	0.26	35%
Short-beaked echidna	0.48	0.06	37%
Short-eared brushtail possum	0.16	0.24	50%
Small dasyurid	0.23	0.12	46%
Superb lyrebird	0.37	0.23	31%

For the remaining species, there was little to no power to detect change in occupancy (Table 6), indicating that the WildCount program could not reliably monitor changes in the distributions of these species during the monitoring period. These species generally had low occupancy rates and/or low detection rates.

Table 6 Species for which there was little power to monitor change in occupancy

Species occupancy and detectability estimates averaged over 10 years. The detectable change in occupancy is based on the average number of WildCount sites surveyed each year (sites = 202, number of days = 14, $\alpha = 0.1$, power = 0.80). Species listed alphabetically by common name.

Species	Occupancy	Detectability	Detectable change
Australian brush-turkey	0.15	0.24	53%
Australian magpie	0.15	0.13	55%
Black-striped wallaby	0.03	0.22	100%
Cat	0.37	0.04	50%
Dingo/dog	0.25	0.04	60%
Euro	0.12	0.14	61%
Fallow deer	0.06	0.19	81%
Goat	0.05	0.20	83%
Long-nosed potoroo	0.04	0.29	88%
Mountain brushtail possum	0.08	0.24	68%
Northern brown bandicoot	0.14	0.18	54%
Pied currawong	0.19	0.07	56%
Pig	0.13	0.12	60%
Rabbit	0.11	0.23	61%
Red-legged pademelon	0.04	0.35	94%
Red-necked pademelon	0.08	0.22	71%
Spotted-tailed quoll	0.12	0.06	73%
White-winged chough	0.16	0.18	51%
Wonga pigeon	0.18	0.11	52%

5. Discussion

WildCount was a landscape-scale, 10-year monitoring program aimed at improving knowledge of native mammals across the eastern seaboard of NSW by assessing broadscale trends in species distributions.

The program increased the amount of data available on 27 threatened species (Appendix A). However, due to the restricted distributions of many threatened species, they were detected at a limited number of sites. Although WildCount could not effectively monitor changes in the distributions of these species, it significantly contributed to improving our understanding of their distributions.

Long-term monitoring of species is critical for identifying species at risk of extinction and in need of increased conservation management to prevent further decline. Furthermore, monitoring needs to be effective and have adequate statistical power to be informative. WildCount was one of the first landscape-scale multi-species monitoring programs for NSW and provided an opportunity to assess the utility of camera traps to survey a large suite of species.

The WildCount camera method proved highly effective in detecting large- and medium-sized native mammals, which were the primary focus of the design. However, the method was less successful in achieving good detection rates for several feral mammals (such as horses, cats and pigs). Furthermore, many detections of small mammals (such as antechinus, dunnarts, rats and mice) had low confidence in accurate identification due to poor image quality, resulting in aggregation into species groups and potential misidentifications. To improve detection of small mammals in future monitoring, potential solutions include using white-flash cameras to capture fur colour, placing lures closer to the cameras and employing higher magnification lenses (Meek and Cook 2022).

Detection probability is an important parameter in ecological studies because it accounts for the fact that a species might be present but not detected during a survey. Detection probability can be influenced by a species' biology, the survey methods employed and environmental factors. Species with low detection probabilities require longer camera deployments to reach high confidence that a species is absent from a site. Therefore, WildCount could have benefited from deployments longer than 14 days to boost detection probabilities and subsequently improve the estimation of occupancy for several species.

The effectiveness of a monitoring program in detecting trends depends not only on design elements (such as sample sizes) but also on species-specific detection and occupancy probabilities (Steenweg et al. 2019). Generally, a greater number of sites are required to detect any proportional change in occupancy for species that are difficult to detect (MacKenzie and Royle 2005). Additionally, the number of sites needed increases as the size of the desired effect diminishes (for example, monitoring for a 50% versus a 30% change in occupancy). Furthermore, the higher the initial probability of occupancy a species has, the greater the power to detect changes in occupancy over subsequent years. For example, the common brushtail possum, red fox and swamp wallaby occupied more than 45% of the WildCount sites and were highly detectable, making them ideal species for monitoring throughout the program. However, many species had low detection probabilities and did not occur across enough sites for effective monitoring. For species that are rare in the landscape, tailored monitoring programs may be necessary.

