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Kangaroo Island glossy black-cockatoo at a breeding site that escaped the Jan 2020 fires. Photo Nicolas Rakotopare

# Design considerations for post natural disaster (fire) on-ground assessment of status of species, ecological communities, habitats and threats

Darren Southwell, August Hao, Adam Smart, Roozbeh Valavi, David Wilkinson, Brendan Wintle

The University of Melbourne

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## Executive summary

The purpose of this document is to highlight design considerations for conducting post-fire reconnaissance surveys to assess fire severity, habitat condition and threats, as well as the status of priority threatened species and ecological communities listed by the federal Government as most vulnerable to the 2019-20 wildfires. The document consists of five parts. Section 1 reviews the published literature to discuss general survey design considerations when conducting surveys following large, unplanned fires. Section 2 provides more specific survey guidelines for federally listed priority species (birds, mammals, frogs, reptiles, fish, crayfish) specifically, the preferred sampling methods, the optimal timing of surveys, preferred habitat and the minimum survey effort. Section 3 provides a brief summary of general survey methods for sampling these species with reference to existing guidelines. Section 4 lists species that are already the focus of post-fire reconnaissance surveys across Australia. Finally, section 5 develops species distribution models (where possible) for priority vertebrates and crayfish, and presents the results of a spatial prioritisation to identify regions for new post-fire surveys.

# Section 1: General post-fire survey design considerations

## Background

Fire plays a crucial role shaping the abundance and distribution of biota around the world (Bowman et al. 2009). Although many species are resilient to fire (Bradstock et al. 2002), high intensity burns can result in the direct mortality of native animals and plants, and adversely affect shelter and resources well after the fire event. The likelihood of species persisting through fire depends on physical and ecological traits such as dispersal ability, body size and patterns of habitat utilisation (Friend 1993, Sutherland and Dickman 1999, Monamy and Fox 2000). Refugia, such as rocky outcrops or mosaics of unburnt habitat (Turner et al. 1998), also play an important role in survival and how post-fire recovery proceeds (Robinson et al. 2013). Although the impact of low intensity prescribed burns on the status and distribution of native species is relatively well studied, the infrequency of large high-intensity fires means that the response of species to these disturbances is poorly understood.

Post-fire surveys are critical for assessing the immediate impact of bushfires on native species and ecological communities. Organisations might conduct a rapid inventory of plants, animals or invertebrates following a large high-intensity fire to: 1) assess the survival rate of individuals and populations (Banks et al. 2011b); 2) determine whether populations were extinguished, or at worst, species were driven to extinction; 3) identify the presence and quality of post-fire refugia to aid population recoveries (Robinson et al. 2013); 4) measure the presence and intensity of threats (Russell et al. 2003), and; 5) assess the response of species and communities to variations in fire characteristics, such as fire severity (Lindenmayer et al. 2013). Such information, if collected appropriately, can improve understanding of the response of species to large catastrophic disturbances and help prioritise post-fire management actions to aid recovery (Rouget et al. 2003).

Effective and efficient surveying of biodiversity is a complex issue that requires careful design, implementation and analysis, often within budgetary constraints (Legg and Nagy 2006, Lindenmayer and Likens 2018). Although the importance of monitoring is well recognised in the literature, it is often poorly implemented in practice (Legge et al. 2018, Scheele et al. 2019). While the general principles for effective monitoring will remain (Lindenmayer et al. 2020), some aspects of survey design will become particularly important immediately following bushfires. Decisions about what, how, where and when to sample to achieve survey objectives will be affected by changes in the distribution, density, movement and behaviour of both native and introduced species as well as the habitat in which they occupy (Driscoll et al. 2012). Post-fire survey design is further complicated by the fact that bushfires are highly unpredictable and surveys must usually be conducted with little time for planning (Parker and Wiens 2005).

## Aim of section 1

In this section, we review key steps and design considerations for post-fire surveys with a focus on threatened species and ecological communities. Our motivation is the 2019-20 bushfires that burnt vast amounts of habitat in southern Australia. The fires were unprecedented in terms of their size, severity and timing, with millions of hectares burnt over several months. An estimated one billion mammals, birds and reptiles were likely killed as a direct result of the fires (The University of Sydney 2020), while the impact on other

taxonomic groups, such invertebrates, frogs and fish, is unknown. Threatened species and ecological communities were especially vulnerable: 92 vertebrates, 471 plants, 218 invertebrates and 19 ecological communities were listed by the Wildlife and Threatened Species Bushfire Recovery Expert Panel as being most at risk of extinction due to the 2019-20 fires (Legge et al. 2020). Cost-effective post-fire surveys are needed to assess the immediate impact of the 2019-20 fires on these species and ecological communities (Dickman et al. 2020).

We review the post-fire survey literature to provide guidance on important design considerations when planning and implementing post-fire reconnaissance surveys. We highlight these considerations by drawing on threatened species and ecological communities believed to be most vulnerable to bushfires due to their distribution and ecological traits. The time following the 2019-20 bushfires is a unique opportunity to improve our knowledge of how fire affects native species. We hope that this section will provide some guidance for more effective on-ground assessments. This will only become more important in future given that the extent, frequency and severity of bushfires are expected to increase due to climate change (Bradstock et al. 2002, Cary et al. 2012).

**Define the objective of post-fire surveys**

After a major bushfire, land managers, researchers or government agencies might conduct a rapid inventory of plants and animals for a variety of reasons. Like any monitoring program, the aim of post-fire surveys should be clearly defined early in the design stage (Yoccoz et al. 2001, Legg and Nagy 2006). Failing to clearly articulate the objective from the outset is a common barrier to effective monitoring (Lindenmayer and Likens 2018). This is because the survey objective will directly influence decisions about what to measure, which in turn will influence the type of sampling method, timing of surveys and location of sites within the fire zone. Small changes in a survey objective can result in very different survey designs. Unfortunately, objective setting is widely recognised as one of the most difficult components of ecological monitoring (Tear et al. 2005), yet it might be easily overlooked in post-fire surveys where there is generally an urgency to survey immediately after a fire event. We outline post-fire survey objectives below and how they might influence survey design considerations. We note that some designs might achieve simultaneous objectives.

***What is the short-term effect of fire on survival?***

The abundance of individuals following a bushfire is critical for determining how populations recovery over time (Turner et al. 1998, Franklin et al. 2000). Reproductive output shortly after fire is also likely to be a key driver of population persistence and recovery. A common objective of post-fire surveys is therefore to determine the short-term effect of bushfires on survival and reproductive output of target species. Banks et al. (2011b) provide a good example of this scenario. They recorded the behaviour and movement of the arboreal mountain brushtail possum (*Trichosurus cunninghami*) with proximity-logging radio transmitters before and after the 2009 Black Saturday bushfires in Victoria, Australia. Although arboreal mammals are thought to be highly vulnerable to large, high severity fire, possum abundance was found to be relatively stable before and after the fire, suggesting very little short-term effect of large, high-intensity fire on the survival of this species.

***Has fire caused a population or species to go extinct?***

We have few precedents to know whether large fires cause large-scale extinction of plants and animals (Gill and Bradstock 1995, Bradstock 2008), post-fire surveys might determine whether whole populations were extinguished, or in the worst case, entire species were driven to extinction. This objective might be most relevant to species with highly restricted distributions and/or lack of specialised fire tolerant traits. Freshwater fish are good examples because species are often restricted to small streams in upper river catchments prone to fire (McMahon and de Calesta 1990). One example is McDowall's Galaxias, known only from the headwaters of the Rodger River in the Snowy River National Park in East Gippsland, Victoria. In early 2014 a series of fires burnt the entire known range of the species, prompting a series of post-fire surveys to determine whether the species survived (Raadik and Nicol 2015).

***What is the effect of fire on distribution or range extent?***

Post-fire surveys might aim to determine a change in the extent or distribution of species (Knight and Holt 2005). An example of this objective is early surveys for the Tasmanian pencil pine (*Athrotaxis cupressoides*) following the 1960-61 fires. Adults and juvenile *A. cupressoides* are killed by all but the lowest intensity fire due to the absence of any specialised fire tolerant traits, such as aerial or soil seedbanks, epicormic re-sprouting or fire-resistant bark. These traits restrict the distribution of this species to fire-proof landscapes on the central plateau of Tasmania (Kirkpatrick and Dickinson 1984*)*. In 1960-61, fires burned over 60% of the plateau, substantially impacting on populations of *A. cupressoides*. Surveys aimed at documenting the effect of the fires on the species distribution revealed one third of the geographic extent had been destroyed (Johnson and Marsden-Smedley 2002).

***How do species respond to fire characteristics?***

Given fire is a major driver of species diversity and distribution, understanding relationships between fire characteristics and biodiversity is important (Bowman et al. 2009). While the majority of studies examine the effect of time since fire (Driscoll et al. 2010), there are far fewer examples where the survey objective is to learn about the response of species to variations in fire characteristics (Lindenmayer et al. 2013, Robinson et al. 2013). One example is a study by Lindenmayer et al. (2013) who quantified the effect of fire severity on arboreal marsupials following the 2009 Black Saturday fires in Victoria. By sampling sites across a range of fire severity classes, they found a negative response of the Greater glider (*Petauroides Volans*) to fire severity, while the Mountain Brushtail Possum was less frequent in moderate fire severity sites.

***Monitoring population recoveries***

Post-fire surveys might be conducted not only to learn about the immediate status of species, but also to form the foundations for short-to-medium term monitoring to track population recoveries, or lack thereof, over time (Lindenmayer et al. 2008). For example, Banks et al. (2011a) conducted surveys following the 2009 Black Saturday Bushfires in Victoria, Australia to determine the post-fire status of small mammals. They found that the number of the Agile Antechinus (*Antechinus agilis*) and Bush Rat (*Rattus fuscipes*) decreased by 70% and 88% respectively, in burned compared to unburned habitat. However, their study was designed to determine whether recoveries were driven by individuals

immigrating from outside the burn zone or from survivors from within. They demonstrated that recolonisation from unburnt habitat is a major driver of recovery for some small mammals.

**Deciding where to survey**

The positioning of survey sites within the burn zone is highly sensitive to the survey objective. For range restricted species found in only a few locations, there will be no decision about where to survey if it is possible to sample or conduct a census of all known populations. If the goal is to determine whether a species or population persists or not after a fire, sites should be positioned to maximise the chance of confirming a species presence. This might involve targeting a subset of known populations within the burn zone or identifying refugia in regions most suitable for target species prior to a fire. Alternatively, if the survey goal is to obtain a 'snap-shot' of the post-fire distribution of target species, sites should cover the full extent of the target species' known range. Similarly, when the objective is to learn about the response of species to fire characteristics, such as fire severity, learning will be maximised by stratifying sites across characteristics of interest in regions where target species were most likely found before a fire (Lindenmayer et al. 2013). Remotely sensed fire severity maps and species distribution models can help decide where to position sites within the burn zone to achieve these objectives (see section 5) (Elith and Leathwick 2009).

Some post-fire survey objectives, however, require more than a snapshot of a state variable at one point in time because they seek to measure the impact of fire. A major challenge in assessing whether a change has occurred is that populations fluctuate naturally over space and time. To disentangle naturally occurring spatial or temporal variation from an affect caused by a fire, experimental survey designs are needed. The unpredictable nature of large bushfires; however, makes robust experimental designs difficult to implement in practice. Control-impact designs are probably most feasible for large, unplanned bushfires because burnt and unburnt sites can be established after the event. The limitation of this design is that control-impact surveys do not account for any variation among sites that might have existed beforehand (Parker and Wiens 2005). Banks et al. (2011a) partly minimised this risk by replicating burnt-unburnt sites across multiple sets of geographically discrete clusters.

Ideally, 'before-after-control-impact' (BACI) designs are needed to disentangle the impact of fire on populations, where burnt and unburnt sites are surveyed before and after a fire event. This approach is statistically powerful because it isolates the effect of fire on the state variable of interest, however, it is difficult to achieve in practice because it is difficult to predict, where and when large, intense bushfires will occur. It is also important that there are enough sites to ensure there is sufficient statistical power to detect an effect due to fire. Although the approach is commonly applied to planned prescribed burns, application of BACI survey designs to assess the impact of large unplanned bushfires is mostly opportunistic. For example, Lindenmayer et al. (2009) recorded the recovery of the endangered Eastern Bristlebird (*Dasyornis brachypterus*) following fire at Booderee National Park, using a BACI survey design. In this study, presence of *D. brachypterus* was recorded at 110 sites before and after major unplanned fires which burnt 59 of these sites in 2003. The unexpected fire created a relatively unique opportunity where burnt and unburnt sites were stratified randomly across vegetation classes, increasing inferences that could be made about the effect of fire on occupancy.

Even if surveys were not designed explicitly as BACI experiments, it may be possible to achieve a similar effect by establishing post-fire control-impact sites in regions with historical population data. This would help compare post-fire variation with baseline trends (if available), improving inferences that can be made about the impact of the fire event. If designed this way, care should be taken to ensure 'after' surveys are conducted at a similar time of year to the 'before' surveys, using consistent sampling methodologies to ensure compatibility across datasets. A good example of this is a study by Lyon and O'Connor (2008). They surveyed the effect of sediment runoff after the 2003 bushfires in Victoria, Australia on fish populations. Their study was opportunistic, in that 12 impact and 8 control sites were surveyed after the fire. However, these sites were positioned in regions with historic data so that baseline fish diversity and abundance could be included in the analysis. Post-fire surveys were also conducted using the same methodology as the historical data to ensure compatibility across years.

**Deciding when to survey**

Many animals that survive a fire are still at risk well after the event because of increased predation and lack of shelter and resources in the months following (Russell et al. 2003, Leahy et al. 2015). Surveys should generally be conducted immediately following a fire so that the status of species can be understood, and management actions can be prioritised towards those in most need of assistance (Rouget et al. 2003). However, surveying immediately may not always align with when species are most detectable due to seasonal activity and breeding patterns and may not be possible due to safety concerns. For example, frogs and reptiles in particular, are generally more active during the summer months or breeding season, leading to higher rates of detection (Canessa et al. 2012). Seasonal changes in detectability creates a trade-off in the optimal timing to survey; delaying surveys to known peaks in activity can increase detectability and reduce false-absences, but come at the cost of decreasing the probability of persistence due to continued exposure to post-fire threat.

The survey objective might also influence the timing of surveys. For example, if the goal is to identify the mechanisms of population recovery after a fire, surveys must be conducted early to ensure recruits can be identified as originating from either refugia within the burnt zone or from unburnt habitat outside the fire extent. This design consideration was highlighted by Banks et al. (2011a), who surveyed the abundance, body mass and sex ratio of two small mammals after the 2009 Victorian Black Saturday fires. They sampled sites along transects and recorded the trapping rate as a function of distance from the fire edge. Capture rates across this gradient suggested that population recoveries were driven by survivors in unburnt refugia, rather than from immigrants from outside the fire zone. Importantly, surveys had to be conducted early so that the distribution of survivors, and therefore the source of colonisers, could be quantified.

**Deciding on a state variable to be measured**

The survey objective and characteristics of the target species will determine what population state to measure during post-fire surveys (Yoccoz et al. 2001). A complete census of individuals might be possible for conspicuous species with highly restricted distributions. Alternatively, counts or indices of abundance might be preferable if the aim is to estimate direct mortality due to fire. Presence-absence data is suitable if the goal is to measure

changes in the extent or distribution of species, especially those with widespread distributions. Occurrence data is often much easier and cheaper to collect than abundance or activity data because only direct or indirect evidence of an individual being present is required (Joseph et al. 2006). However, it is less sensitive to changes in a population than abundance or activity measures. In post-fire surveys, care should be taken to ensure that indirect signs, such as scats, markings or burrows, do not pre-date a fire, as this could result in false-presences giving the impression that individuals survived when in fact they did not. The effect of fire on indirect signs has received little attention in the literature; however, it is possible that indirect signs may still be available for detection even when individuals themselves have perished.

**Deciding on sampling methods**

Like any monitoring program, the choice of sampling method for post-fire surveys is determined by the objective, the choice of state variable and the target species. The preferred method should also consider cost and the level of skill required by observers. Some sampling methods might be less effective following fire due to changes in the abundance, movement or behaviour of target species (Driscoll et al. 2012, Teasdale et al. 2013). For example, snorkelling along a transect or within an area is a common survey method for detecting freshwater turtles; but this approach may not be suitable after a bushfire if sediment runoff decreases water visibility. Driscoll et al. (2012) point out that pitfall traps for reptiles may be less effective in post-fire surveys because they are relatively ineffective at trapping species occurring in low densities. Instead, they suggest other sampling methods might perform better in post-fire environments, such as manual searches or stationary visual surveys; however, changing methods could make comparisons with pre-fire data difficult.

Post-fire surveys should also consider implementing multiple sampling methods at a site to either increase the chance of detecting a single species or increasing the number of species detected (i.e. complementarity). Complementarity can greatly improve the cost-effectiveness of surveys but will depend on the species available for detection and whether they occupy broadly similar habitats. Teasdale et al. (2013) reported that it is typical for post-fire studies to use only one sampling method. They argue that different methods bias different subsets of the fauna, so results based on a single approach will likely not represent the response of all taxa at a site.

**Accounting for detectability and survey effort**

Post-fire surveys should account for sources of uncertainty inherent in biodiversity sampling (Wintle et al. 2005). Accounting for detectability, which is the probability of recording a species given it is present at a site, is especially important (MacKenzie et al. 2002). Detectability of plants and animals varies naturally in response to time of day (day versus night), lunar cycle, temperature, humidity and seasonality. Detection of frogs and reptiles are some of the most variable amongst all faunal groups, as many are only conspicuous at breeding locations when weather conditions are suitable (e.g. after heavy rain). Failing to account for detectability during post-fire surveys can result in species being wrongly declared as absent (Garrard et al. 2008), which can result in a mis-allocation of management interventions designed to aid recovery. This might result in management being baised towards species with low detectability rather than ones in genuine need of intervention.

Determining the minimum survey effort for a preferred sampling method needed to reduce the chance of false-negatives to acceptable levels is an important part of post-fire survey design. Estimating the minimum effort can be achieved using multiple event probability theory if the probability of detection for a target species is known for a single unit of effort (Canessa et al. 2012). However, the challenge with post-fire surveys is that detection probabilities are rarely known *a priori*, and when they are known, they are often only relevant to unburnt habitat. The effect of large, unplanned fire on detectability has received little attention in the literature. There is evidence to suggest that activity and movement of some species might increase post-fire, increasing rates of detection (Driscoll et al. 2012, Driscoll et al. 2020). On the other hand, detectability might decrease due to reductions in abundance, movement or behaviour of species (Hodson et al. 2010, Nimmo et al. 2019). For example, Matthews et al. (2017) found frequent use of torpor in antechinus species following a high intensity fire in the Warrumbungle's National Park in New South Wales, as a mechanism to decrease activity and save energy following bushfire.

Given very little is known about how detectability changes for species following large, high-intensity fire, and that detectability will likely differ between burnt and unburnt sites, post-fire surveys should adopt sampling methodologies that estimate detection probability. This is usually achieved by repeatedly sampling a site to generate detection histories, which are then analysed in an occupancy-detection modelling framework (MacKenzie et al. 2002). Dynamic occupancy-detection models may be particularly useful because they can estimate detectability, as well as colonisation and extinction rates of refugia over time. Detection probability can also be estimated for the poorly studied species, which can guide subsequent surveys in response to fire.

**Surveying for threatened ecological communities**

Many of the principles of surveying for threatened species and the condition of their habitat also apply to post-fire surveys of threatened ecological communities (Keith et al. 2018). An assessment of an ecological community in a burnt area might also include measures of species composition, diversity and abundance, areal extent, fragmentation, disturbance history and successional stage. For example, the subalpine *Spahagnum* bog and sedge fen communities were severely burnt by the 2003 bushfires in south-east Australia. There was widespread concern about the impact of the fires on the peatlands given their sensitivity to fire. Post-fire surveys were conducted shortly afterwards to assess surface pH, peat depth, species regeneration and the condition of biomass and peat profile, which formed the foundations of a monitoring program to assess the effectiveness of management, such as the use of fertilizers to promote moss growth (Hope and Whinam 2005).

**Measuring threats**

A range of studies suggest animals and plants that survive fire perish afterwards because of the indirect effects of fire on predation, competition, shelter and resource availability (Christensen et al. 1981). Plants may be affected by increased tree mortality, reduced understorey plant cover, and increased mortality in the soil seed bank following fires. In aquatic systems, indirect effects of fire include increased water temperatures due to a lack of riparian vegetation, increased nutrients from burnt material, altered flow regimes and increased sediment loads and run-off. For animals, high intensity fire can increase predation by invasive and native species. (Russell et al. 2003).

The impact of predation from introduced and native species can become more acute following fire. Fox and cat densities have been shown to increase in the weeks to months following fires as individuals move in from surrounding unburnt areas. For example, feral cats are known to travel more than 10 km from unburnt habitat into a fire zone (McGregor et al. 2016, Davies et al. 2017, Stobo-Wilson et al. 2020). Hunting success can also increase during this period of higher density as there is usually less ground cover for native species to seek refuge. Leahy et al. (2015) recorded an increase in mortality of small mammals in the months after high intensity fire in northern Australia, coinciding with an increase in dingo and cat activity. They also found evidence for predation occurring in waves: dingo activity was significantly higher two weeks after the high intensity fire, whereas cat activity increased after one month when dingo activity subsided. This study demonstrates that threats posed on native species following fire will not always be simultaneous – threat levels will likely be dynamic over time.

The choice of sampling method for predators during post-fire surveys depends critically on the survey objective. If the goal is to measure occupancy or activity, camera trapping is common because; 1) cameras can be left unattended at sites for relatively long periods, increasing detectability; 2) camera-trapping is probably the safest tool in burnt areas as it only requires a single deployment and retrieval, minimising the time surveyors spend in the field, and; 3) camera-trapping is suitable for a range of species. However, camera-trapping may not be suitable if the objective is to estimate predator density. Although feral cats can be individually identified through camera-trap photographs, foxes lack unique markings making it difficult to conduct mark-recapture analyses. Alternatively, live trapping or genetic scat analysis can estimate fox density, although both have their own limitations. For example, live trapping is generally considered the least feasible because predators can become trap shy.