A challenge for monitoring programs is distinguishing between natural year-to-year fluctuations in a species' presence and long-term trends that indicate genuine shifts in populations. Analyses such as occupancy modelling help in this differentiation by incorporating multiple years of data and environmental covariates. By doing so, these analyses can account for natural variability due to changing environmental conditions and identify true trends. Therefore, the collection of systematic environmental data and/or the use of remotely sensed data has the potential to inform and improve estimates of species detectability and occupancy, leading to a better understanding of the factors influencing species occurrence. For example, in the analyses of the WildCount data, precipitation was found to significantly influence site occupancy for several species (Appendix C). Conversely, none of the site ecological variables (Appendix B) recorded during the deployment of cameras for WildCount were significant in explaining variations in the detection of species. Choosing and collecting variables that are informative for specific species is critical for developing accurate models to predict species distributions and monitoring how their populations might change over time. This information is crucial for conservation and biodiversity management.

Part 2

6. Black Summer bushfires

The Black Summer bushfires of 2019–20 affected 85 of the 204 WildCount monitoring sites, meaning approximately 42% experienced some level of burning (Figure 8). Of these, 58 sites had more than 75% of their area impacted by fire. Sites located within wet sclerophyll vegetation formations, both shrub/grass and shrubby understorey, were the most heavily affected, with over 50% of their area burned. These formations were also among the most widely represented vegetation types in the program.