Decisions about where and how to survey for predators is also influenced by the goal of surveys. For example, fox activity can be measured by placing cameras either on or off tracks. Foxes are known to be more active on tracks (Raiter et al. 2018), so placing cameras off-tracks might reduce the number of detections. However, off-track cameras are more likely to measure the 'background' rate of predation on native species, and thus might be a better measure of the level of threat facing a species. Off-track camera detections are also likely to contain less spatial and temporal variation in captures than on-track cameras, which can make this design a better choice if trying to determine differences in capture rates between control-treatment sites (van Hespen et al. 2019). In both cases, post-fire camera trapping for predators may choose not to use baited lures as this might attract predators into the burnt site where native species are most vulnerable (Meek et al. 2014).

**Measuring fire severity**

Reliably estimating fire severity is essential for planning pre- and post-fire management and survey activities, especially when planning the positioning of sites within the burn zone (Collins et al. 2018). Pre- and post-fire difference severity indices (FSI), such as Normalised Burn Ratio (NBR) and Normalised Difference Vegetation Index (NDVI), are collected using remotely sensed imagery. Such indices are compared before and after a fire to estimate its severity and overall impact on habitat features such as understorey vegetation cover and canopy cover (Chafer 2008, Collins et al. 2018). The use of high-resolution (20 cm or less) colour and infra-red aerial photography has substantially improved fire severity and extent mapping in recent years. For example, McCarthy et al. (2017) remotely assessed burnt area

mosaics and patchiness in southern Australian eucalypt forests where tree canopy densities were > 30% cover. Importantly, they accurately mapped the impact of fire severity on the understory layer beneath green canopies that were not damaged by fire. This combination of colour and infra-red imagery is a significant methodological improvement for post-fire severity assessments.

Given the role of fire severity mapping in post-survey design, on-ground assessment of fire severity is crucial for ground-truthing remotely sensed classification of fire severity classes. On-ground methods for assessing fire severity can broadly be divided into those that measure the above ground impacts of fire and those that measure processes occurring at or below the soil surface. Common above ground measures include height and degree of crown consumption and scorch, as well as understorey and ground litter cover. The edges of fire severity classes and burnt/unburnt areas can also be walked with a GPS to ground truth remotely sensed maps. In heathlands and potentially some woodlands, the minimum twig diameter method is a well-established post-hoc method for estimating fire severity (Whight and Bradstock 1999). This involves calculating the mean minimum diameter of branch tips remaining after fire and assumes that high severity fires consume greater twig biomass. Below the ground, post fire soil samples can measure charring depth as an indicator of fire severity.

**Measuring habitat condition**

Fire influences the amount of shelter for fauna, which in turn affects the survival and distribution of individuals during the post-fire recovery stage. Measuring the on-ground habitat condition at a site is therefore important for identifying the features that have enhanced population persistence (e.g. logs and rocks) and for identifying the regions or populations in most need of management. On-ground measures of habitat condition should reflect the behaviour and ecology of target species. Measuring understorey cover will be important for ground-dwelling mammals; the presence of tree hollows for birds and arboreal mammals; the presence of logs, leaf litter and rocks for reptiles, mammals and invertebrates, or; water turbidity for fish and crayfish. For example, Lindenmayer et al. (2013) found that the presence and abundance of four arboreal marsupials was characterised by a positive response to the presence of resources in hollow-bearing trees.

**Conclusion**

Post-fire surveys are critical for understanding the immediate impact of large, high intensity fires on biodiversity. The unpredictability of these disturbances and the impact they have on the behaviour, movement and density of species presents a series of survey design challenges. These challenges are further complicated by the fact that most post-fire reconnaissance surveys are usually required urgently after the fire event. Importantly, the survey objective influences subsequent design decisions and should therefore be clearly defined early in the planning process. Given the effect of fire on the detectability of survivors is poorly understood, and the fact that detectability will likely vary across fire severity classes, post-fire surveys should adopt methods that quantify detection probabilities. Careful post-fire survey design will lead to most cost-effective sampling and improve our understanding of the impact of large, high intensity bushfires.

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# Section 2: Survey guidelines for federally listed priority vertebrates

## Background

In response to the 2019-20 bushfires, the Australian Government released a list of 92 vertebrates, 471 plants, 218 invertebrates and 19 threatened ecological communities considered most at risk of extinction as a direct result of the fires. The assessment was based on the likely distribution of species prior to the fires and knowledge of their ecological traits, such as dispersal ability, and pre-fire imperilment (Legge et al. 2020). For each of the priority vertbrates, this section aims to review the published and grey literature to provide guidance on: 1) the preferred sampling method(s); 2) detectability, 3) habitat requirements, and; 4) minimum survey effort to have a high chance of detecting species that are present at sites.

It is important to note, however, that this section is designed to provide organisations with a starting point for designing post-fire surveys. Almost all of the reported estimates of detectability and minimum survey effort are from studies in unburnt habitat. It is unclear how detectability will change immediately following a large, high-intensity fire, nor how it might vary across degrees of fire severity. Detectability is also highly dependent on the sampling equipment, the local survey conditions and the experience of field staff. It is therefore strongly recommended species experts be consulted prior to conducting post-fire surveys for target species to identify the most appropriate survey protocol for that species/region.

Post-fire reconnaissance surveys should also only be conducted when burnt areas are declared safe. Fire grounds and areas with burnt vegetation may be dangerous. Death or serious injury may result from entering bushfire affected areas, for example due to falling trees or hazardous materials. Furthermore, surveys must be conducted with appropriate permits and animal ethics approval.

## Data recording and management

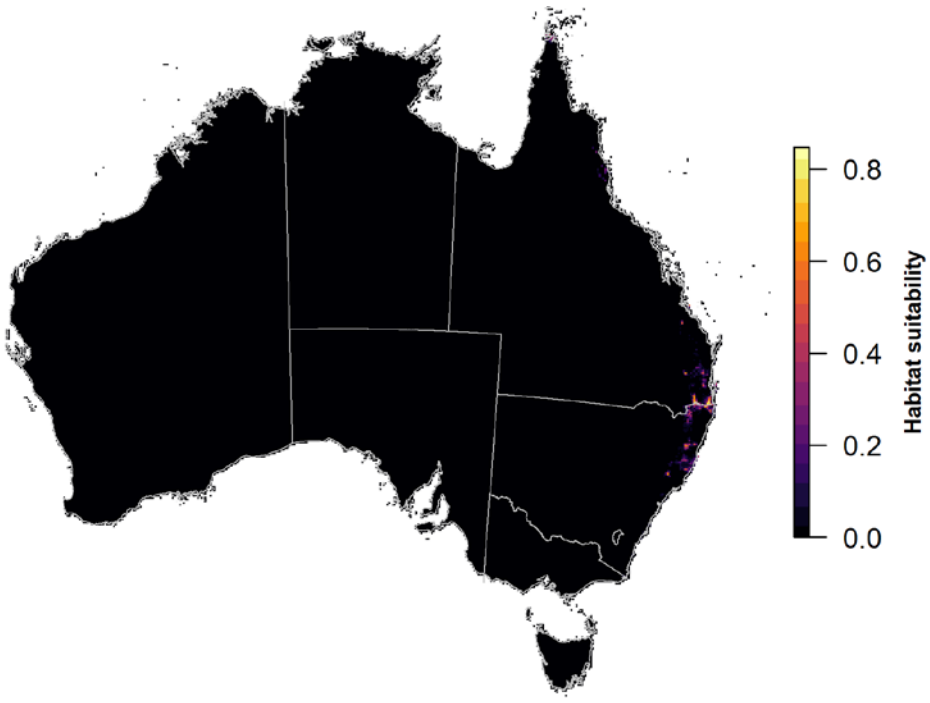
Data management is fundamental to extending the value of survey effort across different landscapes and across time. If survey data are not well described and repeatable, it is impossible to make meaningful use of them apart from the immediate insight they provide to the surveyor on the day of survey. Data from all surveys must therefore be well described and published, with appropriate protection of location information for threatened species (as per the Commonwealth's Sensitive Ecological Data Policy). The Department of Agriculture, Water and the Environment is currently discussing ways to collect standardised metadata for post-fire surveys.

### Birds

The following section presents information on the preferred survey methods, timing of surveys and detectability estimates for 114 priority species. Please note that two species initially included on the priority list but were later removed are also included: Tyler's Toadlet and Swan Galaxias. Species distribution maps are presented for a subset of species (see section 5). Where species distribution models could not be developed, range maps were sourced from the Species of National Environmental Significance Database. Please note that these species do not contain a coloured legend on the right-hand side of each figure. Also note that EPBC listed status may have changed since preparation of this document. Please check the Department of Agriculture, Water and the Environment website for latest listing.

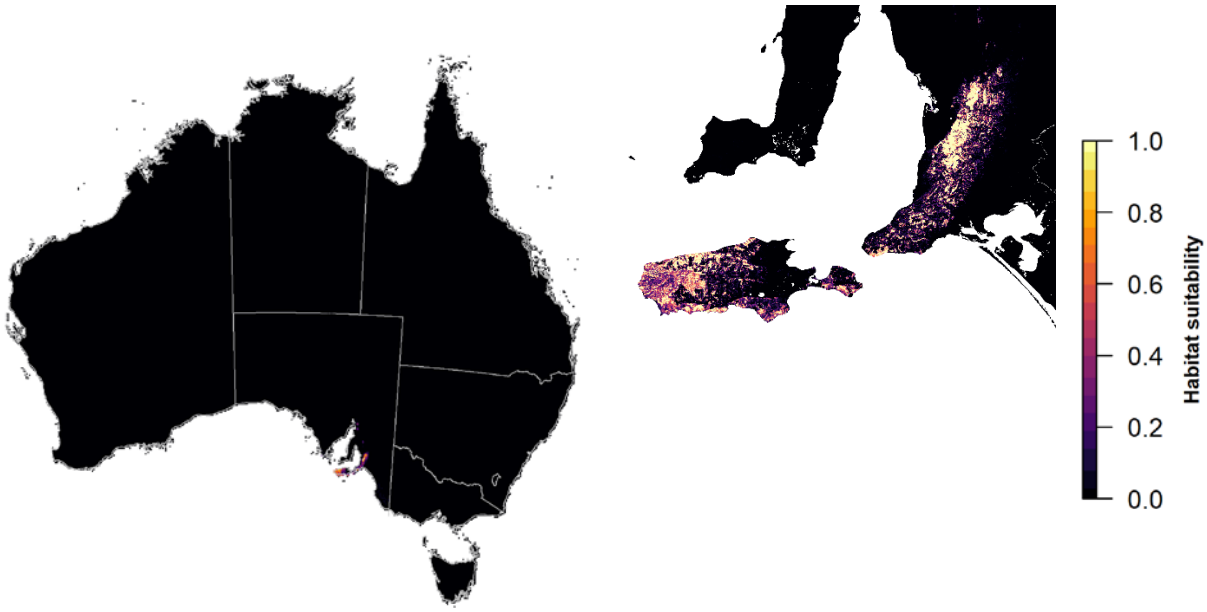
## Albert's Lyrebird

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Menura alberti* |
| EPBC listed status: Vulnerable |
| State: QLD, NSW |
| Description and habitat: Ground-dwelling bird that prefers rainforest or wet sclerophyll forest with a dense understorey. Feeds on invertebrates in the soil and leaf litter |
| Sampling methods: Listening for calls during area search or point survey along transect |
| Timing of surveys: shortly after dawn |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Higgins PJ, Peter JM and Steele WK (eds) (2001) *Handbook of Australian, New Zealand and Antarctic Birds. Volume 5: Tyrant-flycatchers to Chats*. Melbourne, Victoria, Oxford University Press.<br>Chester, G. and Bushnell, S. (2005) Central Eastern Rainforest Reserves of Australia: A Monitoring Strategy. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. (156 pp). |



## Bassian Thrush (South Australian), Western Bassian Thrush

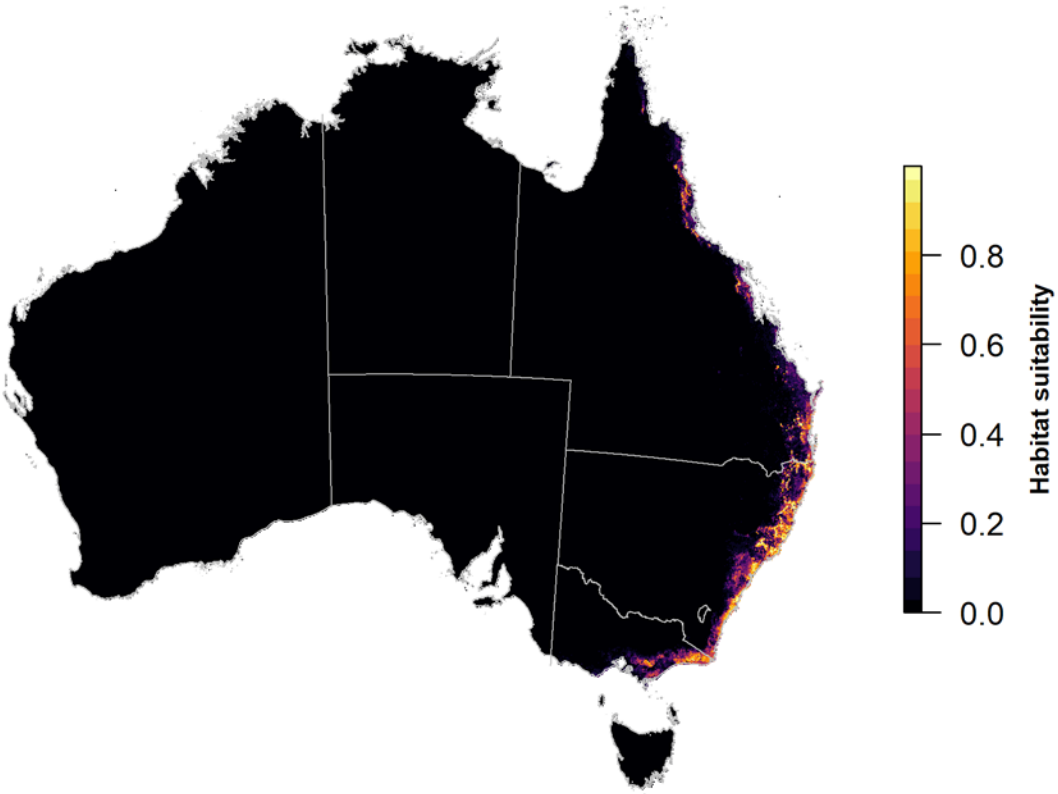
| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Zoothera lunulata halmaturina* |
| EPBC listed status: Vulnerable |
| State: SA |
| Description and habitat: Cryptic species that forages amongst dense vegetation (Garnett et al. 2011). Is easily flushed during searches. |
| Sampling method: Area search or point survey along transect |
| Timing of surveys: Dawn and dusk |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Garnett ST, Szabo JK and Dutson G (2011) The Action Plan for Australian Birds 2010. Birds Australia, CSIRO Publishing, Melbourne |



## Black-faced Monarch

| |
|---|
| Taxonomic group: Birds |
| Scientific name *Monarcha melanopsis* |
| EPBC listed status: Migratory |
| State: NSW QLD Vic |
| Description and habitat: Found in eucalypt woodlands, rainforests, coastal scrub and damp gullies. |
| Sampling method: Area search or point survey along transect |
| Timing of surveys: Migrant to south-eastern Australia from September – March. |
| Single visit detection probability: Detectability for 10 min point count estimated at 0.352 (± 0.056) (Pavlacky et al. 2015) |
| Minimum survey effort: Seven 10-minute point surveys needed for a 0.95 detection probability |
| References and further reading:<br><br>Pavlacky, D., Possingham, H., and Goldizen, W (2015) Integrating life history traits and forest structure to evaluate the vulnerability of rainforest birds along gradients of deforestation and fragmentation in eastern Australia, Biological Conservation 188:89-99 |

*Detectability estimates are based on surveys in unburnt areas.



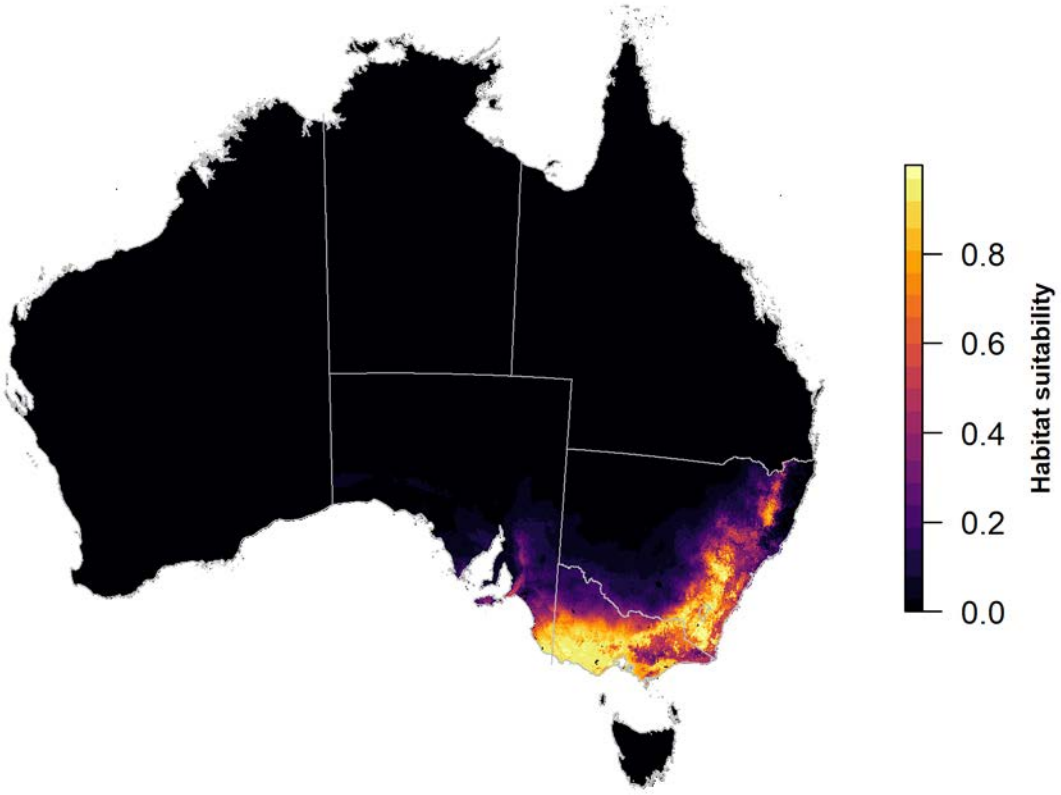
## Eastern Bristlebird

| |
|---|
| Taxonomic group: Birds |
| Scientific name *Dasyornis brachypterus* |
| EPBC listed status: Endangered |
| State: NSW QLD Vic |
| Description and habitat: cryptic species mostly occurring in dense, coastal vegetation. They are commonly detected by their sharp alarm-call or loud, melodic song, or when scampering across open clearings. |
| Sampling method: Area search or point survey along transect (with call playback). Acoustic monitors sometimes used. |
| Timing of surveys: Dusk, dawn |
| Single visit detection probability: Detectability for 5 min point count estimated at 0.23 (± 0.043) in unburned and 0.16 (± 0.031) in burned landscapes (Lindenmayer et al. 2009a, Lindenmayer et al. 2009b). |
| Minimum survey effort: Federal guidelines recommend 9 hours of transects/area searches over 3 days, 5 hours of call playback over 5 days (Department of the Environment 2017). |
| References and further reading:<br>Lindenmayer, D.B., et al. (2009a) What factors influence rapid post-fire site re-occupancy? A case study of the endangered Eastern Bristlebird in eastern Australia. International Journal of Wildland Fire 18, 84-95.<br>Lindenmayer, D.B., et al. (2009b) Do observer differences in bird detection affect inferences from large-scale ecological studies? Emu 109, 100-106.<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

## Gang-gang Cockatoo

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Callocephalon fimbriatum* |
| EPBC listed status: Not listed |
| State: SA Vic NSW ACT |
| Description and habitat: Nests in eucalypt hollows that are at least 10 cm in diameter well above the ground. Favours old growth forest and woodland attributes for roosting and nesting. |
| Sampling methods: Area searches of feeding or roosting groups |
| Timing of surveys: Dusk, dawn |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Garnett ST, Szabo JK and Dutson G (2011). The Action Plan for Australian Birds 2010. Birds Australia, CSIRO Publishing, Melbourne<br>Higgins PJ, Peter JM and Steele WK (eds) (2001) *Handbook of Australian, New Zealand and Antarctic Birds. Volume 5: Tyrant-flycatchers to Chats*. Melbourne, Victoria, Oxford University Press. |

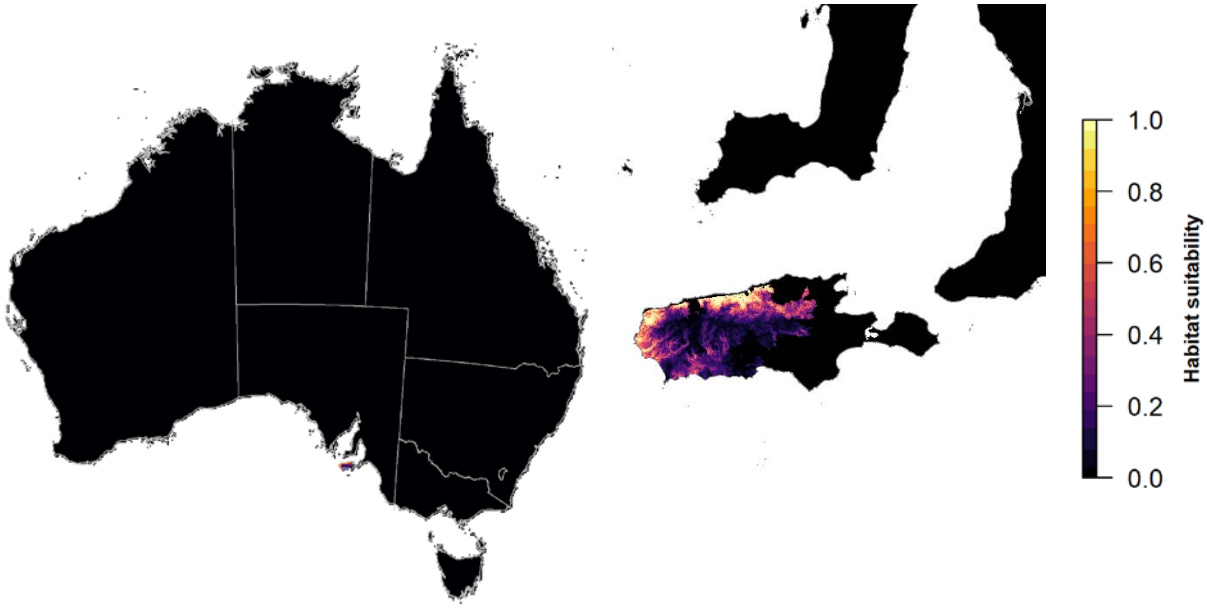
*Detectability estimates are based on surveys in unburnt areas.