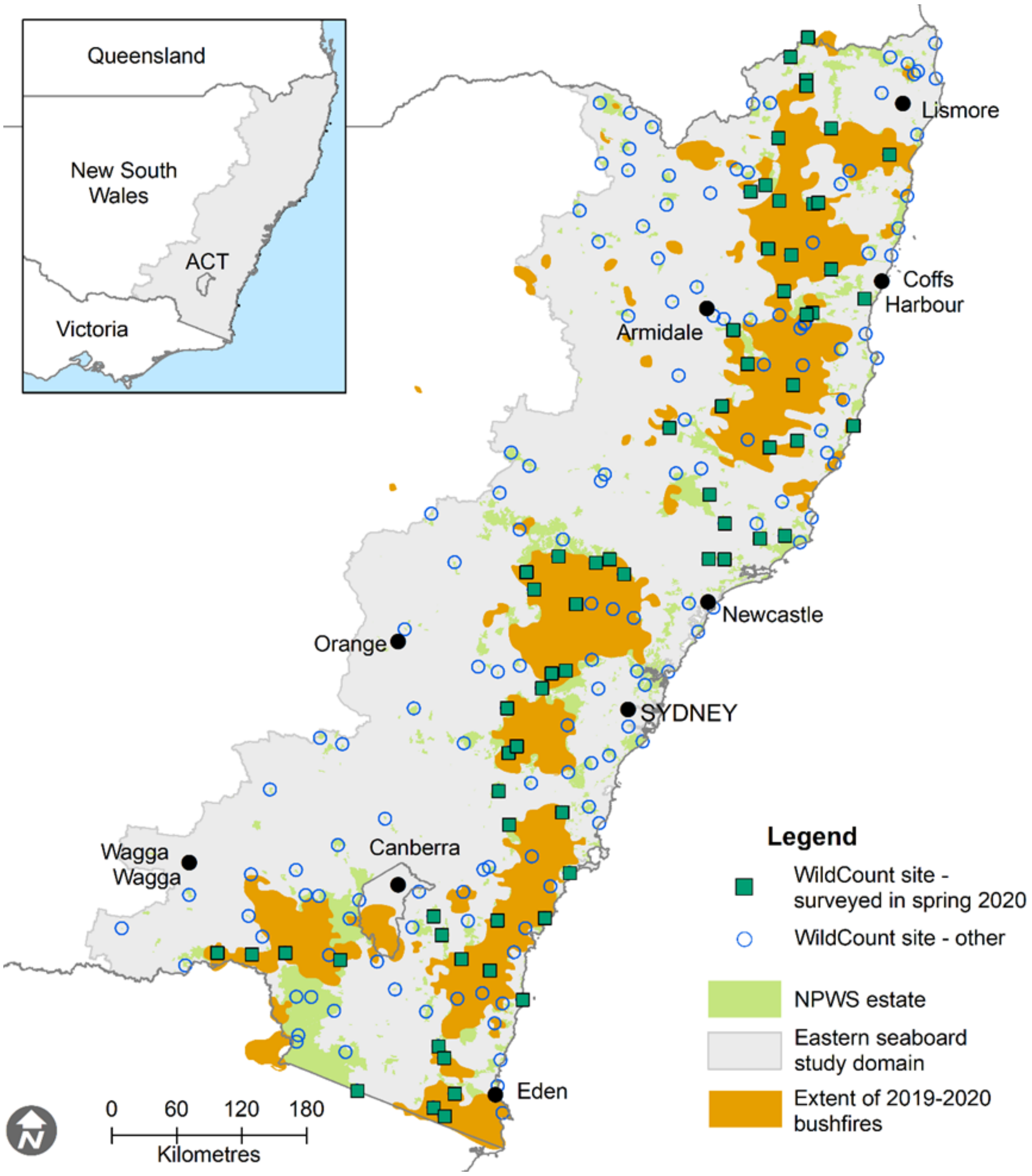


Figure 8 Location of WildCount sites in relation to the Black Summer fires of 2019–20

WildCount sites are denoted by open blue circles and sites surveyed in spring 2020 as green squares. The extent of the 2019–20 bushfires is represented by orange polygons.

6.1 Fire analyses

The extensive fire impact provided an opportunity to examine species' responses, both in relation to fire severity and through comparisons of occupancy estimates before and after the event. Surveys across the monitoring sites continued in the autumn of 2020 and 2021, which provided an opportunity to compare species occupancy before and after the fires.

Furthermore, in spring 2020, shortly after the Black Summer bushfires, 67 of the 85 burnt sites (Figure 8) were surveyed to assess the immediate impacts on wildlife. These sites were selected based on vegetation type and the severity of fire impact. This targeted approach enabled an assessment of species' immediate responses to both the extent and intensity of fire at these locations.

6.1.1 Fire severity

To quantify fire impacts, a fire severity score was developed for each WildCount monitoring site based on the spatial extent of Fire Extent and Severity Mapping (FESM) (Gibson et al. 2020) classes within a 100-ha buffer around the camera arrays. FESM mapping describes the impacts on the forest canopy (Table 7). The fire severity score ranged from zero (completely unburnt) to 100 (entirely burnt at the highest severity). However, a limitation of this approach is that similar scores can result from very different spatial distributions of fire severity classes. For example, a score of 50 could reflect either a mix of extreme and unburnt areas or an even distribution across all severity levels. Using the dominant FESM class as an ordinal covariate was considered but rejected, as it would misrepresent sites with mixed fire severity.

Table 7 Fire Extent and Severity Mapping (FESM) classes

Severity class	FESM class description
Unburnt	Unburnt understory and canopy
Low	Burnt understory with unburnt canopy
Medium	Partial canopy scorch
High	Full canopy scorch (+/- partial canopy consumption)
Extreme	Full canopy consumption

This approach formed the basis for selecting 67 sites to be monitored in the spring of 2020, with selection aimed at ensuring representation across vegetation types and fire severity classes. Occupancy models were developed for species with sufficient data across sites, and included fire severity and vegetation formation as covariates.

6.1.2 Before and after fire response

To assess changes in species occupancy before and after the Black Summer bushfires of 2019–20, analyses focused on the 85 of the 204 WildCount sites which were burnt. Species detection data collected in autumn between 2018 to 2021 were used in analyses providing a before and after comparison.

Analyses were conducted across 2 time periods:

- A comparison in occupancy for 2019 (pre-fire) versus 2020 (post-fire).
- An assessment of changes in occupancy over the 2018 to 2021 period to assess patterns beyond the immediate pre- and post-fire period.

Occupancy models were run to assess species' responses to the fires for those with sufficient data, and were applied to the null, year and trend models outlined in section 3.1.1.

6.2 Fire responses

Data from 28 native species were analysed for their **immediate response** to fire severity (spring 2020 surveys). Of these, 21 species showed no significant change in occupancy in response to fire extent and severity.

Three species showed strong evidence of a negative response to fire extent and severity ($p < 0.05$), while 3 others showed weaker evidence of a negative response ($p > 0.05$) (Table 8). All 6 species – eastern grey kangaroo, long-nosed bandicoot, short-beaked echidna, short-eared brushtail possum, Australian brush-turkey and spotted-tailed quoll – had higher occupancy at unburnt sites compared to sites burnt at high severity.

One species, the pied currawong, showed strong evidence of a positive response to fire extent and severity (Table 8), with significantly higher occupancy observed at sites extensively burnt at high severity.

Table 8 Species for which there was evidence of a response to fire extent and severity

P-values in bold indicate statically significant results at a significance level (α) of 0.05.

Species	Fire severity response	P-value
Australian brush-turkey	Negative	**p = 0.004**
Eastern grey kangaroo	Negative	p = 0.073
Long-nosed bandicoot	Negative	p = 0.052
Pied currawong	Positive	**p = 0.027**
Short-beaked echidna	Negative	**p = 0.002**
Short-eared brushtail possum	Negative	**p = 0.014**
Spotted-tailed quoll	Negative	p = 0.056

Assessment of changes in occupancy **before and after** the Black Summer bushfires (autumn 2018 to autumn 2021), or between 2019 and 2020, showed no observable declines in occupancy for any of the species analysed. Power analyses indicated that the number of WildCount sites monitored was insufficient to reliably detect changes in occupancy for most species. Given the relatively small proportion of sites which were affected by fire, it is unsurprising that the modelling approach taken could not identify fire-related effects.

However, a subsequent analysis of the WildCount data used dynamic occupancy models (MacKenzie et al. 2003, 2018) to examine species responses in the immediate pre- and post-fire period (2018 to 2021) (Lavery et al. 2024). This study revealed discernible colonisation and extinction patterns in 4 species. For 3 species – short-eared brushtail possum, northern brown bandicoot and long-nosed bandicoot – there was an increase in the probability of site colonisation at sites with greater extent of area burnt at high severity. In contrast, the swamp wallaby showed an increase in the probability of extinction with greater fire severity and extent. These findings are consistent with those of another study which found limited evidence that extensive wildfires broadly impact the persistence of widespread, common species (Linley et al. 2024). However, the impacts are likely to vary among species, climatic factors and the landscape matrix (Chia et al. 2016).

Appendices

Appendix A

Species and species groupings classified from camera trap images over the 10 years of WildCount surveys are provided in Table 9. Threatened species listing is indicated for those species listed under the NSW *Biodiversity Conservation Act 2016* ('BC Act') and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* ('EPBC Act'). Asterisk (*) indicate non-native species. Species and groups are listed alphabetically by common name.