## Kangaroo Island Glossy Black-Cockatoo

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Calyptorhynchus lathami halmaturinus* |
| EPBC listed status: Endangered |
| State: SA |
| Description and habitat: Prefers woodlands dominated by Drooping Sheoak. Nest hollows are used for breeding often in successive seasons. |
| Preferred sampling method: Area searches in sheoak forests for feeding groups and evidence of feeding under trees. Soft feeding calls are also an indicator of presence. |
| Secondary sampling method: Observations at water points in the late afternoon. |
| Timing of surveys: Birds can be found feeding throughout the day but are most readily found during first or last two hours of daylight. |
| Minimum survey effort: Federal guidelines recommend 5 hours of area searchers for 1 day, 20 hours of targeted searches for sign of feeding or nests over 4 days (Department of the Environment 2017). |
| References and further reading:<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Hourigan, C. (2012) Glossy black-cockatoo, Calyptorhynchus lathami. Targeted species survey guidelines. Queensland Herbarium, Department of Environment and Science, Brisbane. |

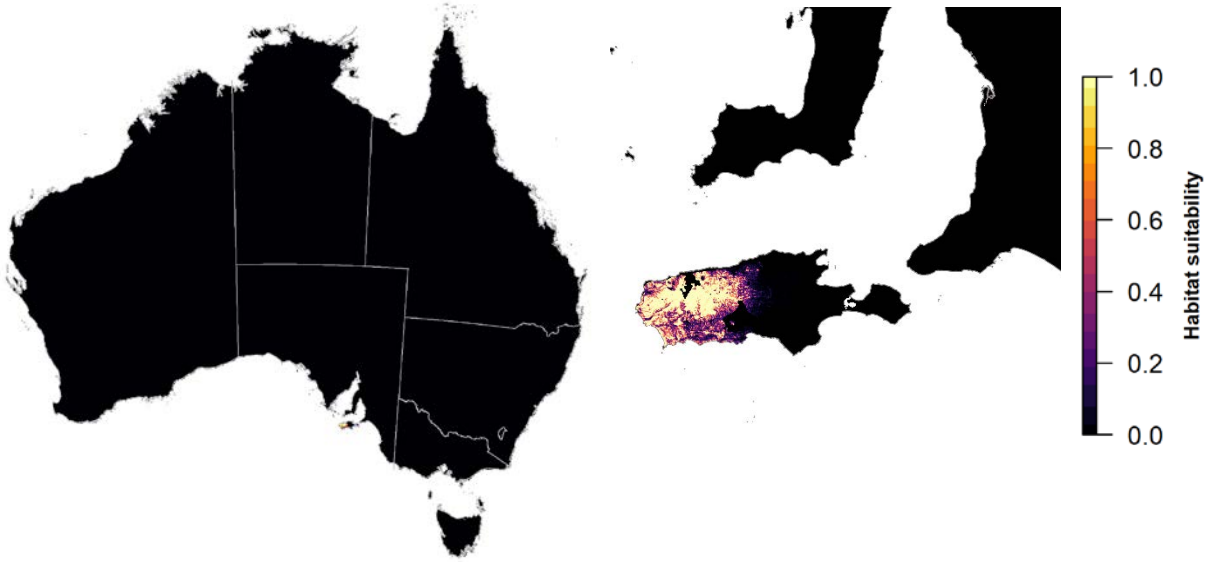
*Detectability estimates are based on surveys in unburnt areas.



## Kangaroo Island Southern Emu-wren

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Stipiturus malachurus halmaturinus* |
| EPBC listed status: Not listed |
| State: SA |
| Description and habitat: Found in marshes, low heathlands and dune areas. |
| Sampling methods: Area search or point survey along transect, call playback |
| Timing of surveys: Early in the day. Birds are less likely to respond to played calls during and immediately after the breeding season (late summer to autumn) |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Federal guidelines for the similar Mt Lofty southern emu wren recommends 10 hours of areas searches over 5 days, 6 hours of call playback over 3 days (Department of the Environment 2017). |
| References and further reading:<br>The Australian Government's Australian Government's Department of the Environment, Water, Heritage and the Arts (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Wilson, D., Paton, D.C., (2004) Habitat use by the Southern Emu-wren, *Stipiturus malachurus* (Aves: Maluridae) in South Australia, and evaluation of vegetation at a potential translocation site for *S. m. intermedius*. Emu 104(1): 37-43. |

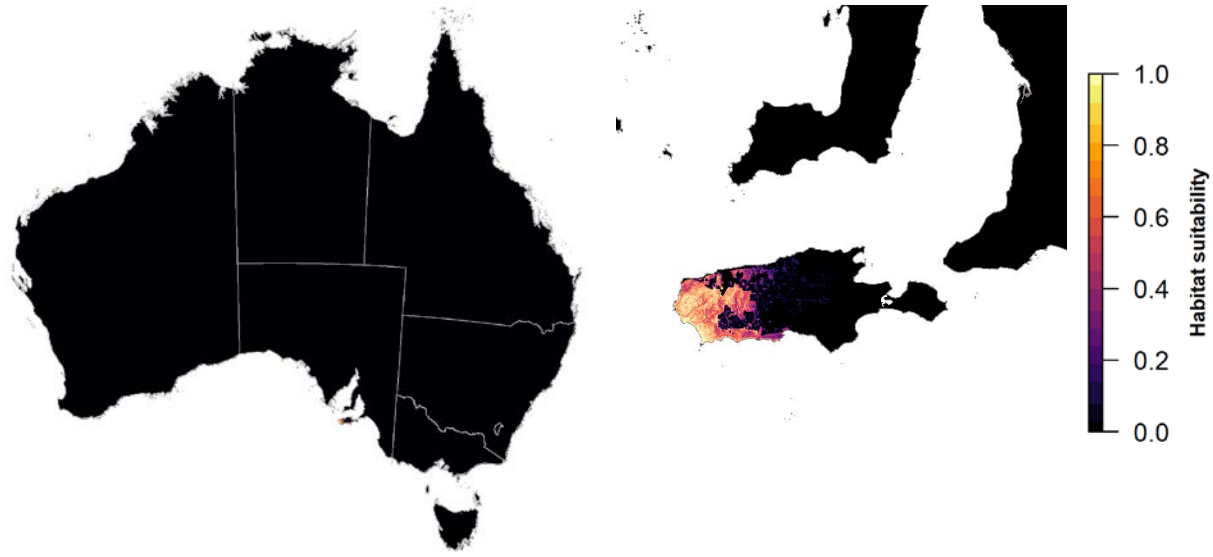
*Detectability estimates are based on surveys in unburnt areas.



## Kangaroo Island Western Whipbird

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Psophodes nigrogularis lashmari* |
| EPBC listed status: Not listed |
| State: SA |
| Description and habitat: Prefers vegetation with a dense, tall shrub layer up to 1.5 m tall. Nests are placed low in dense shrub making them vulnerable to predation. |
| Sampling methods: Area search or point survey along transect (with call playback), acoustic recordings |
| Timing of surveys: Early morning or late afternoon. Song output peaks from July to September |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Federal guidelines for the Western whipbird (eastern) recommend 12 hours of area searches or transect surveys over 6 days and/or 10 hours of call playback over 4 days (Department of the Environment 2017). |
| References and further reading:<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>McGuire A, Johnston G, Kleindorfer S (2011) Comparison of survey methods for detection of the elusive Western Whipbird, *Psophodes nigrogularis*, with notes on its distribution. South Australian Ornithologist 37(2): 49-59 |

*Detectability estimates are based on surveys in unburnt areas.



## Mainland Ground Parrot

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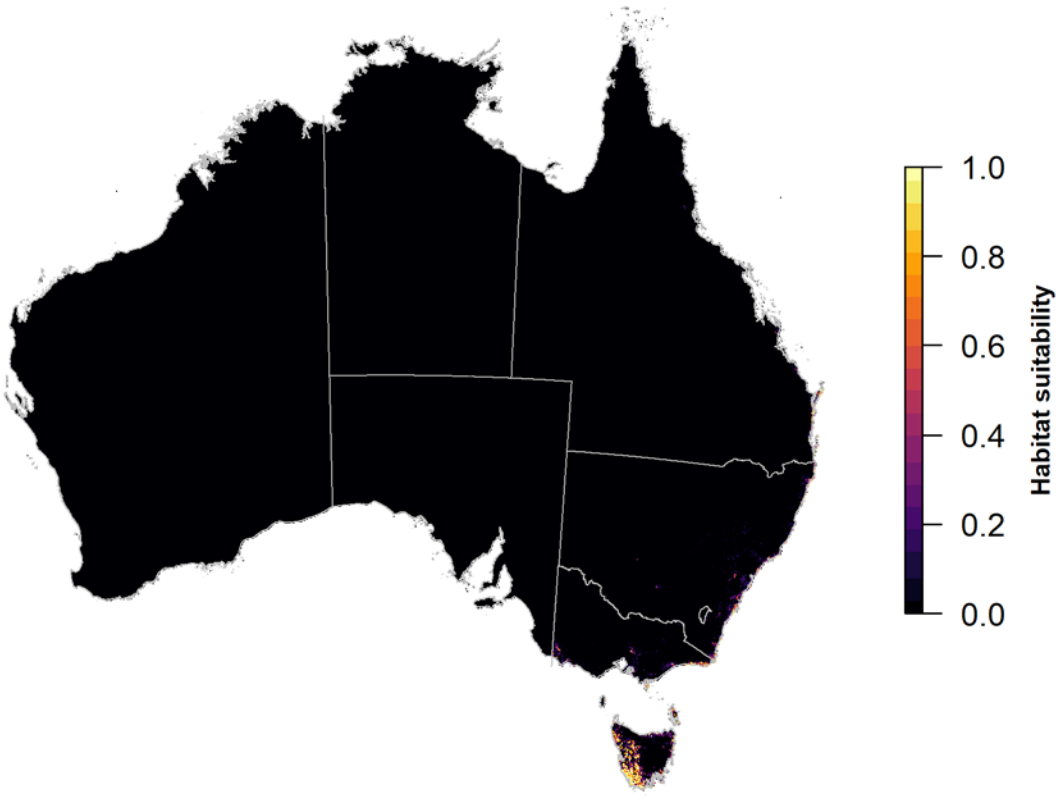
|---|
| Taxonomic group: Birds |
| Scientific name: *Pezoporus wallicus wallicus* |
| EPBC listed status: Not listed |
| State: NSW QLD Vic |
| Description and habitat: Occurs in coastal heathland or sedgeland with very dense cover. Nests on the ground beneath low, dense vegetation. |
| Sampling method: Automated acoustic recording; auditory surveys from fixed points (when there's multiple observers); transect point method (when there's a single observer) |
| Timing of surveys: 60-90 min before-after sunrise-sunset |
| Single visit detection probability: Single visit detection probability for 30-min sound recordings was 0.678 (95% CI 0.575-0.766) and 0.647 (0.404-0.832) for a 60 min observer visit (Bluff 2016). |
| Minimum survey effort: 30 min sound recordings repeated 3 times has 0.96 probability of detection. 60 min observer counts repeated 3 times has 0.95 detection probability |
| References and further reading:<br>Baker, J., et al. (2010) Managing the Ground Parrot in its fiery habitat in south-eastern Australia. Emu 110, 279-284.<br>Bluff, L.A., (2016) Ground Parrots and fire in east Gippsland, Victoria: habitat occupancy modelling from automated sound recordings. Emu 116, 402-410. |

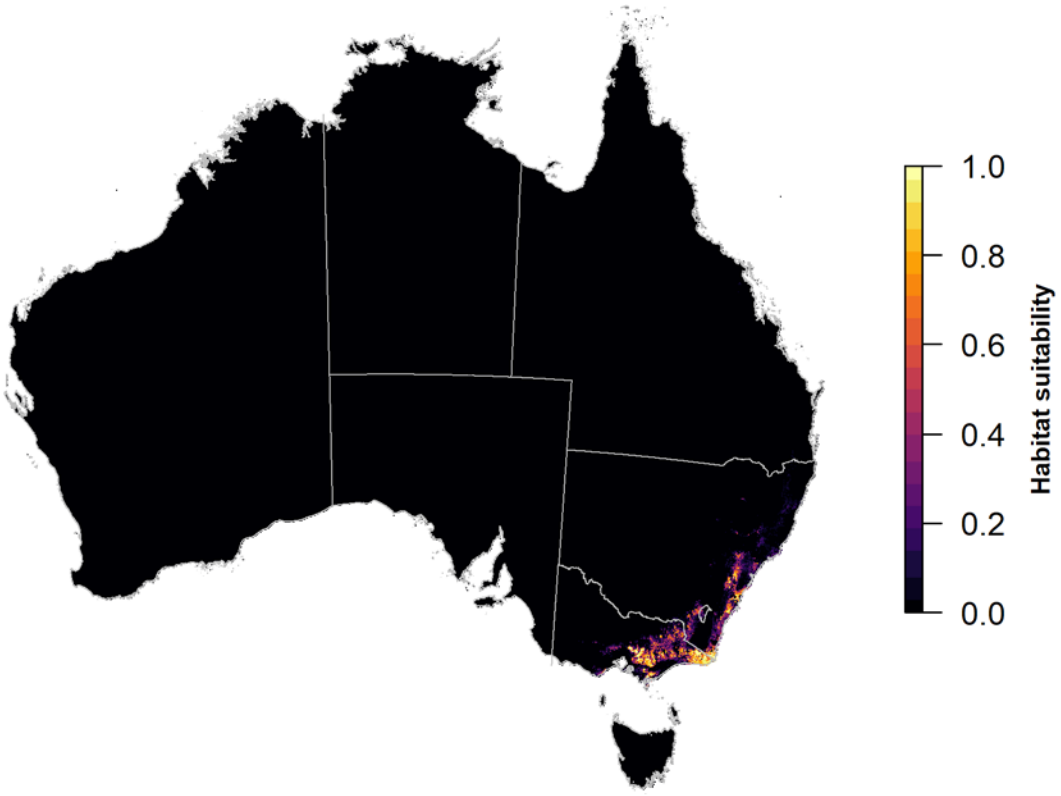
*Detectability estimates are based on surveys in unburnt areas.



## Pilotbird

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Pycnoptilus floccosus* |
| EPBC listed status: Not listed |
| State: ACT NSW Vic |
| Description and habitat: Occupies temperate wet sclerophyll forests and occasionally rainforest. |
| Sampling method: Area search or point survey along transect |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Garnett ST, Szabo JK and Dutson G (2011) The Action Plan for Australian Birds 2010. Birds Australia, CSIRO Publishing, Melbourne |

*Detectability estimates are based on surveys in unburnt areas.



## Red-browed Treecreeper

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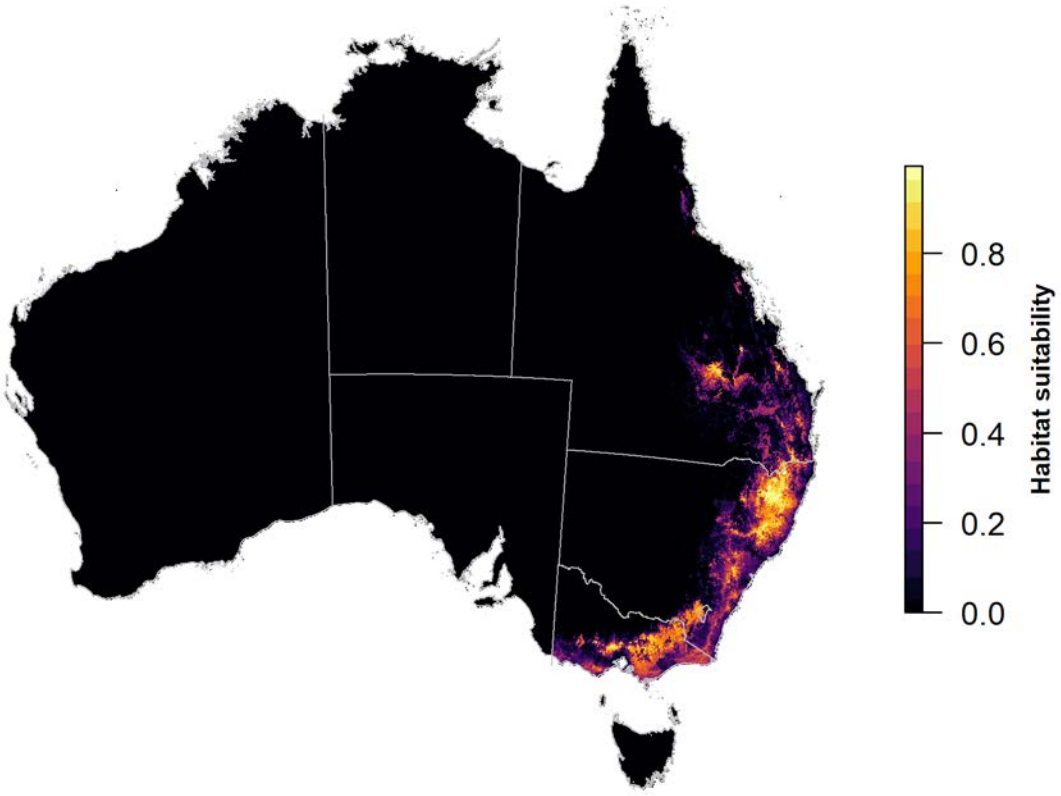
|---|
| Taxonomic group: Birds |
| Scientific name: *Climacteris erythrops* |
| EPBC listed status: Not listed |
| State: ACT NSW QLD Vic |
| Description and habitat: May remain silent for long periods, but its chattering call can be heard from nearby. It is usually seen climbing up trunks of old trees feeding on insects and invertebrates. |
| Sampling method: Area search or point survey along transect |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Stuart, A., Newman, M., (2019) Spring bird surveys in the Gloucester Tops. The Whistler 13: 26-34 |

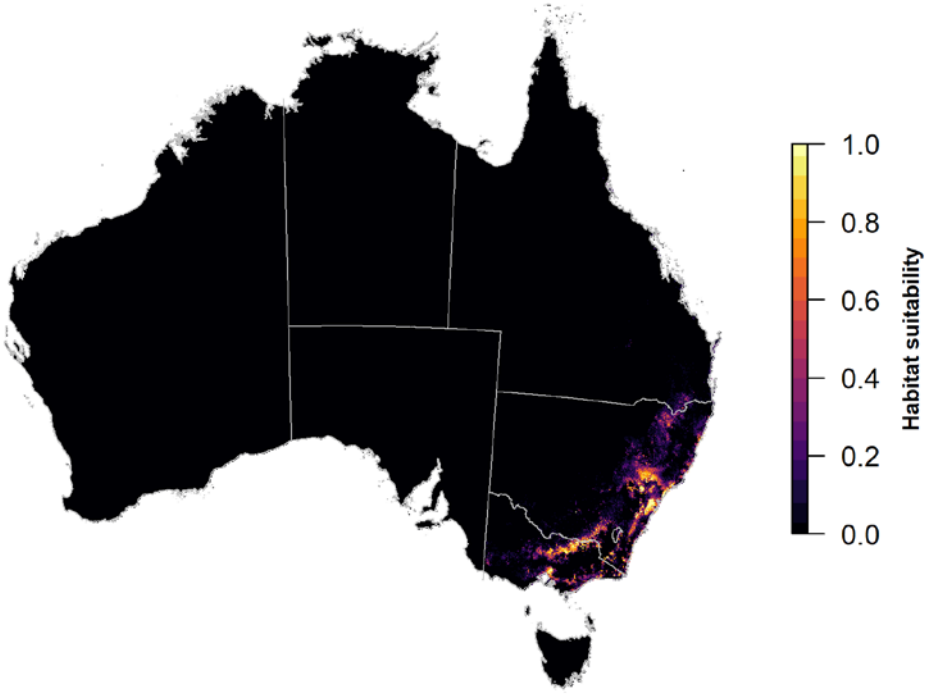
*Detectability estimates are based on surveys in unburnt areas.



## Regent Honeyeater

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Anthochaera phrygia* |
| EPBC listed status: Critically Endangered |
| State: ACT NSW QLD SA Vic |
| Description and habitat: Inhabits dry open forest and woodland, particularly Box-Ironbark woodland that supports large numbers of mature trees and high canopy cover. |
| Sampling methods: Area search or point survey along transect (with call playback), mist netting, acoustic recorders |
| Timing of surveys: Crates et al (2017) found site and weather covariates such as time of day had no impact on detectability. Can be conspicuous in the breeding season. |
| Single visit detection probability: Detectability for 5 min point count with playback equal to 0.59 +/- 0.07 (Crates et al. 2017). |
| Minimum survey effort: Federal guidelines recommend 20 hours of area searchers over 10 days or 20 hours of targeted searches over 5 days (Department of the Environment 2017). Single visit detection estimates by Crates et al. (2017) suggests four 5 min point counts has 0.97 detection probability. |
| References and further reading:<br><br>Crates, R., et al. (2017) An occupancy approach to monitoring regent honeyeaters. Journal of Wildlife Management 81, 669-677.<br><br>The Australian Government's Department of the Environment, Water, Heritage and the Arts. (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br><br>National Recovery Plan for the Regent Honeyeater (*Anthochaera phrygia*) (2016) Commonwealth of Australia |

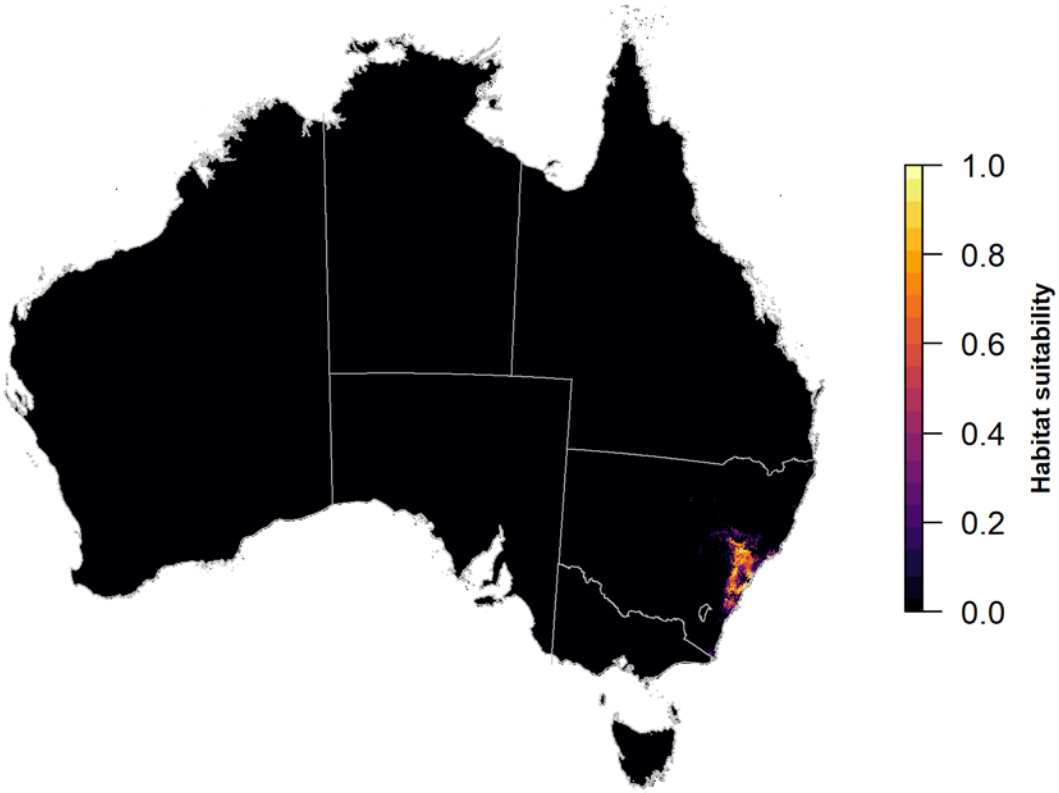
*Detectability estimates are based on surveys in unburnt areas.



## Rockwarbler

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Origma solitaria* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Prefers woodlands and gullies with exposed sandstone. Restricted to the Sydney region of New South Wales. |
| Sampling methods: Area search or point survey along transect |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Probets C, Palmer G, Fitzsimmons J, (2019) Nectarivory in the Rockwarbler *Origma solitaria*. Australian Field Ornithology 36: 34-35 |

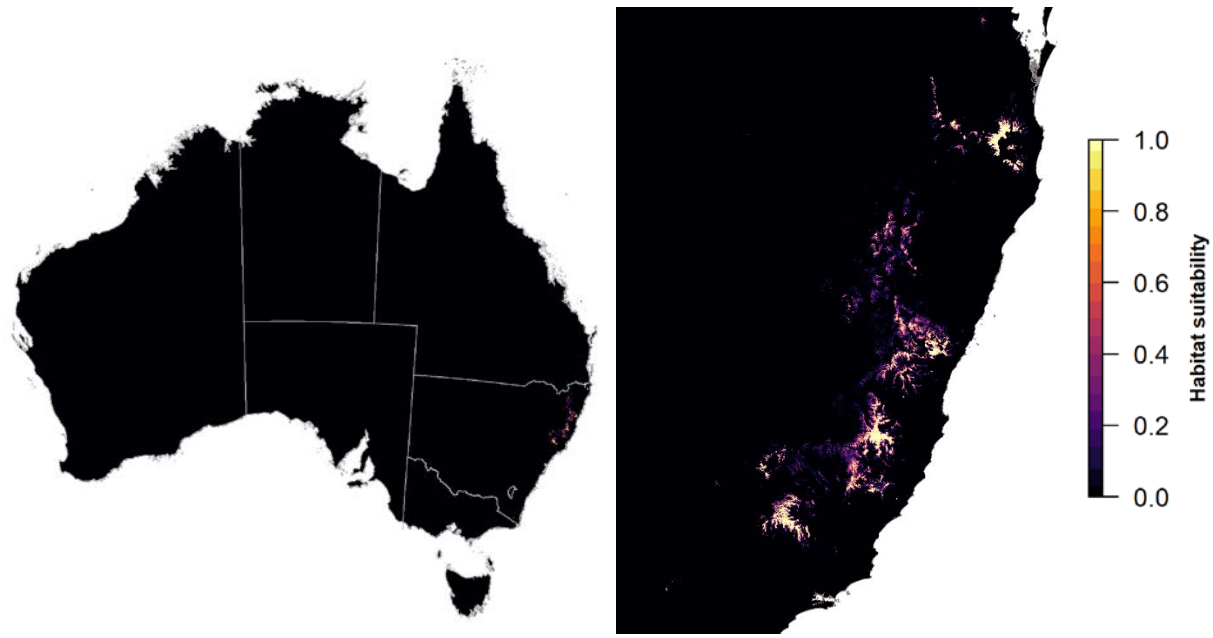
*Detectability estimates are based on surveys in unburnt areas.



## Rufous Scrub-bird

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Atrichornis rufescens* |
| EPBC listed status: Endangered |
| State: NSW QLD |
| Description and habitat: Requires dense ground cover and deep leaf-litter in rainforest and wet eucalypt forest. |
| Sampling methods: Point counts along transect, automated acoustic recording |
| Timing of surveys: Dawn and dusk. Surveys should be undertaken during the breeding season between September and December |
| Single visit detection probability: Ferrier (1984) estimated a 0.4 probability of detecting a male call in one survey in rainforest and a 0.6 detection probability out of rainforest. |
| Minimum survey effort: Chester (2005) recommended surveys for 7.5 minutes at each point over 2 days on two separate occasions, approximately 2 weeks apart. |
| References and further reading:<br>Newman M, Sturt A, F Hill (2014) Rufous scrub bird monitoring at the extremities of the species range in New South Wales, Australian Field Ornithology 31: 77-98.<br>Chester, G. and Bushnell, S. (2005) Central Eastern Rainforest Reserves of Australia: A Monitoring Strategy. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. (156 pp).<br>Stuart A, Newman M, Stuart P, I Martin (2012) Development of non-intrusive method for investigating the calling pattern of Rufous Scrub birds. The Whistler 6:24-34.<br>Stuart A, O'Leary (2019) A method for investigating rufous scrub birds using automated recording and rapid, semi-automated data analysis, Corella 43: 57-64. |

*Detectability estimates are based on surveys in unburnt areas.



## South-eastern Glossy Black-Cockatoo

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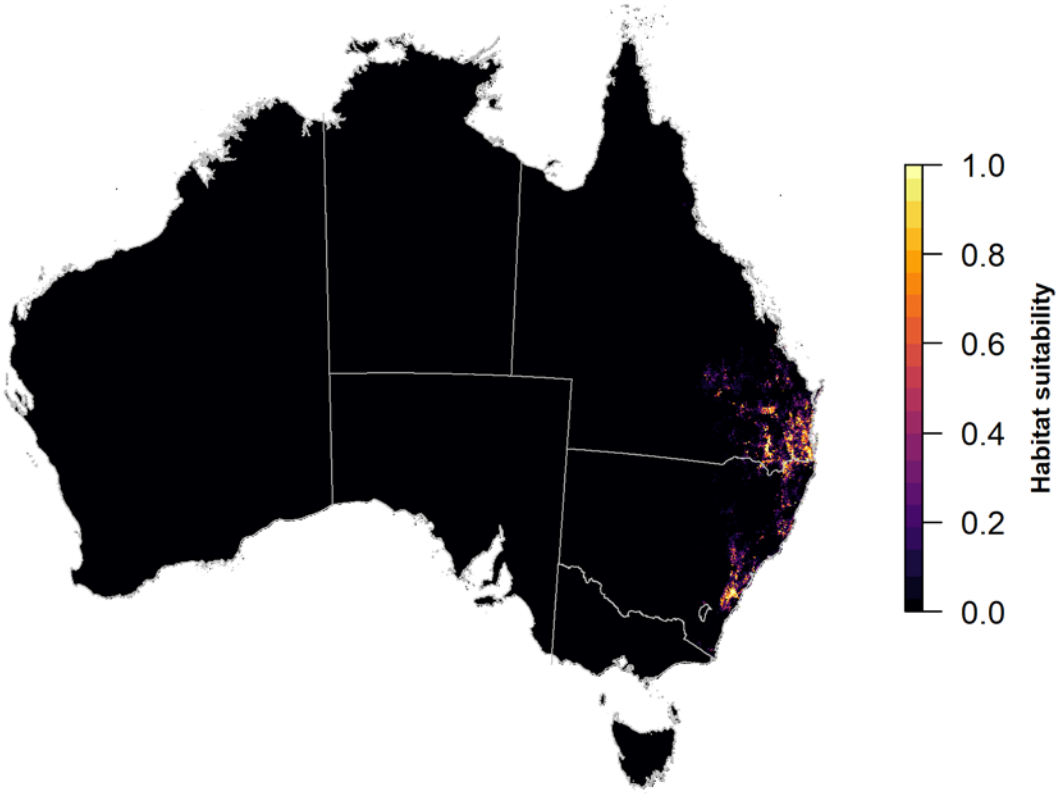
|---|
| Taxonomic group: Birds |
| Scientific name: *Calyptorhynchus lathami lathami* |
| EPBC listed status: Not listed |
| State: Vic NSW ACT QLD |
| Description and habitat: Prefers woodlands dominated by Drooping Sheoak. Nest hollows are used for breeding often in successive seasons.<br>Sampling methods: Area searches in sheoak forests for feeding groups and evidence of feeding under trees. Soft feeding calls are also an indicator of presence. Observations at water points in the late afternoon.<br>Timing of surveys: Dawn and late afternoon. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Federal guidelines recommend 5 hours of area searchers for 1 day, 20 hours of targeted searches for sign of feeding or nests over 4 days (Department of the Environment 2017). |
| References and further reading:<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Cameron, M., Cunningham, R., (2006) Habitat selection at multiple spatial scales by foraging Glossy Black-cockatoos. Austral Ecology 31, 597–607<br>Hourigan, C. (2012) Glossy black-cockatoo, Calyptorhynchus lathami. Targeted species survey guidelines. Queensland Herbarium, Department of Environment and Science, Brisbane. |

*Detectability estimates are based on surveys in unburnt areas.



## Superb Lyrebird

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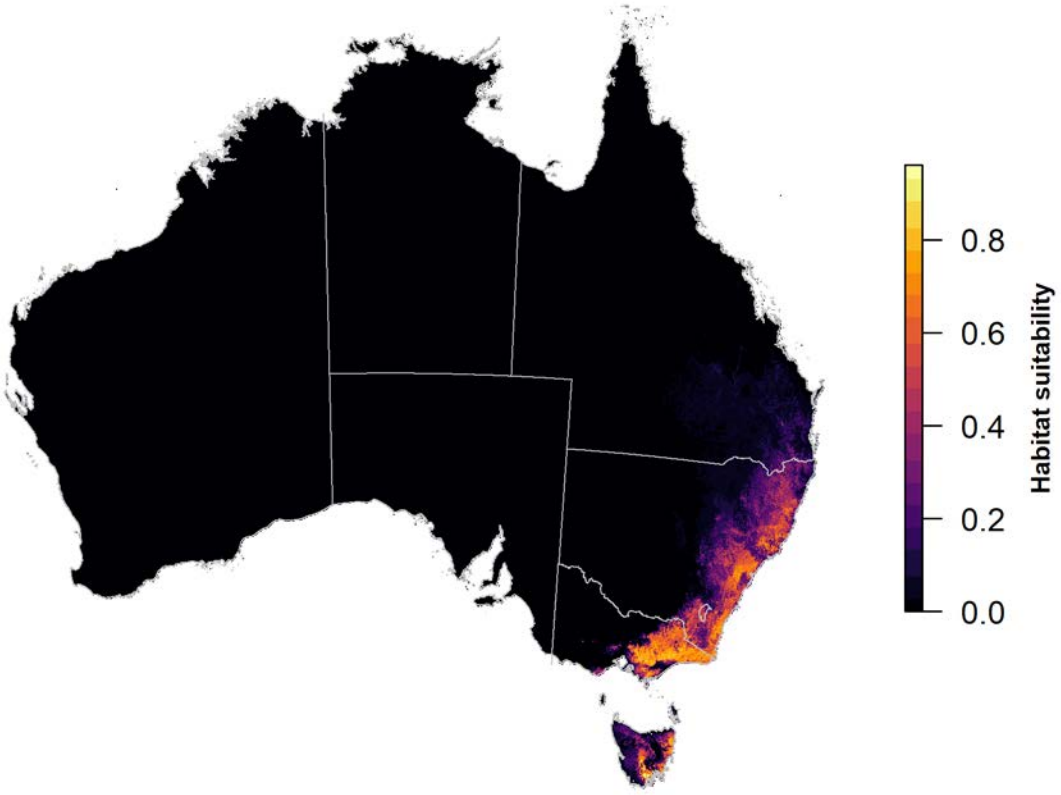
|---|
| Taxonomic group: Birds |
| Scientific name: *Menura novaehollandiae* |
| EPBC listed status: Not listed |
| State: ACT NSW QLD Vic |
| Description and habitat: Nests most likely to occur in rainforest or wet forest with deep litter and complex vegetation (Maisey et al. 2019). |
| Sampling methods: Point survey along transect |
| Timing of surveys: Shortly after dawn |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Maisey, A.C., et al. (2019) Habitat selection by the Superb Lyrebird (*Menura novaehollandiae*), an iconic ecosystem engineer in forests of south-eastern Australia. Austral Ecology 44, 503-513.<br>Nugent DT, Leonard SW, Clarke MF (2014) Interactions between the superb lyrebird (*Menura novaehollandiae*) and fire in south-eastern Australia. Wildlife Research 41: 203-211. |

*Detectability estimates are based on surveys in unburnt areas.



## Western Ground Parrot

| |
|---|
| Taxonomic group: Birds |
| Scientific name: *Pezoporus wallicus flaviventris* |
| EPBC listed status: Critically Endangered |
| State: WA |
| Description and habitat: Occurs in coastal heathland or sedgeland with very dense cover. Nests on the ground beneath low, dense vegetation. |
| Sampling method: Automated acoustic recordings, auditory surveys from fixed grids, transect point method |
| Timing of surveys: 60-90 min before-after sunrise-sunset |
| Single visit detection probability: Single visit detection probability for 30-min sound recordings for the mainland ground parrot estimated at 0.678 (95% CI 0.575 0.766) and 0.647 (0.404-0.832) for a 60 min observer visit (Bluff 2016). |
| Minimum survey effort: Federal guidelines recommend point surveys for 12 hours (4 days), broadcast surveys 6 hours over 3 days (Department of the Environment 2017). Given detectability reported by Bluff (2016), 30 min sound recordings repeated 3 times has 0.96 probability of detection. 60 min observer counts repeated 3 times has 0.95 detection probability. |
| References and further reading:<br>Bluff, L.A., (2016) Ground Parrots and fire in east Gippsland, Victoria: habitat occupancy modelling from automated sound recordings. Emu 116, 402-410.<br>The Australian Government's Department of Environment, Water., Heritage and Arts, (2017) Survey guidelines for Australia's threatened birds: guidelines for detecting birds listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Burbidge, A.H., Rolfe, J., McNee, S., Newbey, B., Williams, M., (2007) Monitoring population change in the cryptic and threatened Western Ground Parrot in relation to fire. Emu 107, 79-88. |

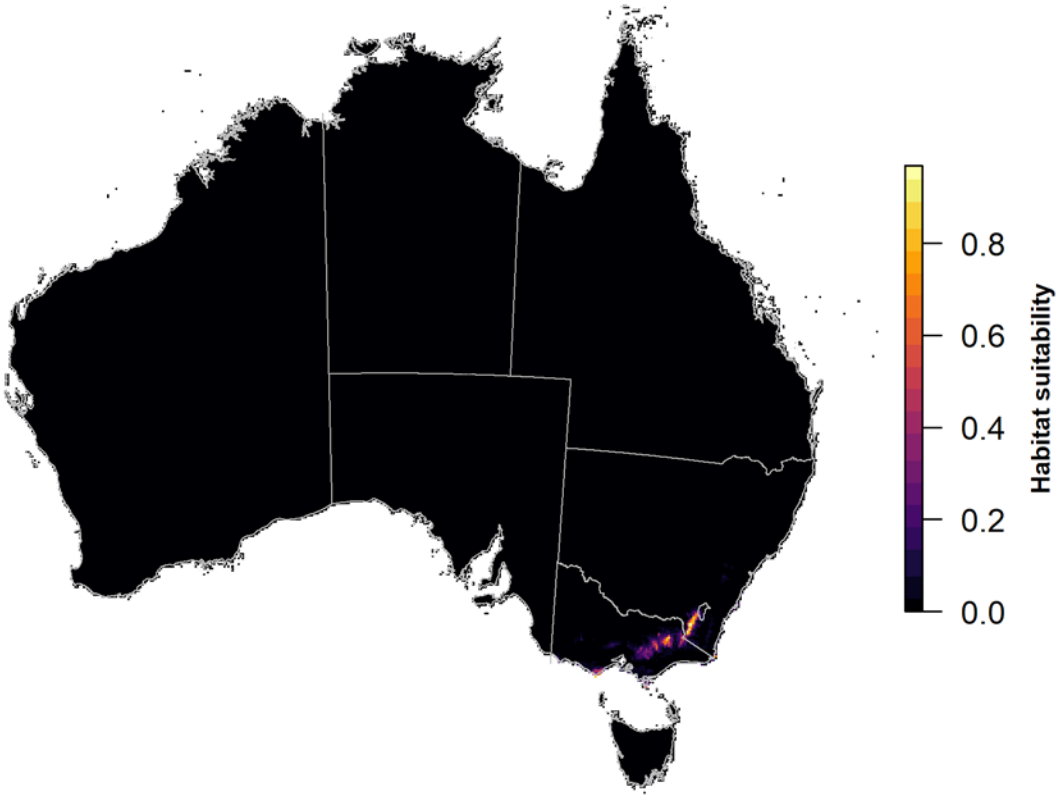
*Detectability estimates are based on surveys in unburnt areas.

**Mammals**

## Broad-toothed Rat (mainland), Tooarrana

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Mastacomys fuscus mordicus* |
| EPBC listed status: Vulnerable |
| State: ACT NSW Vic |
| Description and habitat: Sheltering nests are built in the understorey or under logs. |
| Sampling methods: Area search for scats, camera trapping |
| Timing of surveys: Year-round |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Milner et al. (2015) Distribution and habitat preference of the broad-toothed rat (*Mastacomys fuscus*) in the Australian Capital Territory, Australia. Australian Mammalogy 37, 125-131.<br><br>Cherubin R, Venn S, Driscoll D, Doherty T Ritchie E (2019) Feral horse impacts on threatened plants and animals in sub-alpine and montane environments in Victoria, Australia. Ecological Management And Restoration 20: 47-56.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br><br>Green K and Osborne WS (2003) The distribution and status of the Broad-toothed rat *Mastacomys fuscus* (Rodentia: Muridae) in New South Wales and the Australian Capital Territory. Australian Zoologist 32: 229-237. |

*Detectability estimates are based on surveys in unburnt areas.