Table 9 Species and species groups classified from WildCount camera-trap images

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Albert's lyrebird	9	3	1.47	BC Act
Apostlebird	5	2	0.98	–
Australasian bittern	1	1	0.49	BC Act, EPBC Act
Australasian grebe	1	1	0.49	–
Australasian shoveler	1	1	0.49	–
Australian brush-turkey	10	64	31.4	–
Australian king-parrot	2	1	0.49	–
Australian magpie	10	86	42.2	–
Australian owlet-nightjar	5	6	2.9	–
Australian shelduck	1	1	0.49	–
Australian white ibis	1	1	0.49	–
Australian wood duck	2	2	0.98	–
Bar-shouldered dove	10	11	5.4	–
Bassian thrush	10	39	19.1	–
Bearded dragon	8	9	4.4	–
Black rat*	6	16	7.8	–
Black swan	1	1	0.49	–
Black-striped wallaby	10	7	3.4	BC Act
Blotched blue-tongue lizard	1	1	0.49	–
Brown cuckoo-dove	4	2	0.98	–
Brown goshawk	4	2	0.98	–
Brown hare*	10	25	12.3	–
Brown quail	5	9	4.4	–
Brown treecreeper	2	2	0.98	BC Act, EPBC Act

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Brush bronzewing	8	9	4.4	–
Brush-tailed phascogale	9	12	5.9	BC Act
Brush-tailed rock-wallaby	10	6	2.9	BC Act, EPBC Act
Buff-banded rail	8	7	3.4	–
Bush rat	3	3	1.47	–
Cat*	10	134	65.7	–
Chestnut teal	1	1	0.49	–
Chestnut-rumped heathwren	3	1	0.49	–
Chital deer*	1	1	0.49	–
Common blackbird*	2	1	0.49	–
Common bronzewing	10	23	11.3	–
Common brushtail possum	10	169	82.8	–
Common dunnart	1	1	0.49	–
Common ringtail possum	10	59	28.9	–
Common wombat	10	110	53.9	–
Corvid	10	35	17.2	–
Crimson rosella	10	43	21.1	–
Cunningham's skink	3	2	0.98	–
Dingo or wild dog	10	89	43.6	–
Domestic fowl*	1	1	0.49	–
Dusky moorhen	1	1	0.49	–
Dusky woodswallow	1	1	0.49	BC Act
Eastern blue-tongued lizard	4	6	2.9	–
Eastern bristlebird	1	1	0.49	BC Act, EPBC Act
Eastern grey kangaroo	10	115	56.9	–
Eastern pygmy-possum	6	5	2.5	BC Act
Eastern rosella	5	4	1.96	–
Eastern snake-necked turtle	1	1	0.49	–
Eastern water dragon	3	2	0.98	–
Eastern whipbird	10	84	41.2	–
Eastern yellow robin	10	41	20.1	–
Emerald dove	10	10	4.9	–
Emu	10	10	4.9	–
Euro	10	48	23.5	–
European cattle*	10	19	9.3	–

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Fairy-wren	5	15	7.4	–
Fallow deer*	10	32	15.7	–
Flame robin	4	2	0.98	BC Act
Galah	5	2	0.98	–
Goat*	10	23	11.3	–
Greater glider	3	2	0.98	BC Act, EPBC Act
Green catbird	10	22	10.8	–
Grey butcherbird	9	19	9.3	–
Grey currawong	10	37	18.1	–
Grey fantail	6	11	5.4	–
Grey shrike-thrush	10	172	84.3	–
Grey-crowned babbler	4	2	0.98	BC Act
Heath monitor	1	1	0.49	BC Act
Horse*	10	5	2.5	–
Koala	10	30	14.7	BC Act, EPBC Act
Lace monitor	10	83	40.7	–
Land mullet	10	20	9.8	–
Laughing kookaburra	10	84	41.2	–
Lewin's honeyeater	1	1	0.49	–
Lewin's rail	4	3	1.47	–
Little wattlebird	3	2	0.98	–
Logrunner	9	12	5.9	–
Long-nosed bandicoot	10	120	58.8	–
Long-nosed potoroo	10	27	13.2	BC Act, EPBC Act
Magpie-lark	9	6	2.9	–
Masked lapwing	1	1	0.49	–
Masked owl	1	1	0.49	BC Act
Mountain brushtail possum	10	30	14.7	–
Mouse sp.	3	12	5.9	–
New holland honeyeater	4	3	1.47	–
Noisy friarbird	1	1	0.49	–
Noisy miner	10	5	2.5	–
Noisy pitta	10	15	7.4	–
Northern brown bandicoot	10	59	28.9	–