## Brush-tailed Rock-wallaby

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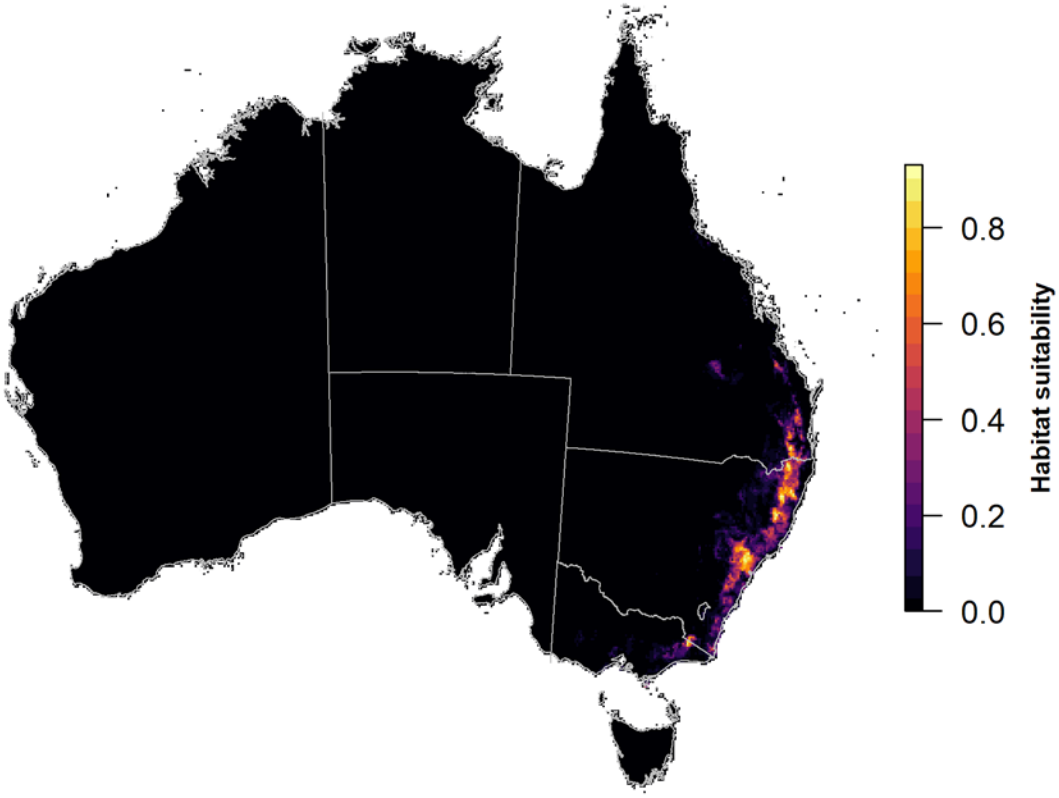
|---|
| Taxonomic group: Mammals |
| Scientific name: *Petrogale penicillata* |
| EPBC listed status: Vulnerable |
| State: NSW QLD Vic |
| Description and habitat: Prefers rocky habitats, including loose builder-piles, rocky outcrops, steep rocky slopes, cliffs and gorges. |
| Sampling methods: Camera trapping, cage trapping, scat search, area search |
| Timing of surveys: Year-round |
| Single visit detection probability: Probability of recording one individual at a colony with four cameras (with baited lure) ranged from 0.24-0.43 (Gowen and Vernes 2014). |
| Minimum survey effort: Assuming estimates reported by Gowen and Vernes (2014) are daily, four cameras deployed for 11 days gives a 0.95 probability of detection. |
| References and further reading:<br>Gowen C, Vernes K (2014) Population estimates of an endangered rock-wallaby (Petrogale penicillata) using time-lapse photography from camera traps. In: Fleming P, Meek P, Banks P, Claridge A, Sanderson J, Swann DS, Ballard G, Swann D (eds), 61-68. CSIRO Publishing, Collingwood.<br>Bluff LA, Clausen L, Hill A, Bramwell MD (2011) A decade of monitoring the remnant Victorian population of the brush-tailed rock-wallaby (Petrogale penicillata). *Australian Mammalogy* 33: 195. doi:10.1071/ZO05064.<br>Jarman PJ, Capararo SM (1997) Use of rock-wallaby faecal pellets for detecting and monitoring populations and examining habitat use. *Australian Mammalogy* 19: 257-264.<br>Telfer W, Griffiths A, Bowman D (2006) Scats can reveal the presence and habitat use of cryptic rock-dwelling macropods. *Australian Journal of Zoology* 54: 325–334. doi:10.1071/ZO05074. |

*Detectability estimates are based on surveys in unburnt areas.



## Golden-tipped Bat

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Phoniscus papuensis* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Roost mainly in rainforest gullies on small first- and second-order streams. May also roost in dense foliage or tree hollows. |
| Sampling method: Harp trapping, echolocation |
| Timing of surveys: Year-round |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Law et al. (1998) suggested two harp traps set for 5 nights required to have >90% detection probability. |
| References and further reading:<br>Law, B., Anderson, J., Chidel, M., (1998) A bat survey in State Forests on the south-west slopes region of New South Wales with suggestions of improvements for future surveys. Australian Zoologist 30, 467-479<br>Schulz M and Eyre TJ, (2000) Habitat selection by the rare golden-tipped bat *Kerivoula papuensis*. Australian Mammalogy 22: 23-33.<br>Law, B., Chidel, M, (2004) Roosting and foraging ecology of the golden-tipped bat (*Kerivoula papuensis*) on the south coast of New South Wales. Wildlife Research 31(1): 73-82 |

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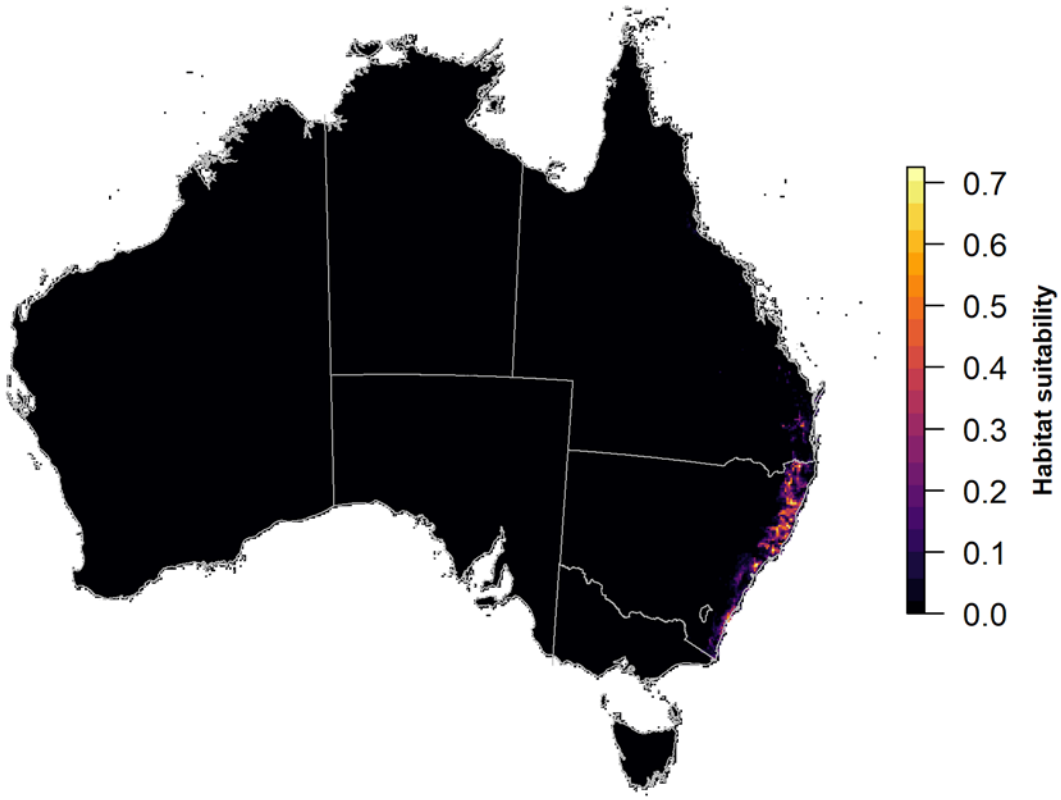

## Greater Glider

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|---|
| Taxonomic group: Mammals |
| Scientific name: *Petauroides volans* |
| EPBC listed status: Vulnerable |
| State: ACT NSW QLD Vic |
| Description and habitat: Highest abundance is typically in taller, montane, moist eucalypt forests, with relatively old trees and abundant hollows. |
| Sampling method: Spotlighting |
| Timing of surveys: Year-round |
| Single visit detection probability: Single visit detection probabilities over a 40 min / 2 ha area for Greater Glider ranged from 10 – 70% depending on the environmental conditions, particularly temperature and habitat quality. |
| Minimum survey effort: Under average environmental conditions five visits were needed to yield a detection probability of about 90% (Wintle et al. 2005). |
| References and further reading:<br>Wintle, B.A., Kavanagh, R.P., McCarthy, M.A., Burgman, M.A., (2005) Estimating and dealing with detectability in occupancy surveys for forest owls and arboreal marsupials. Journal of Wildlife Management 69, 905-917.<br>The State of Victoria Department of Sustainability and Environment Approved Survey Standards: Greater Glider *Petauroides Volans 2* May (2011) Version 1<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Lindenmayer, D.B., Cunningham, R.B., Donnelly, C.F., Incoll, R.D., Pope, M.L., Tribolet, C.R., Viggers, K.L., and Welsh, A.H. (2001) How effective is spotlighting for detecting the greater glider (Petauroides volans)? Wildlife Research 28: 105-109. |

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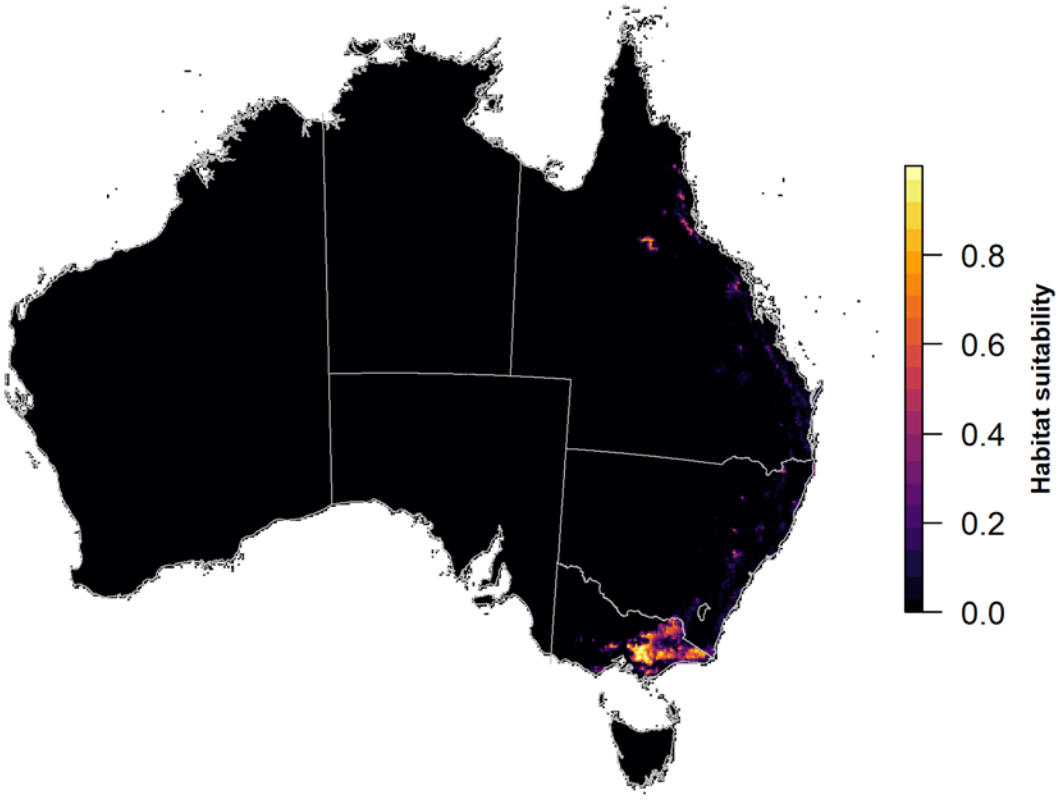

## Grey-headed Flying-fox

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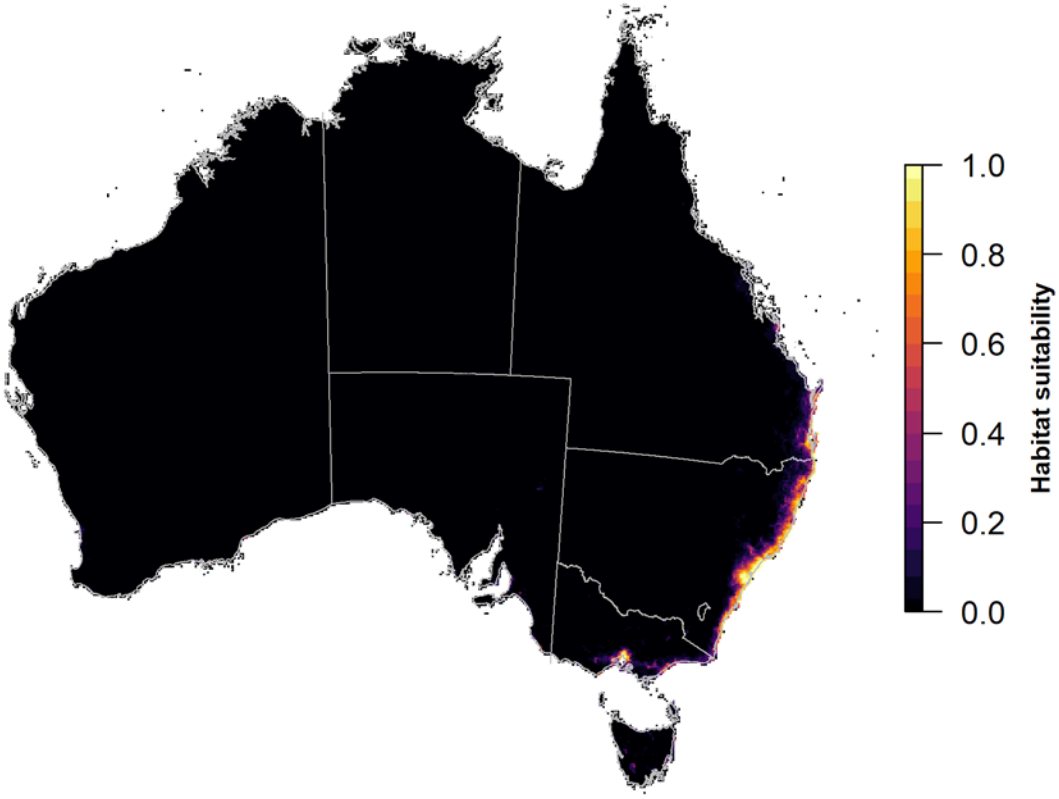
|---|
| Taxonomic group: Mammals |
| Scientific name: *Pteropus poliocephalus* |
| EPBC listed status: Vulnerable |
| State: ACT NSW QLD SA Vic |
| Description and habitat: Roost sites are typically near water, such as lakes, rivers or the coast. Roost vegetation includes rainforest patches, stands of Melaleuca, mangroves and riparian vegetation. |
| Sampling method: Ground counts of known roosting sites |
| Timing of surveys: Presence will be dependent on food resources. The time and location of flowering and fruiting of diet plants varies among seasons and years. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Office of Environment and Heritage (2018) suggests 6 hours (2 hours/day for 3 days). |
| References and further reading:<br>NSW Office of Environment and Heritage (2018) 'Species credit' threatened bats and their habitats: NSW survey guide for the Biodiversity Assessment Method<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts. (2010) Survey guidelines for Australia's threatened bats: guidelines for detecting bats listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Westcott DA, McKeown A, Murphy H, Fletcher CS (2011) A monitoring method for the grey-headed flying-fox, *Pteropus poliocephalus*. CSIRO |

*Detectability estimates are based on surveys in unburnt areas.



## Hastings River Mouse, Koontoo

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|---|
| Taxonomic group: Mammals |
| Scientific name: *Pseudomys oralis* |
| EPBC listed status: Endangered |
| State: NSW QLD |
| Description and habitat: Requires dense, low ground cover with a diverse mixture of ferns, grasses, sedges and herbs within close proximity to creeks and gullies. Rocky outcrops and fallen logs are important for shelter. |
| Sampling methods: Camera trapping, Elliott trapping |
| Timing of surveys: No estimates available |
| Single visit detection probability: Detection probability for 20 Elliot traps over one night estimated at 0.43 (Lawes 2016). |
| Minimum survey effort: Surveys should conform to the survey guidelines provided in the species' recovery plan (NSW DECC 2005). Detectability estimates reported by Lawes (2016) suggest six nights of camera trapping gives 0.95 detection probability. |
| References and further reading:<br>Law B, Brassil T, Gonsalves L, (2016) Recent decline of an endangered, endemic rodent: does exclusion of disturbance play a role for Hastings River mouse (*Pseudomys oralis*) Wildlife Research 43(6): 482-491<br>Meek P, Vernes K, (2015) Can camera trapping be used to accurately survey and monitor the Hastings River Mouse (*Pseudomys oralis*) Australian Mammalogy 38(1): 44-51<br>NSW DECC 2005. Recovery Plan for the Hastings River Mouse (*Pseudomys oralis*), Department of Environment and Climate Change (NSW) (now NSW Department of Environment, Climate Change and Water), Hurstville<br>Tweedie TD, York A, (1993) Survey guidelines for the Hastings River Mouse (*Pseudomys oralis*), Technical Paper No. 62, Research Division, Forestry Commission of New South Wales, Sydney |

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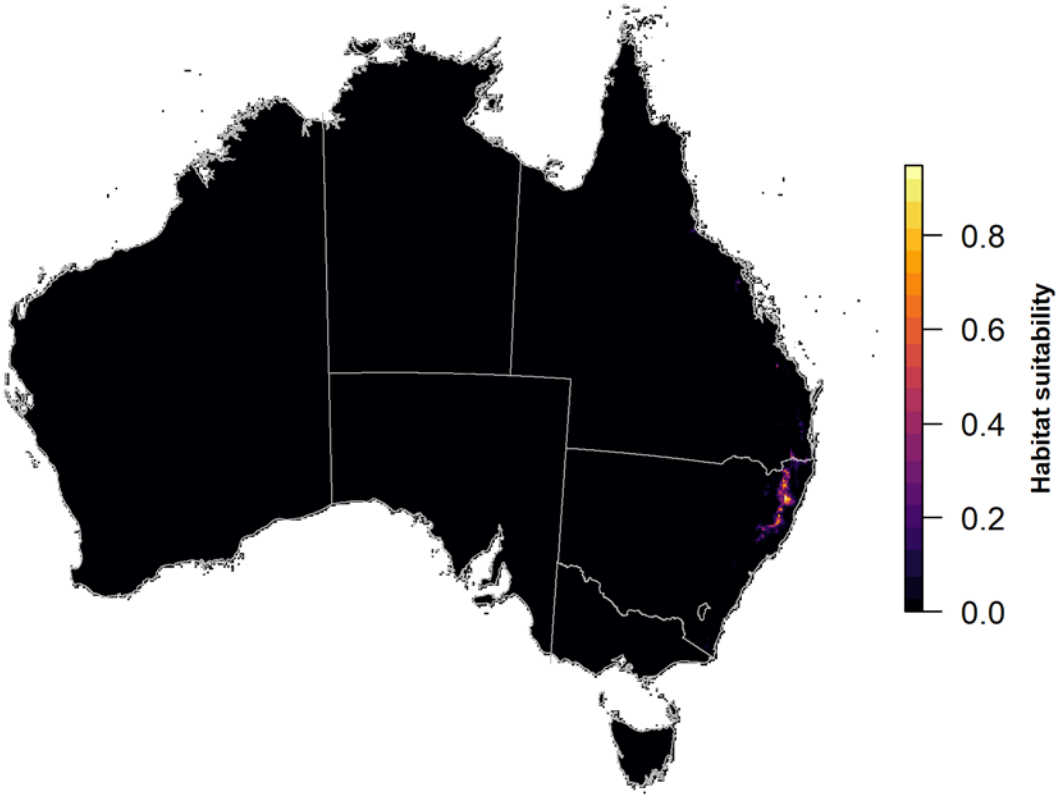

## Kangaroo Island Dunnart

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|---|
| Taxonomic group: Mammals |
| Scientific name: *Sminthopsis griseoventer aitkeni* |
| EPBC listed status: Endangered |
| State: SA |
| Description and habitat: Inhabits mallee heath and laterite soils. It is believed that there are fewer than 500 individuals prior to the fires. |
| Sampling method: Camera trapping on drift lines, Elliott traps, Pitfall Traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: |
| Minimum survey effort: To reach a cumulative nightly detection probability of 95%, a site should either be trapped for 51 nights; an array of 6 cameras on fence lines need 29 nights, or; 3 baited camera traps need 125 trap nights (Hohnen et al. 2018) |
| References and further reading:<br><br>Hohnen, R., Murphy, B., Gates, J., Legge, S., Dickman, C., Woinarski, J., (2018) Detecting and protecting the threatened Kangaroo Island dunnart. Conservation Science and Practice.<br><br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2004) Survey guidelines for Australia's threatened mammals: guidelines for detecting mammals listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999.<br><br>Gates, J.A. (2011) Recovery Plan for the Kangaroo Island Dunnart Sminthopsis aitkeni. Department of Environment and Natural Resources, South Australia |

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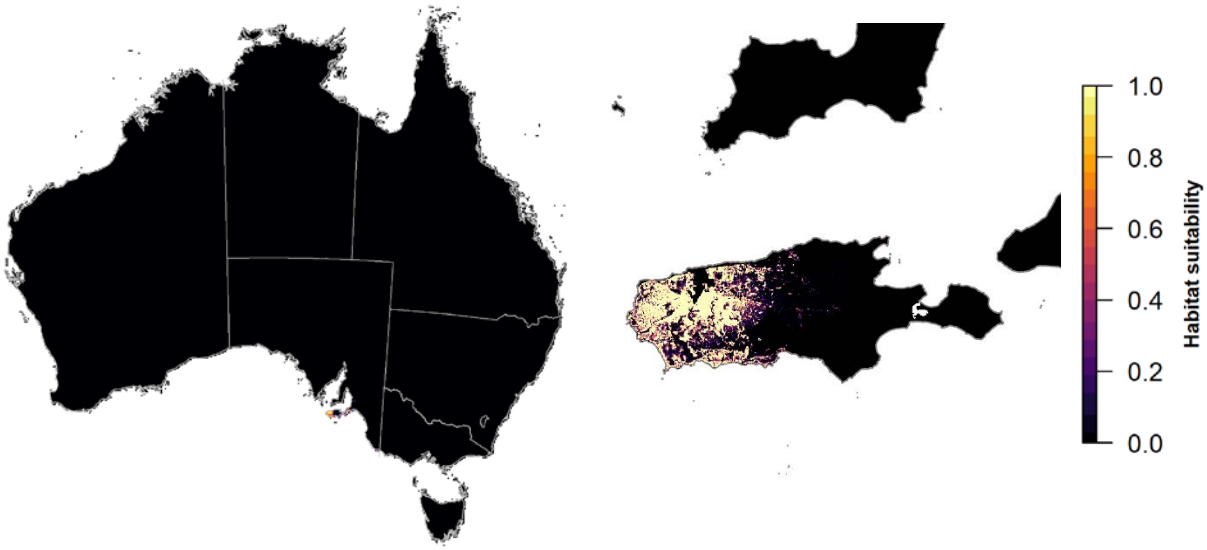
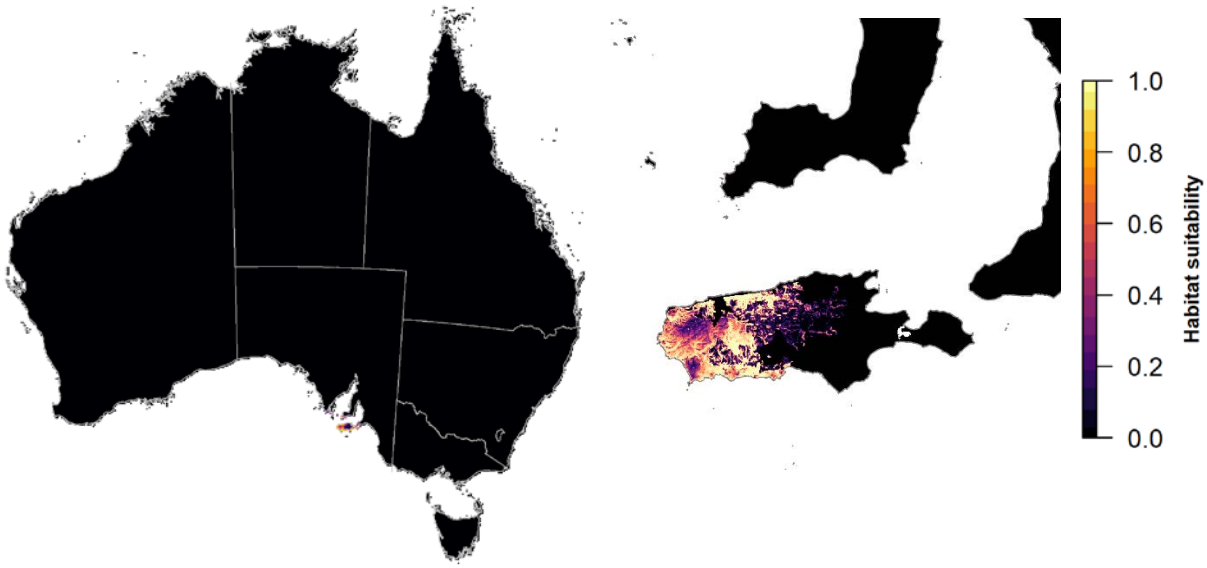


## Kangaroo Island Echidna

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Tachyglossus aculeatus multiaculeatus* |
| EPBC listed status: Endangered |
| State: SA |
| Description and habitat: Widely distributed through all types of habitats |
| Sampling methods: Camera trapping, area search |
| Timing of surveys: Year-round |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Rismiller, P. D. & McKelvey, M. W. (2000) Frequency of breeding and recruitment in the shortbeaked echidna, Tachyglossus aculeatus. Journal of Mammalogy 81, 1-17. |

*Detectability estimates are based on surveys in unburnt areas.