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Olive whistler	4	2	0.98	BC Act
Olive-backed oriole	1	1	0.49	–
Pacific black duck	3	3	1.47	–
Painted button-quail	10	43	21.1	–
Paradise riflebird	1	1	0.49	–
Parma wallaby	10	13	6.4	BC Act, EPBC Act
Peaceful dove	3	3	1.47	–
Pheasant coucal	10	11	5.4	–
Pied butcherbird	2	1	0.49	–
Pied currawong	10	111	54.4	–
Pig*	10	75	36.8	–
Pilotbird	6	3	1.47	BC Act, EPBC Act
Purple swamphen	1	1	0.49	–
Rabbit*	10	67	32.8	–
Rat sp.	10	182	89.2	–
Red deer*	7	4	1.96	–
Red fox*	10	159	77.9	–
Red wattlebird	4	5	2.5	–
Red-backed fairy-wren	1	1	0.49	–
Red-browed finch	4	4	1.96	–
Red-legged pademelon	10	9	4.4	BC Act
Red-necked pademelon	10	30	14.7	–
Red-necked wallaby	10	111	54.4	–
Rockwarbler	5	5	2.5	–
Rufous bettong	7	4	1.96	BC Act
Rufous fantail	2	1	0.49	–
Rusa deer*	9	3	1.47	–
Sambar*	10	14	6.9	–
Satin bowerbird	10	49	24	–
Scarlet robin	3	3	1.47	BC Act
Scrubwren	5	7	3.4	–
Sheep*	6	6	2.9	–
Short-beaked echidna	10	166	81.4	–
Short-eared brushtail possum	10	52	25.5	–

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Silvereye	3	2	0.98	–
Small dasyurid	10	157	77	–
Southern brown bandicoot	8	2	0.98	BC Act, EPBC Act
Speckled warbler	2	2	0.98	BC Act
Spotless crake	2	2	0.98	–
Spotted pardalote	1	1	0.49	–
Spotted quail-thrush	10	79	38.7	–
Spotted turtle-dove*	1	2	0.98	–
Spotted-tailed quoll	10	55	27	BC Act, EPBC Act
Squirrel glider	3	1	0.49	BC Act
Straw-necked ibis	1	1	0.49	–
Sugar glider	3	1	0.49	–
Superb fairy-wren	8	9	4.4	–
Superb lyrebird	10	117	57.4	–
Swamp rat	9	4	1.96	–
Swamp wallaby	10	200	98	–
Tawny frogmouth	7	13	6.4	–
Teal duck sp.	1	1	0.49	–
Thornbill	3	3	1.47	–
Thrush sp.	10	44	21.6	–
Turquoise parrot	2	2	0.98	BC Act
Variegated fairy-wren	7	6	2.9	–
Water-rat	8	11	5.4	–
Wedge-tailed eagle	5	6	2.9	–
Whiptail wallaby	2	2	0.98	–
White-bellied sea-eagle	1	1	0.49	BC Act
White-browed babbler	3	2	0.98	–
White-browed scrubwren	10	51	25	–
White-cheeked honeyeater	1	1	0.49	–
White-eared honeyeater	2	3	1.47	–
White's skink	2	1	0.49	–
White-throated treecreeper	2	1	0.49	–
White-winged chough	10	80	39.2	–
Willie wagtail	8	9	4.4	–
Wonga pigeon	10	94	46.1	–

Species	Number of years detected	Number of sites detected	Proportion of sites detected	Threatened
Yellow-faced honeyeater	2	2	0.98	–
Yellow-footed antechinus	3	1	0.49	–
Yellow-rumped thornbill	1	1	0.49	–
Yellow-tailed black-cockatoo	8	6	2.9	–
Yellow-throated scrubwren	10	25	12.3	–
Yellow-tufted honeyeater	1	1	0.49	–

Appendix B

Ecological covariates described in Table 10 were recorded at each camera location within a site at the time of deployment (see also section 2.3). These variables were then used in occupancy models to assess their influence on species detectability. None of the ecological variables were significant in explaining variations in the detection of species.