## Koala (combined populations of QLD, NSW, ACT)

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|---|
| Taxonomic group: Mammals |
| Scientific name: *Phascolarctos cinereus* (combined populations of QLD, NSW, ACT) |
| EPBC listed status: Vulnerable |
| State: ACT NSW QLD |
| Description and habitat: Lives in eucalypt woodlands and forest. |
| Sampling methods: Scat sampling, spotlighting, acoustic surveys, detection dogs |
| Timing of surveys: Year-round |
| Single visit detection probability: Acoustic recorders have 0.45 detection probability per night. Declined from 0.57 per night at 3C minimum to 0.32 at 23C (Law et al. 2018) |
| Minimum survey effort: Five nights of acoustic monitoring needed for 0.95 probability of detection |
| References and further reading:<br><br>Law, B.S., Brassil, T., Gonsalves, L., Roe, P., Truskinger, A., McConville, A., (2018) Passive acoustics and sound recognition provide new insights on status and resilience of an iconic endangered marsupial (koala *Phascolarctos cinereus*) to timber harvesting. Plos One 13.<br><br>Cristescu RH, Foley E, Markula A, Jackson G, Jones D, Frere C (2015) Accuracy and efficiency of detection dogs: a powerful new tool for koala conservation and management. Scientific Reports Vol. 5, Article No. 8349<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary<br><br>Department of Environment and Climate Change NSW (2008) Recovery plan for the Koala (*Phascolarctos cinereus*) |

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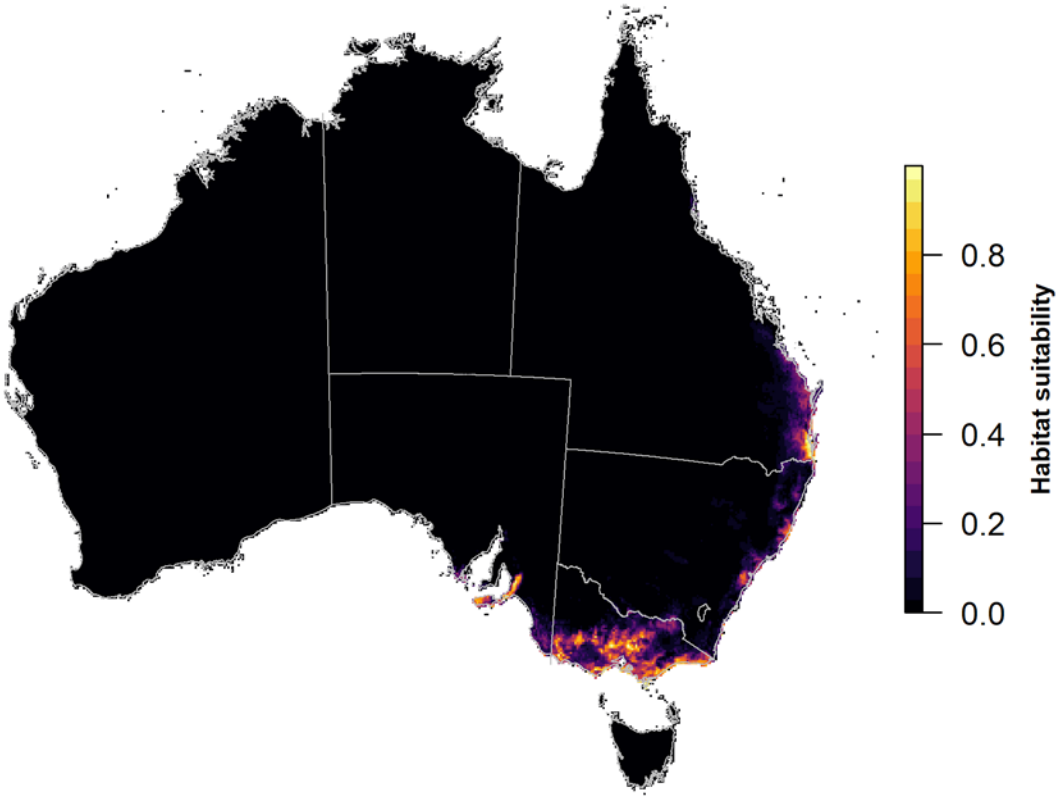

## Long-footed Potoroo

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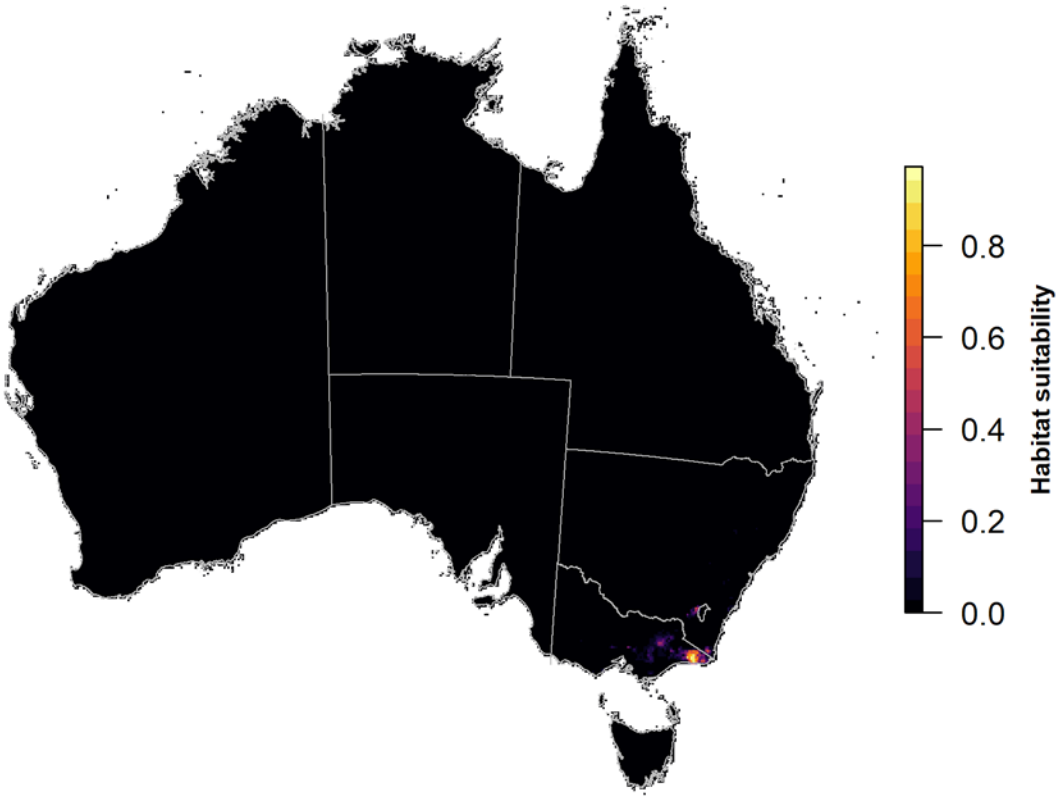
|---|
| Taxonomic group: Mammals |
| Scientific name: *Potorous longipes* |
| EPBC listed status: Endangered |
| State: NSW Vic |
| Description and habitat: Occurs in a range of forest types where there is dense understorey, a mixed-species overstorey and moist soils. |
| Sampling methods: Vertical cameras with lure, hair tubing, cage traps |
| Timing of surveys: Year-round |
| Single visit detection probability: Vertical camera placement influenced detection probability significantly. |
| Minimum survey effort: The Federal guidelines recommends an integrated approach that combines detection methods (Department of the Environment 2004). Smith and Coulson (2012) concluded that vertical camera trapping (with lure) is required for 17 days to reach 95% probability of detection; while horizontal cameras (with lure) require 97 days. Taylor et al. (2014) suggests horizontal camera should survey for 6 nights to achieve 95% detection probability. |
| References and further reading:<br>Smith, J.K., Coulson, G., (2012) A comparison of vertical and horizontal camera trap orientations for detection of potoroos and bandicoots. Australian Mammalogy 34, 196-201.<br>Taylor, B.D., Goldingay, R.L., Lindsay, J.M., (2014) Horizontal or vertical? Camera trap orientations and recording modes for detecting potoroos, bandicoots and pademelons. Australian Mammalogy 36, 60-66.<br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary |

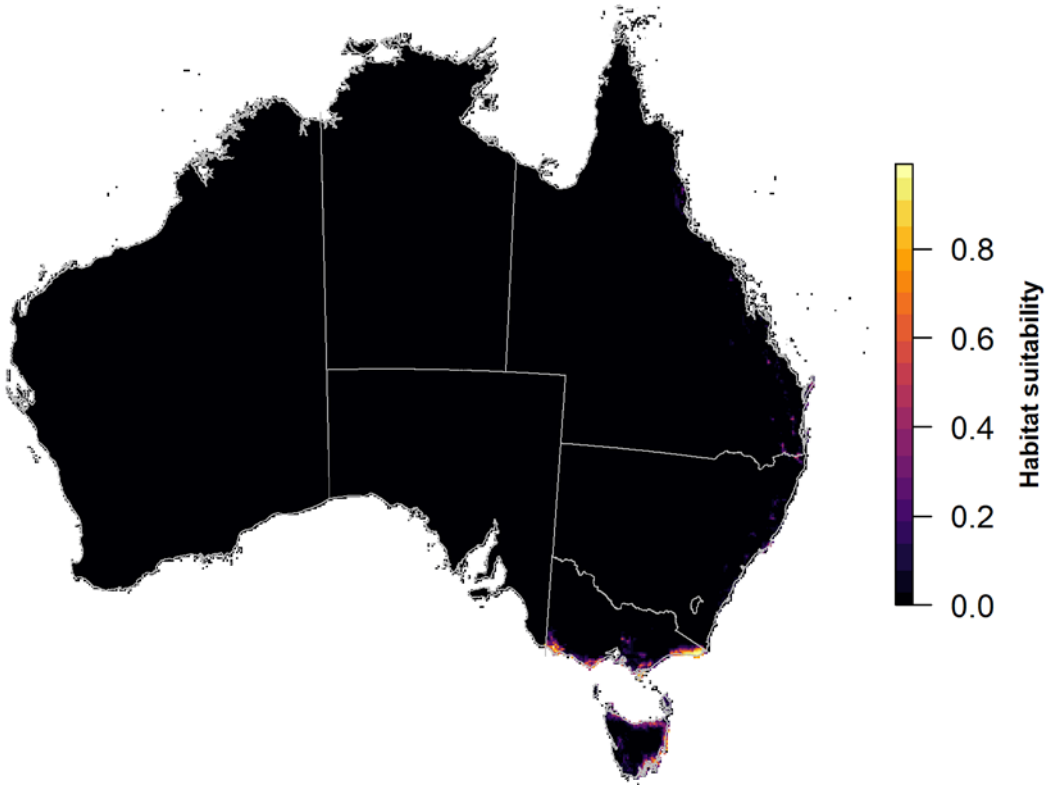
*Detectability estimates are based on surveys in unburnt areas.



## Long-nosed Potoroo (SE Mainland)

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Potorous tridactylus tridactylus* |
| EPBC listed status: Vulnerable |
| State: NSW QLD SA Vic |
| Description and habitat: Require dense understorey with occasional open areas in coastal heathland and dry and wet sclerophyll forests. |
| Sampling methods: Vertical cameras with lure, hair tunnels, cage traps |
| Timing of surveys: Year-round |
| Single visit detection probability: Vertical camera placement influenced detection probability significantly. |
| Minimum survey effort: The Federal guidelines recommends an integrated approach that combines detection methods (Department of the Environment 2004). Smith (2012) concluded that vertical camera trapping (with lure) is required for 17 days to reach 95% probability of detection; while horizontal cameras (with lure) require 97 days (Smith 2012). In contrast, Taylor (2014) suggests horizontal camera should survey for 6 nights to achieve 95% detection probability. |
| References and further reading:<br>Smith, J.K., Coulson, G., (2012) A comparison of vertical and horizontal camera trap orientations for detection of potoroos and bandicoots. Australian Mammalogy 34, 196-201.<br>Taylor, B.D., Goldingay, R.L., Lindsay, J.M., (2014) Horizontal or vertical? Camera trap orientations and recording modes for detecting potoroos, bandicoots and pademelons. Australian Mammalogy 36, 60-66.<br>The State of Victoria Department of Sustainability and Environment. Approved Survey Standards: Long-footed Potoroo *Potorous longipes*. 2 May 2011<br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary |

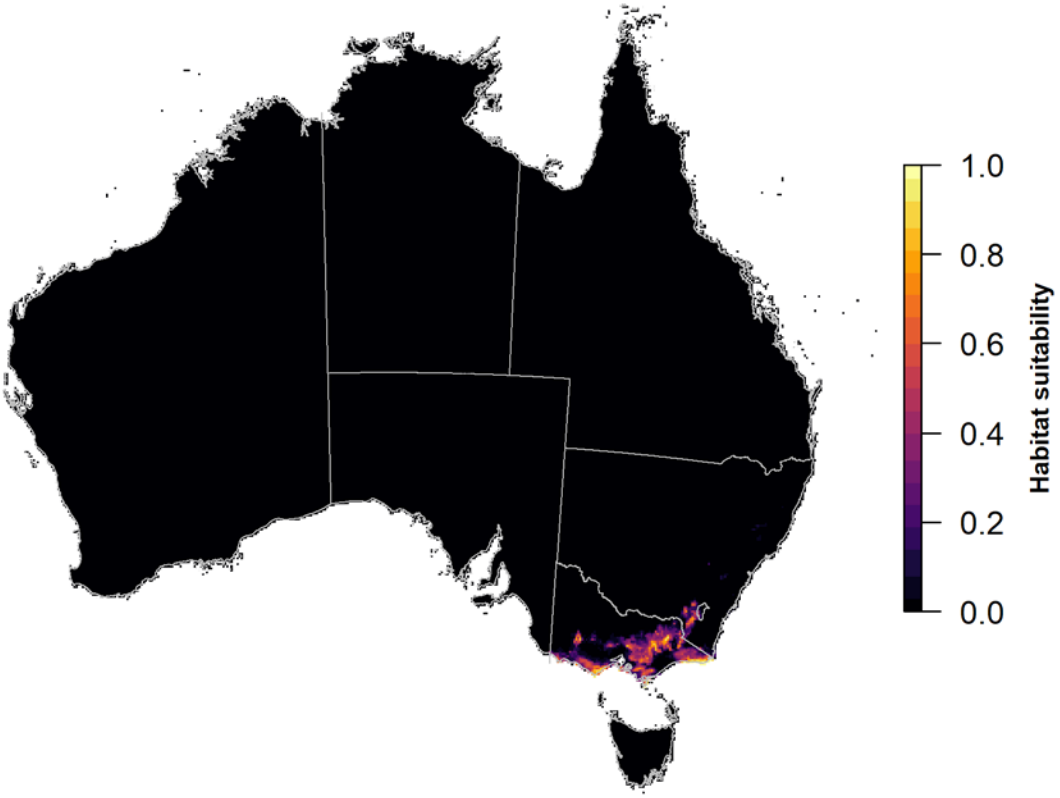
*Detectability estimates are based on surveys in unburnt areas.



## Mainland Dusky Antechinus

| |
|---|
| Taxonomic group: Mammals |
| Common name: |
| Scientific name: *Antechinus mimetes* |
| EPBC listed status: Not listed |
| State: Vic NSW ACT |
| Description and habitat: No data available |
| Sampling methods: Camera trapping, Elliott trapping |
| Timing of surveys: No estimates available |
| Single visit detection probability: No available estimates |
| Minimum survey effort: No available estimates |
| References and further reading:<br>Watchorn DJ, Ashman KR, Harley DKP (2019) Observations of arboreal behaviour in the mainland dusky antechinus (*Antechinus mimetes*) *Australian Mammalogy* 42(2) 226-229 |

*Detectability estimates are based on surveys in unburnt areas.



## Mountain Pygmy-possum

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Burramys parvus* |
| EPBC listed status: Endangered |
| State: NSW Vic |
| Description and habitat: Confined to builder fields in alpine environments |
| Sampling methods: Camera trapping, Elliott trapping, Hairtube |
| Timing of surveys: Nov - Dec |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Broome L, Ford F, Dawson M, Green K, Little D, McElhinney N (2013) Re-assessment of Mountain Pygmy-possum *Burramys parvus* population size and distribution of habitat in Kosciuszko National Park. Australian Zoologist 36(4): 381-403<br><br>Schultz M, Wilks G, Broome L (2012) An uncharacteristic new population of the Mountain Pygmy-possum *Burramys parvus* in New South Wales. Australian Zoologist 36(1): 22-28<br><br>The Australian Government's Department of Environment, Land, Water and Planning. 2016. National Recovery Plan for the Mountain Pygmy-possum *Burramys parvus*, Canberra.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary |

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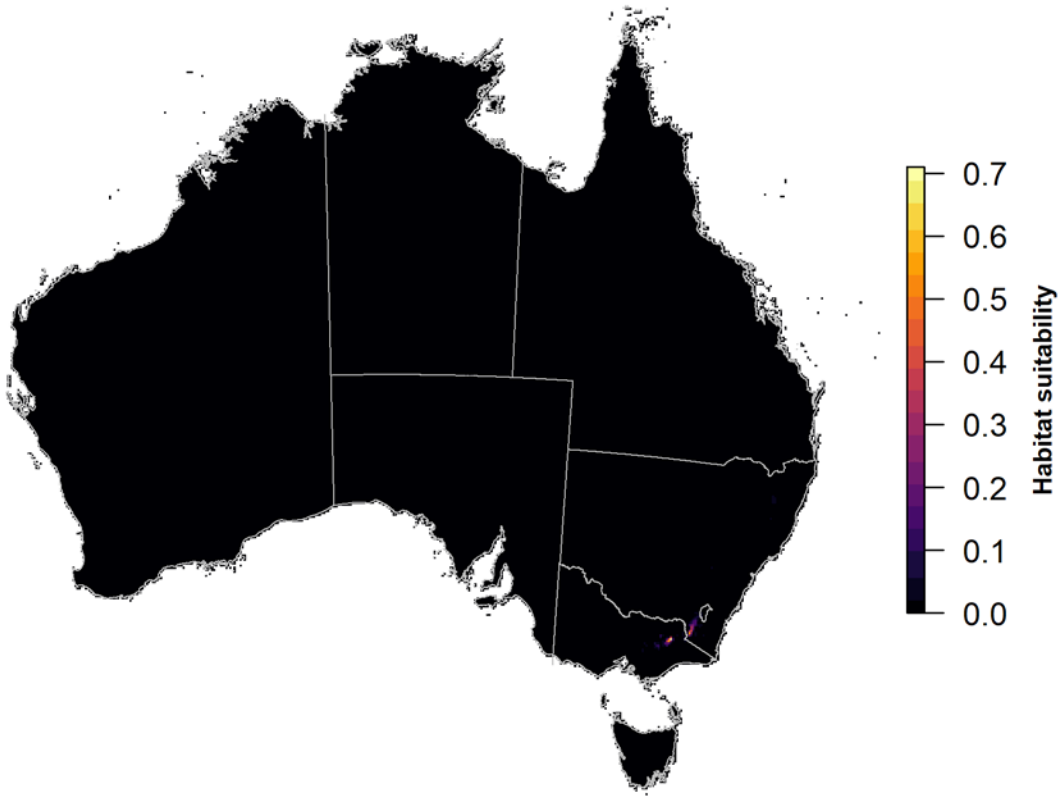

## New Holland Mouse, Pookila

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Pseudomys novaehollandiae* |
| EPBC listed status: Vulnerable |
| State: NSW QLD Tas Vic |
| Description and habitat: Consume seeds, stem and leaf tissues, roots, fungi, insects and other invertebrates. Mostly associated with early to mid-stages of vegetation succession following fire. |
| Sampling methods: Elliot traps, Camera trapping, Hairtubes |
| Timing of surveys: Burns et al. (2019) found detectability showed considerable variation within and across seasons, with notably lower detection probability in December-February. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Burns et al. (2019) reported that 1-2 nights of surveying in April or October would have 95% confidence of detection with 30 Elliot traps, no rainfall, and 3.5 individuals at a site. At 1 individual per site, the number of nights increases to 5. Surveys in Dec-Feb with full moons required impractically high numbers of consecutive nights. |
| References and further reading:<br><br>Burns, P.A., McCall, C., Rowe, K.C., Parrott, M.L., Phillips, B.L., (2019) Accounting for detectability and abundance in survey design for a declining species. Diversity and Distributions 25, 1655-1665.<br><br>Wilson BA, Lock M, Garkaklis MJ (2018) Long term fluctuations in distribution and populations of a threatened rodent (*Pseudomys novaehollandiae*) in coastal woodlands of the Otway Ranges, Victoria: a regional decline or extinction? Australian Mammalogy 40: 281-293 |

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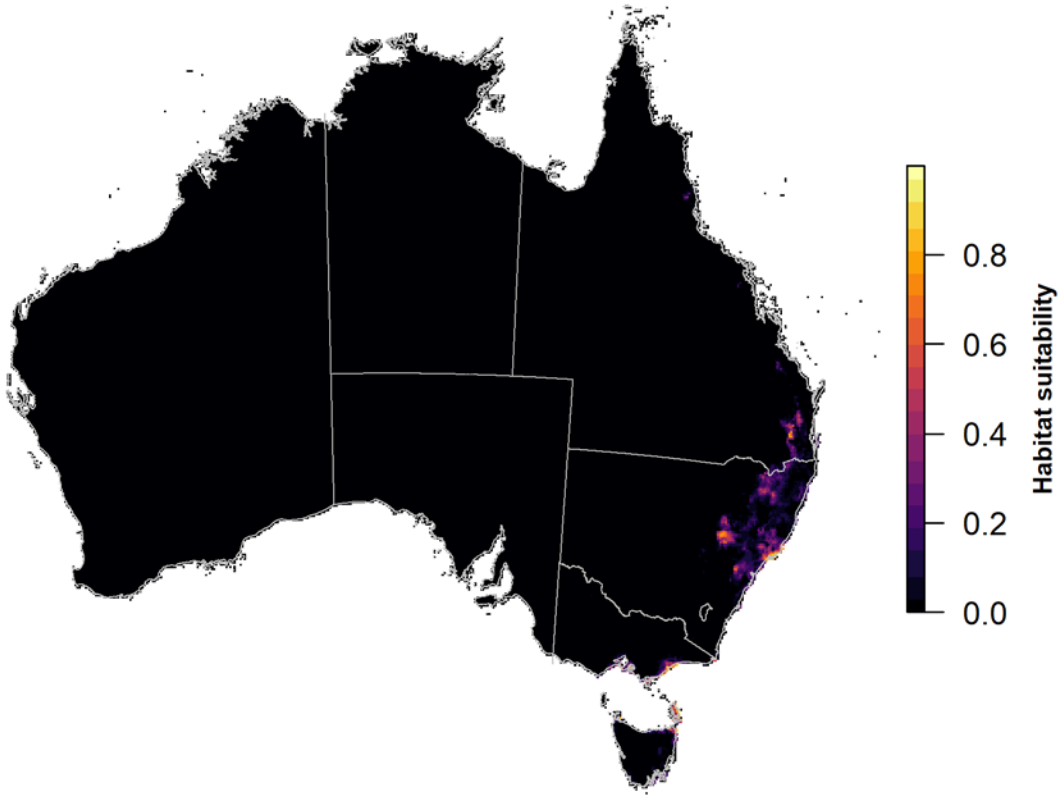

## Parma Wallaby

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Notomacropus parma* |
| EPBC listed status: Not listed |
| State: NSW QLD |
| Description and habitat: Found in wet sclerophyll forest with a dense understorey. |
| Sampling methods: Camera trapping, Cage trapping |
| Timing of surveys: Year-round |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Maynes GM (1977) Distribution and aspects of the biology of the parma wallaby, *Macropus parma*, in New South Wales. Wildlife Research 4(2): 109-125<br>Read DG, Fox BJ (1991) Assessing the habitat of the parma wallaby *Macropus parma* (Marsupialia: Macropodidae). Wildlife Research 18(4): 469-477 |

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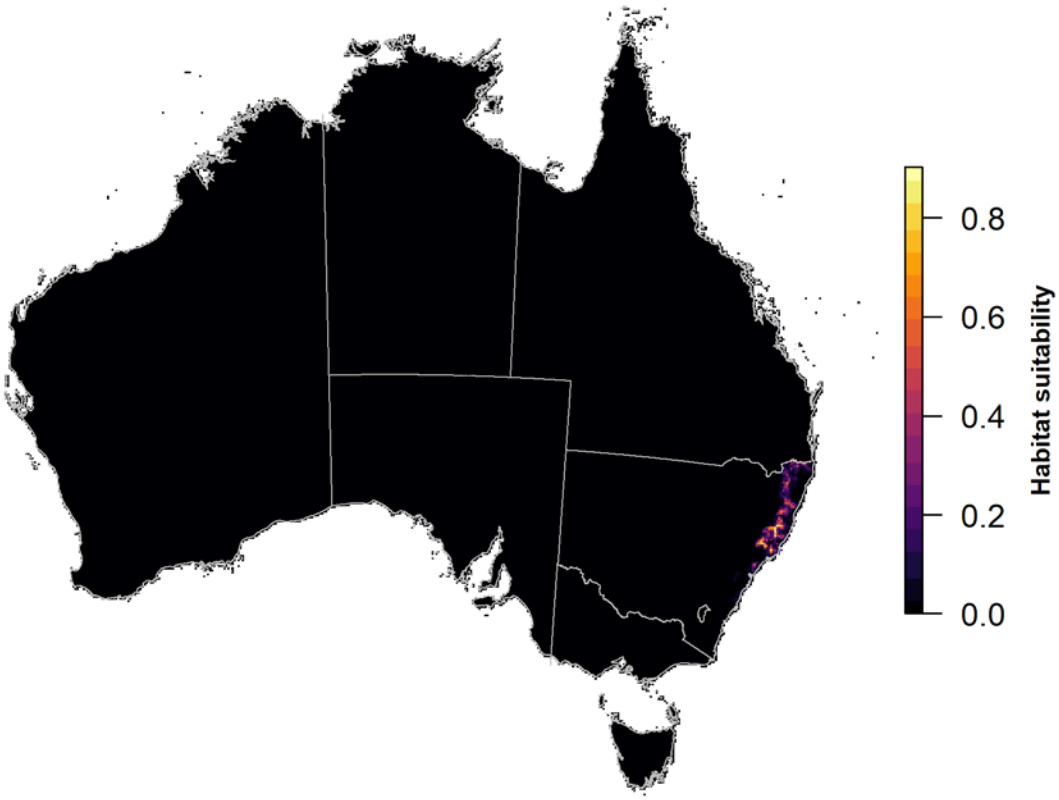

## Platypus

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Ornithorhynchus anatinus* |
| EPBC listed status: Not listed |
| State: ACT NSW QLD SA Tas Vic |
| Description and habitat: Found in permanent freshwater streams and shallow lakes. |
| Sampling methods: Live trapping, underway infrared cameras, eDNA, burrow counts |
| Timing of surveys: Year-round |
| Single visit detection probability: Conditional probabilities of platypus eDNA being captured in a single water sample (paired dataset: 0.838, unpaired: 0.879), and detected in a single water sample by qPCR (paired: 0.892, unpaired: 0.858), were higher than the conditional probability of detecting a platypus with a single trapping visit (paired: 0.470, unpaired: 0.219) (Lugg et al. 2018). |
| Minimum survey effort: Achieving a cumulative detection probability >0.95 would require two water samples, each with two qPCR replicates. For trapping, sites need to be surveyed on 13 (unpaired) or 5 (paired) occasions (Lugg et al. 2018). |
| References and further reading:<br><br>Lugg, W.H., Griffiths, J., van Rooyen, A.R., Weeks, A.R., Tingley, R., (2018) Optimal survey designs for environmental DNA sampling. Methods in Ecology and Evolution 9, 1049-1059.<br><br>Chidami, S., Guenard, G., and Amyot, M. (2007) Underwater infrared video system for behavioural studies in lakes. *Limnology and Oceanography: Methods* 5, 371-378.<br><br>Serena, M., and Williams, G. A. (2012). Effect of sex and age on temporal variation in the frequency and direction of platypus (*Ornithorhynchus anatinus*) captures in fyke nets. *Australian Mammalogy* 34, 75-82. |

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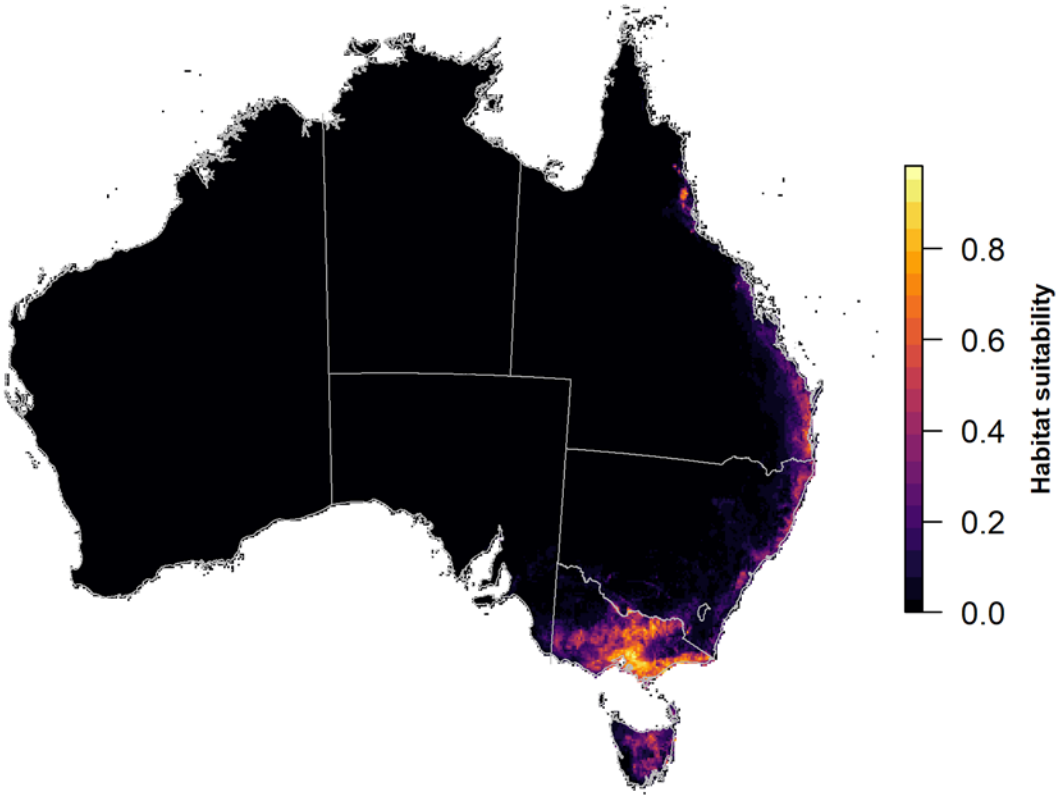

## Silver-headed Antechinus

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Antechinus argentus* |
| EPBC listed status: Endangered |
| State: QLD |
| Description and habitat: The silver-headed antechinus was only described in 2013 and is known only from Kroombit Tops National Park in Southeastern Queensland. |
| Sampling methods: Elliott trapping, camera trapping |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Mason ED, Burwell CJ & Baker AM (2015) Prey of the silver-headed antechinus (Antechinus argentus), a new species of Australian dasyurid marsupial. Australian Mammology 37, 164- 169<br>Baker A, Mutton T, Hines H (2013) A new dasyurid marsupial from Kroombit Tops, south-east Queensland, Australia: the Silver-headed Antechinus, Antechinus argentus sp. nov. (Marsupialia: Dasyuridae). *Zootaxa*, *3746*(2): 201-239.<br>Mason ED, Firn J, Hines H, Baker A (2016) Breeding biology and growth in a new, threatened carnivorous marsupial. Mammal Research 62: 179-187. |

*Detectability estimates are based on surveys in unburnt areas.

## Smoky Mouse, Konoom

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Pseudomys fumeus* |
| EPBC listed status: Endangered |
| State: ACT NSW Vic |
| Description and habitat: Occurs in a range of habitats including heathy woodlands, coastal heathlands, subalpine heathlands, subalpine woodlands, dry Eucalypt forests. |
| Sampling methods: Camera trapping, Elliot trapping, cage trapping |
| Timing of surveys: Year-round |
| Single visit detection probability: Nightly detection probability equal to 0.717 - 0.753 with 20-200 traps per night (Burns et al. 2015). |
| Minimum survey effort: Three nights of camera trapping achieves 0.97 detection probability. |
| References and further reading:<br>Burns, P.A., Rowe, K.M.C., Holmes, B.P., Rowe, K.C., (2015) Historical resurveys reveal persistence of smoky mouse (*Pseudomys fumeus*) populations over the long-term and through the short-term impacts of fire. Wildlife Research 42, 668-677.<br>Burns P, Parrott ML, Rowe KC, Phillips BL (2018) Identification of threatened rodent species using infrared and white-flash camera traps. Australian Mammalogy 40: 188-197<br>Menkhorst, P. and Broome, L. (2006) National Recovery Plan for the Smoky Mouse *Pseudomys fumeus*. Department of Sustainability and Environment, Melbourne.<br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary |

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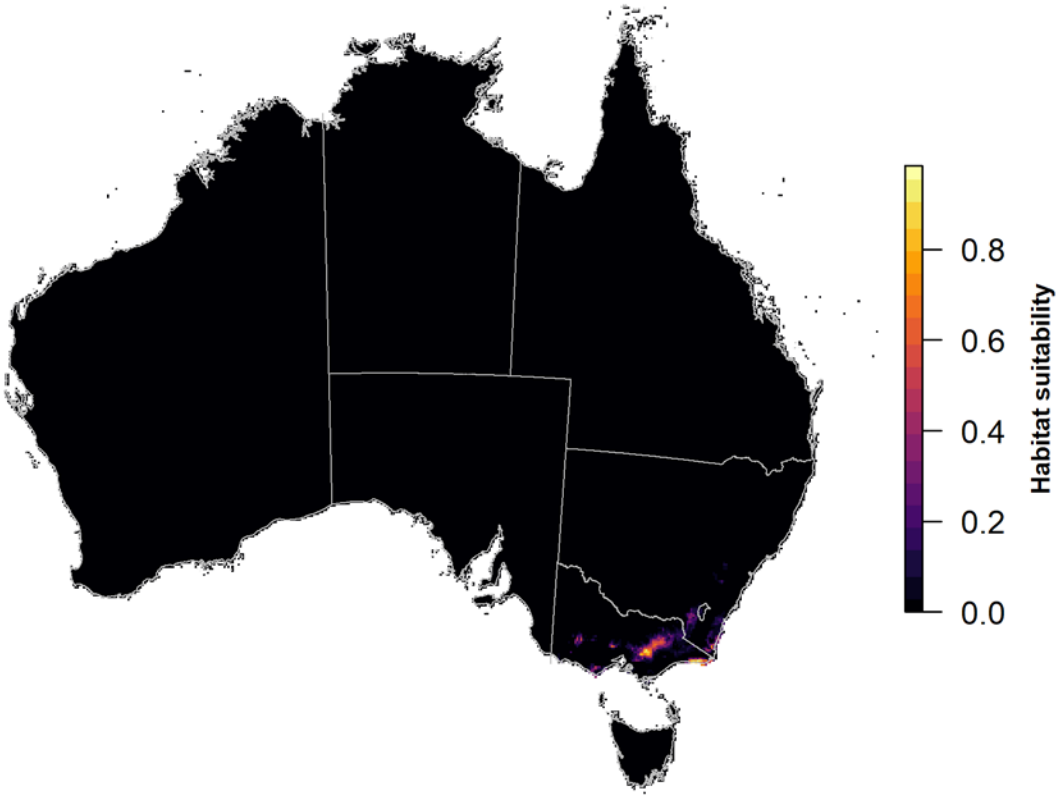

## Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Dasyurus maculatus maculatus* (South-east mainland population) |
| EPBC listed status: Endangered |
| State: ACT NSW QLD Vic |
| Description and habitat: Found in a range of forest types but hollow logs, tree hollows or rocky crevices to den. |
| Sampling methods: Camera trapping, cage, hairtubing |
| Timing of surveys: May - Aug |
| Single visit detection probability: Daily detection probability using 1-4 cameras per 1 $km^2$ was 0.1 (0.06 - 0.170) (Nelson 2014). |
| Minimum survey effort: Deployment for 3 weeks resulted in a cumulative probability of detect >0.8 with 1-4 cameras per $km^2$ (Nelson et al. 2014). 12.6 camera nights to achieve a 95% probability of detecting northern quolls using 5 downward facing baited cameras (WA DBCA 2017). |
| References and further reading:<br>Nelson, J.L., Scroggie, M.P., Belcher, C.A., (2014) Developing a camera trap survey protocol to detect a rare marsupial carnivore, the spotted-tailed quoll (*Dasyurus maculatus*)<br>The State of Victoria Department of Environment, Land, Water and Planning. (2016) National Recovery Plan for the Spotted-tailed Quoll *Dasyurus maculatus*. Australian Government, Canberra<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

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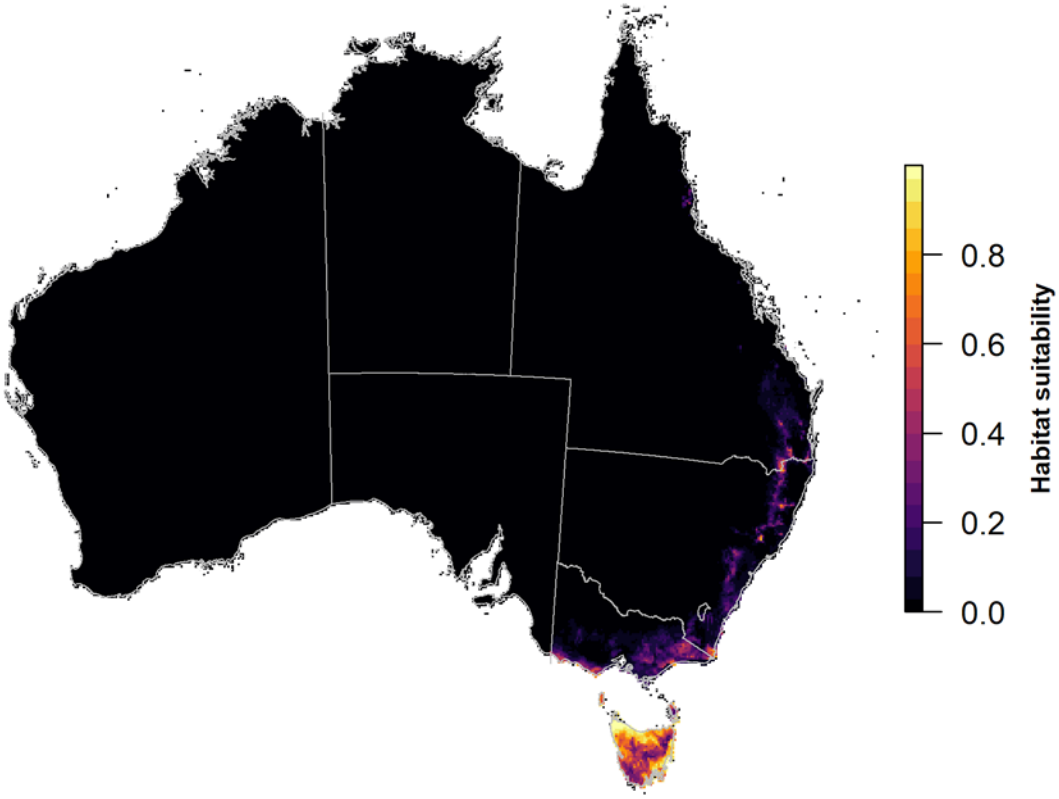

## Yellow-bellied Glider

| |
|---|
| Taxonomic group: Mammals |
| Scientific name: *Petaurus australis* |
| EPBC listed status: Not listed |
| State: NSW QLD SA Vic |
| Description and habitat: Occurs in tall mature eucalypt forest. Require tree hollows in large trees for dens. |
| Sampling methods: Point count for 10 min (with playback for 15 min), then 40 min area spotlighting. |
| Timing of surveys: Year-round |
| Single visit detection probability: Detection probability per night estimated at 0.41 (0.34 - 0.49) (Wintle et al. 2005). Detection per night of spotlighting varied from 0.71 - 0.28 depending on the season (Goldingay 2018). |
| Minimum survey effort: Six nights of spotlighting needed for 0.95 probability of detection. |
| References and further reading:<br><br>Wintle, B.A., Kavanagh, R.P., McCarthy, M.A., Burgman, M.A., (2005) Estimating and dealing with detectability in occupancy surveys for forest owls and arboreal marsupials. Journal of Wildlife Management 69, 905-917.<br><br>Goldingay, R.L., McHugh D, Parkyn JL (2018) Population monitoring of threatened gliding mammal in subtropical Australia. Australian Journal of Zoology 64, 413-420.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