Table 10 Ecological covariates recorded at each camera location

Covariate	Category or unit
Topographic position	Either plateau, crest, upper slope, mid slope, lower slope, flat, streamline, above cliff, below cliff, or simple slope
Vegetation formation	Either alpine complex, arid shrubland (acacia), arid shrubland (chenopod), dry sclerophyll (shrub), dry sclerophyll (shrub/grass), grasslands, forested wetlands, freshwater wetlands, misc. ecosystems, grassy woodland, semi-arid woodland (grass), semi-arid woodland (shrub), wet sclerophyll (grass), wet sclerophyll (shrub), rainforests, or heathlands
Strata height <1 m	% cover
Strata height 1–3 m	% cover
Strata height 3–5 m	% cover
Strata height 5–12 m	% cover
Strata height 12–20 m	% cover
Strata height 20–35 m	% cover
Ground layer – veg <5 cm	% cover
Ground layer – bare soil	% cover
Ground layer – litter	% cover
Ground layer – rock	% cover
Ground layer – logs	% cover
Litter depth	Either 0, 0.1–2.0, 2–10, or >10 cm
Evidence of flowering or fruiting?	yes/no
Maximum circumference of largest tree	cm
Soil type	Either sands, loams, sandy loams, peats, clay loams, light clays, or heavy clays
Soil colour	Either grey, yellow, black, or brown-red
Soil depth	Either deep, shallow, or skeletal
Soil gravel	%
Disturbance – logging	nil/low/medium/high, time since last
Disturbance – grazing	nil/low/medium/high, time since last
Disturbance – ferals	nil/low/medium/high, time since last
Disturbance – other	nil/low/medium/high, time since last
Dieback – non-specific	nil/low/medium/high, time since last

Covariate	Category or unit
Dieback – canopy	yes/no
Dieback – bell miner	yes/no
Dieback – understorey monoculture	yes/no
Weeds – forb or herb	% cover
Weeds – grass	% cover
Weeds – vine	% cover
Weeds – shrub	% cover
Weeds – tree	% cover
Fire – time since last	number of years
Canopy fire	green/burnt/scorched
Under storey fire	green/burnt/scorched
Ground cover fire	green/burnt/scorched
Charcoal on trees	yes/no
Charcoal on logs	yes/no
Charcoal on trunks	yes/no

Appendix C

Spatial and temporal variables which were significant in explaining **species occupancy** for 7 or more years of data are provided in Table 11. 'Negative' indicates a decline in species occupancy as the value of the variable increases, and 'Positive' indicates an increase in occupancy as the value of the variable increases. Acronyms in the vegetation column indicate significant variables explaining species occurrence ('RF' = rainforest, 'WSF' = wet sclerophyll forest). Asterisk (*) indicate non-native species. Species and groups are listed alphabetically by common name.

Table 11 Spatial and temporal variables which were significant in explaining species occupancy for 7 or more years of data

Species	Precipit-ation	Temp-erature	Radia-tion	Latitude	Distance to coast	Evapora-tion	Solar radiation	Min. temperature	Vegeta-tion
Australian brush-turkey	–	–	–	–	–	Positive	–	–	–
Australian magpie	Negative	–	–	–	–	–	–	–	–
Cat*	–	Negative	–	–	–	–	–	–	–
Common brushtail possum	Negative	–	–	–	–	Negative	–	–	–
Common wombat	–	–	–	Negative	–	–	–	–	–
Eastern grey kangaroo	Negative	–	–	–	–	Negative	–	–	–
Euro	Negative	–	–	–	–	–	Positive	–	–
Goat*	Negative	–	–	–	–	–	–	–	–
Grey shrike-thrush	–	–	–	–	–	–	–	Negative	–
Long-nosed bandicoot	–	–	–	–	Negative	–	–	–	–
Long-nosed potoroo	Positive	–	–	–	–	–	–	–	–
Mountain brushtail possum	–	–	–	Positive	–	–	–	Negative	–
Northern brown bandicoot	–	–	–	–	–	–	–	Positive	–
Pied currawong	–	–	–	–	–	–	–	Negative	–
Rabbit*	–	–	–	–	–	–	–	Negative	–

Species	Precipit-ation	Temp-erature	Radia-tion	Latitude	Distance to coast	Evapora-tion	Solar radiation	Min. temperature	Vegeta-tion
Red fox*	Negative	–	–	–	–	Negative	–		–
Red-legged pademelon	–	–	–	Negative	–	Positive	–	–	–
Red-necked pademelon	–	–	–	Negative	–	Positive	–	–	–
Red-necked wallaby	Negative	–	–	–	–	–	–	–	–
Short-beaked echidna	–	–	–	–	–	–	Positive	–	–
Short-eared brushtail possum	–	–	–	–	–	Positive	–	–	RF, WSF
Small dasyurid	–	Negative	–	–	–	–	–	–	–
Spotted-tailed quoll	–	–	Positive	–	–	–	–	–	–
Superb lyrebird	–	–	–	–	–	–	Negative	–	–
Swamp wallaby	Negative	–	–	–	–	–	–	–	–
Thrush sp.	–	–	–	–	–	Positive	–	–	–
White-winged chough	Negative	–	–	–	–	–	–	–	–
Wonga pigeon	–	–	Negative	–	–	–	–	–	–

Appendix D

Variables (see section 3.2.2) which were significant in explaining **species detectability** for 7 or more years of data are shown in Table 12. 'Negative' indicates a decline in species detection probability as the value of the variable increases. For example, short-beaked echidna detectability declined as the season increased (i.e. the number of days since 1 January). 'Positive' indicates an increase in detection probability as the value of the variable increases. For example, bare-nosed wombat detectability increased the further a camera was from the road. The other covariate tested, moon phase, was not significant in explaining species detectability for 7 or more years of data for any species. Asterisk (*) indicate non-native species. Species are listed alphabetically by common name.

Table 12 Variables which were significant in explaining species detectability for 7 or more years of data

Species	Season	Distance to road
Bare-nosed wombat	–	Positive
Common brushtail possum	–	Positive
Goat*	–	Positive
Red-necked wallaby	Positive	–
Short-beaked echidna	Negative	–
Swamp wallaby	–	Positive

Glossary and acronyms

Term	Meaning, description
AIC	Akaike Information Criteria. A model comparison method used which provides a balance between model fit and complexity. The relative amount of information lost is estimated for a given model: the lower the AIC value, the higher the quality of that model.
AIC weight	Derived from AIC values, ranking candidate models (from 0 to 1) to find the most preferred model.
Alpha (α)	The significance level of a statistical test – it represents a threshold probability for rejecting the null hypothesis and corresponds to the risk of making a Type I error (i.e. rejecting a true null hypothesis).
AWAP	Australian Water Availability Project
BIOCLIM	Bioclimatic analysis system based on climate surfaces.
Detectability	The probability of a species being recorded given that it is present at a site.
Detectable change	The change in the proportion of sites where a species is present, used to infer change.
IUCN	International Union for Conservation of Nature
Naive occupancy	A basic measure of the proportion of sites at which a species is detected, not accounting for imperfect detection. It may underestimate true occupancy.
Occupancy	A statistical estimate of the proportion of sites at which a species is present during a specified time period or survey.
Season	Used in occupancy modelling to denote discrete periods of surveys. In the case of WildCount, this refers to the total period cameras were deployed in a given year (minimum 14 days).
Site	A survey site comprising 4 cameras in a 100-ha area.
Survey	A single day that a camera or cameras is/are operable within a site or location.

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More information

- Australian Water Availability Project
- NSW BioNet
- WildCount