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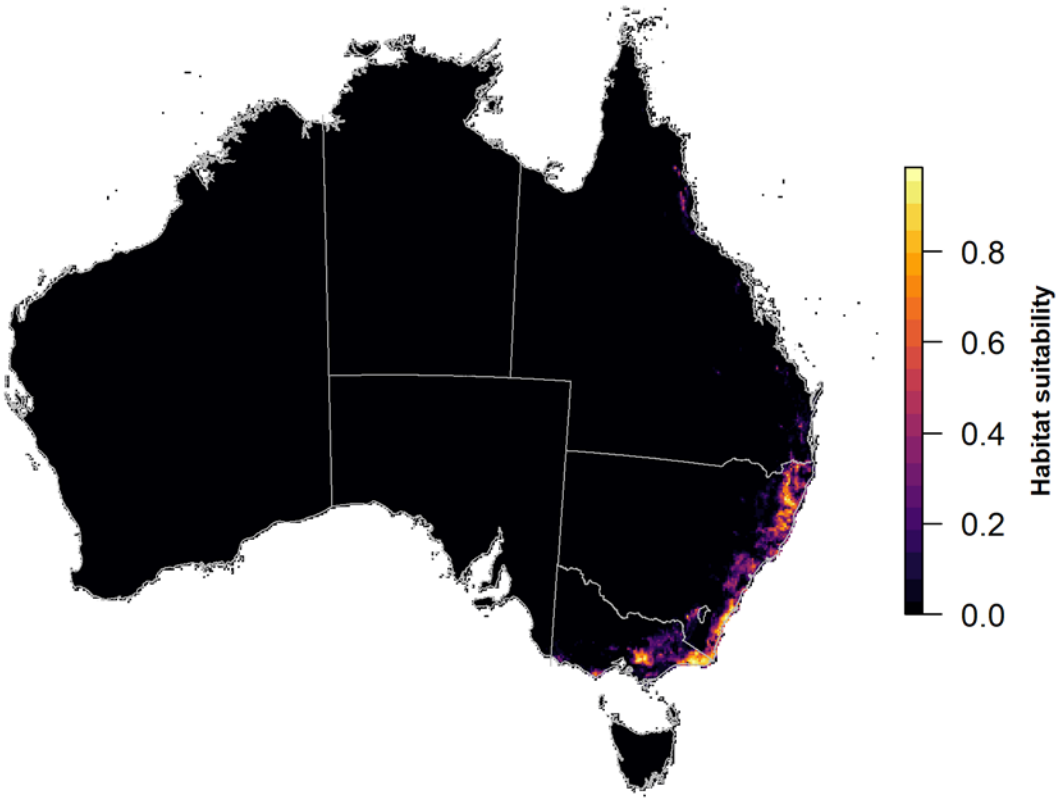

**Frogs**

## Davies' Tree Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Litoria daviesae* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Found in upland streams in heathland or dry open forest on the tablelands or wet sclerophyll and rainforest vegetation on the edge of the escarpment. |
| Sampling methods: Spotlighting with call playback while walking transect along stream or creek, tadpole surveys. |
| Timing of surveys: Sept - March |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Cutajar TP, Rowley JL (2020) Surveying frogs from the bellies of their parasites: invertebrate derived DNA as a novel survey method for frogs. Global Ecology and Conservation 22, e00978<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

*Detectability estimates are based on surveys in unburnt areas.

## Fleay's Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Mixophyes fleayi* |
| EPBC listed status: Endangered |
| State: NSW QLD |
| Description and habitat: Occurs along stream habitats but is not found in ponds or ephemeral pools. |
| Sampling methods: Spotlighting while walking transect along stream or creek. May respond to call playback. |
| Timing of surveys: Oct - May |
| Single visit detection probability: Newell et al. (2013) found detection probability along a 100m transect was highly variable, ranging from 0.08 - 1.00 at Tuntable Falls and 0.38 - 1.00 at Brindle Creek. |
| Minimum survey effort: National guidelines suggest a minimum of two nights under ideal conditions (one week after rainfall). Should be repeated on at least four separate occasions (Department of Environment 2010). |
| References and further reading:<br>Newell, D.A., Goldingay, R.L., Brooks, L.O., (2013) Population Recovery following Decline in an Endangered Stream-Breeding Frog (*Mixophyes fleayi*) from Subtropical Australia. Plos One 8.<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna<br>Knowles R, Thumm K, Mahony M, Hines H, Newell D, Cunningham (2015) Oviposition and egg mass morphology in barred frogs (Anura: Myobatrachidae: Mixophyes Günther, 1864), its phylogenetic significance and implications for conservation management. Australian Zoologist 37(3): 381-402 |

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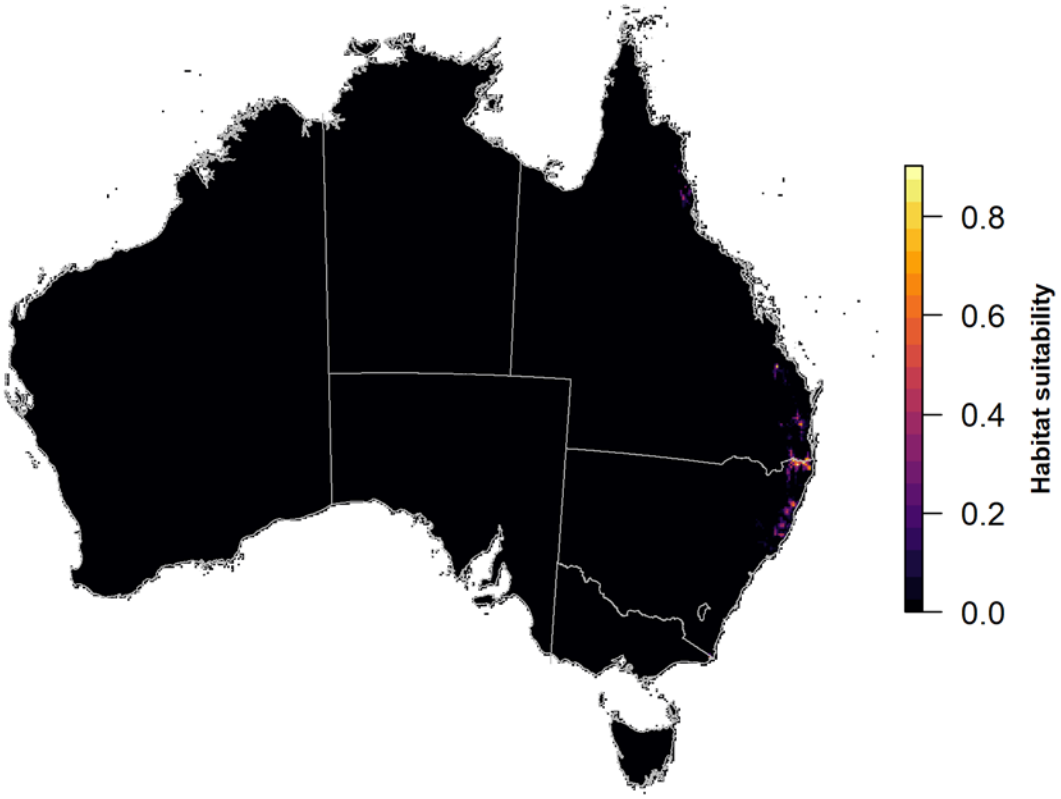

## Giant Barred Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Mixophyes iteratus* |
| EPBC listed status: Endangered |
| State: NSW QLD |
| Description and habitat: Occurs in upland and lowland rainforest and wet sclerophyll forest along streams. |
| Sampling methods: Spotlighting while walking transect along stream or creek, tadpole surveys. May respond to call playback. |
| Timing of surveys: Sept - March |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest a minimum of two nights under ideal conditions (one week after heavy rainfall). Should be repeated on at least four separate occasions (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Mahony M, (1993) The status of frogs in the Watagan Mountains area, the Central Coast of New South Wales. Herpetology in Australia (Eds Lunney and D Ayers) pp. 257-264. Surrey Beatty and Sons, Sydney<br>Lemckert F, Brassil T (2000) Movements and habitat use of the endangered giant barred river frog (*Mixophyes iteratus*) and the implications for its conservation in timber production forests. Biological Conservation 96, 177–184 |

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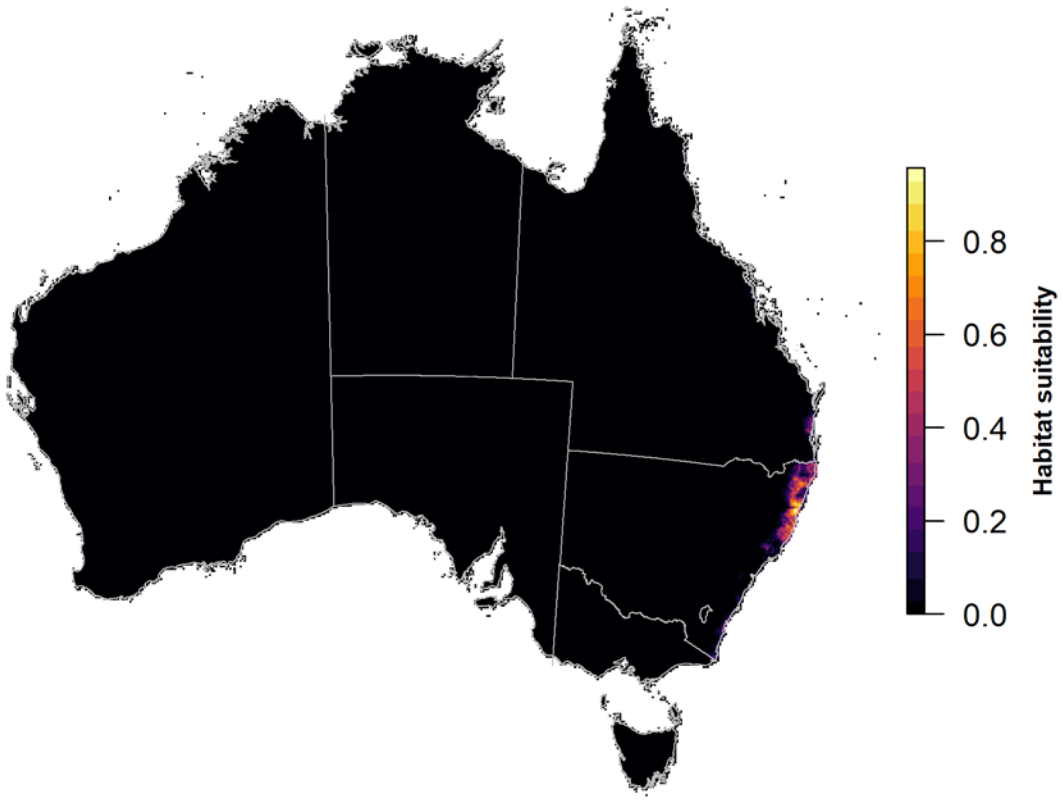

## Giant Burrowing Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Heleioporus australiacus* |
| EPBC listed status: Vulnerable |
| State: NSW Vic |
| Description and habitat: In NSW, it is associated with sandy soils that support heath vegetation. Breeds is small soaks formed in eroded sandstone drainage lines. |
| Sampling methods: Spotlighting, tadpole visual or dip netting. Call surveys generally not effective. |
| Timing of surveys: Sept – May (after heavy rain) |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest a minimum of 4 consecutive nights under ideal conditions (during rainfall) (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

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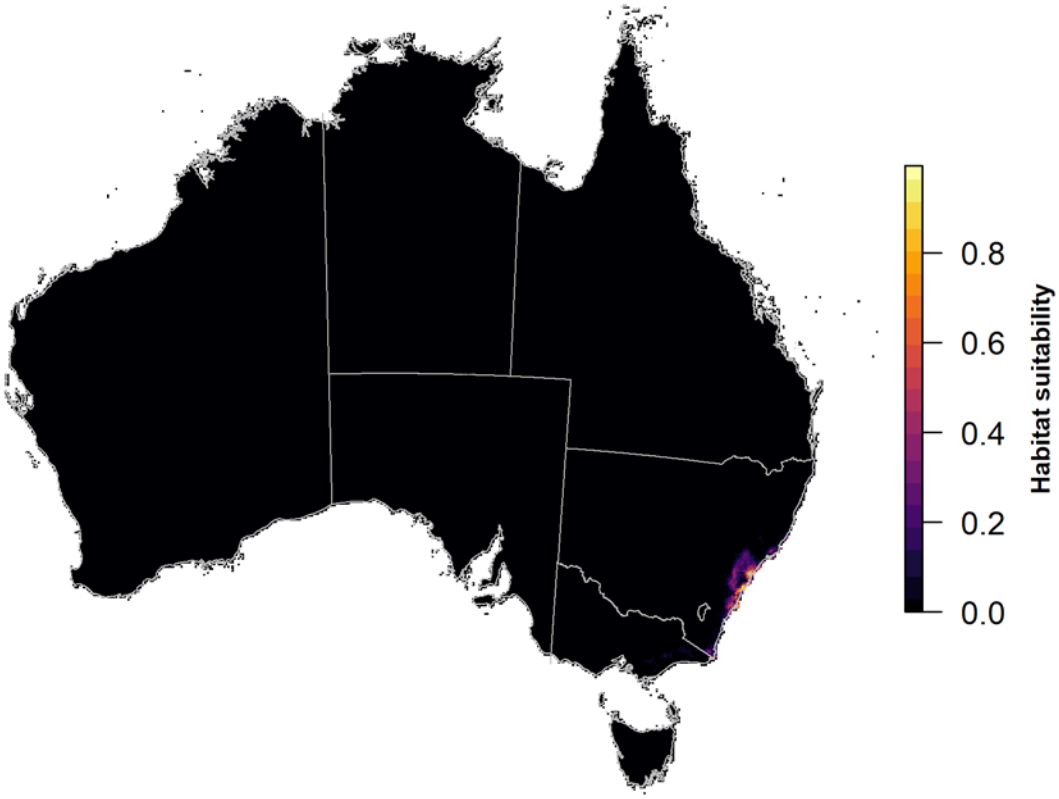

## Kroombit Tinker Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Taudactylus pleione* |
| EPBC listed status: Critically Endangered |
| State: QLD |
| Description and habitat: Associated with Piccabeen Palm rainforest and boulder scree gullies. Found around rocky shelves and boulders, under rocks near seepage zones. |
| Sampling method: Call detection |
| Timing of surveys: Calling period (Sept-Mar), Larval period (unknown). Day and night surveys. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest a minimum of four nights under ideal survey conditions (one week after rainfall), focusing on rocky banks along rocky scree banks in riparian zone along first order streams in subtropical rainforest and wet sclerophyll forest (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Hines H (2014) Kroombit Tops: Endemism and outliers. Queensland Naturalist 52: 1-3 |

*Detectability estimates are based on surveys in unburnt areas.

## Littlejohn's Tree Frog, Heath Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Litoria littlejohni* |
| EPBC listed status: Vulnerable |
| State: NSW Vic |
| Description and habitat: Known to breed in a variety of forest waterbodies, including dams, slow-moving streams and ponds. |
| Sampling methods: Nocturnal call surveys, spotlighting, tadpole visual or netting surveys, call playback. |
| Timing of surveys: June – Aug for call surveys |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Sustainability and Environment. Approved Survey Standards: Large Brown Tree Frog *Litoria littlejohni*. 2 May 2011<br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary<br>Gillespie, G.R. (2010) Survey methods for the Large Brown Tree Frog *Litoria littlejohni* and Giant Burrowing Frog *Heleioporus australiacus*. Unpublished report commissioned by Biosis Research<br>Lemckert, F. & Mahony, M. (2008) Core calling periods of the frogs of temperature New South Wales, Australia. Herpetological Conservation and Biology 3: 71-76. |

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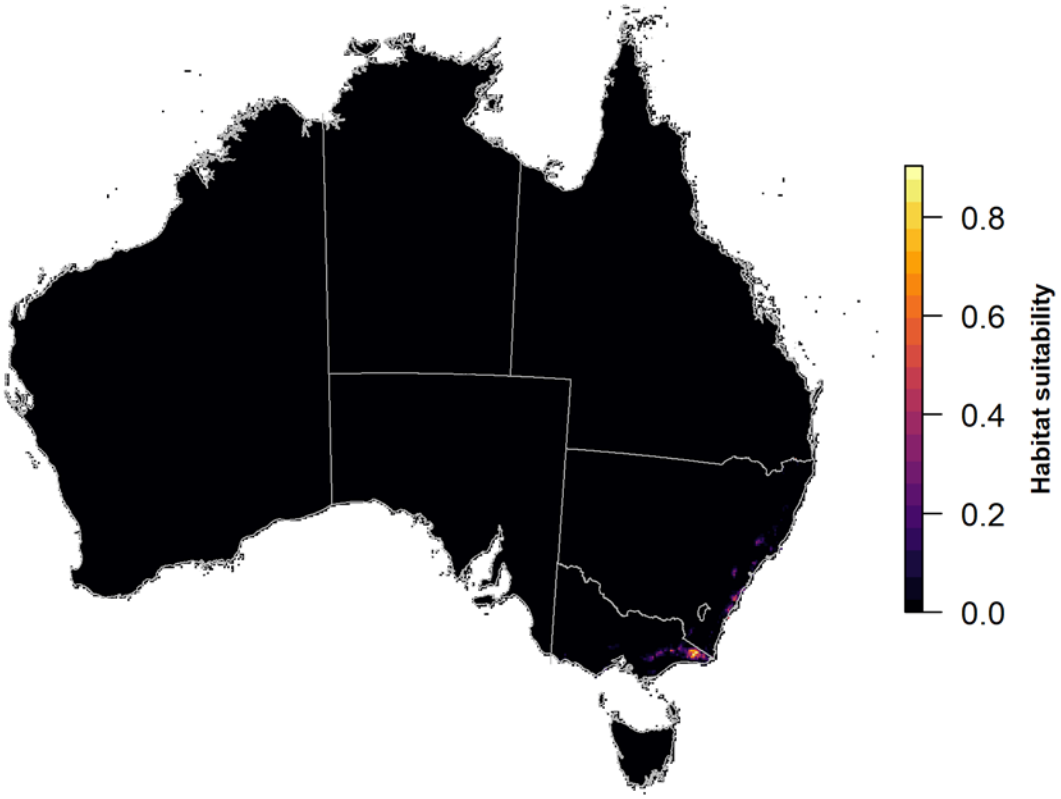
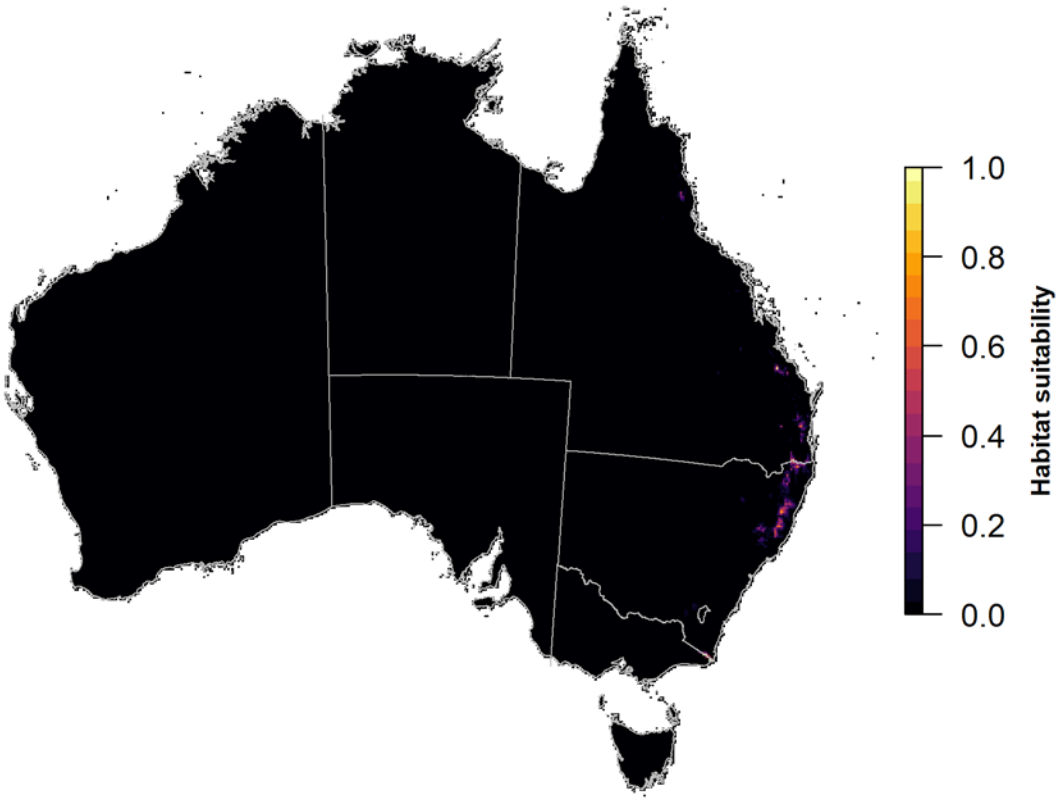


## Mountain Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Philoria kundagungan* |
| EPBC listed status: Not listed |
| State: NSW QLD |
| Description and habitat: Usually found among saturated or moist leaf litter and vegetation near small creeks in rainforest in cooler, wetter, higher elevation areas. |
| Sampling methods: Listen for calling males during day, diurnal surveys while walking transect along stream or creek, tadpole surveys. |
| Timing of surveys: Sept - Feb |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Hines, H. B., Mahony, M. J. and McDonald, K. R. (1999) An assessment of frog declines in wet subtropical Australia. In: Campbell, A. (ed.), Declines and disappearances of Australian frogs. Environment Australia, pp. 44-63.<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

*Detectability estimates are based on surveys in unburnt areas.



## New England treefrog, Glandular Frog

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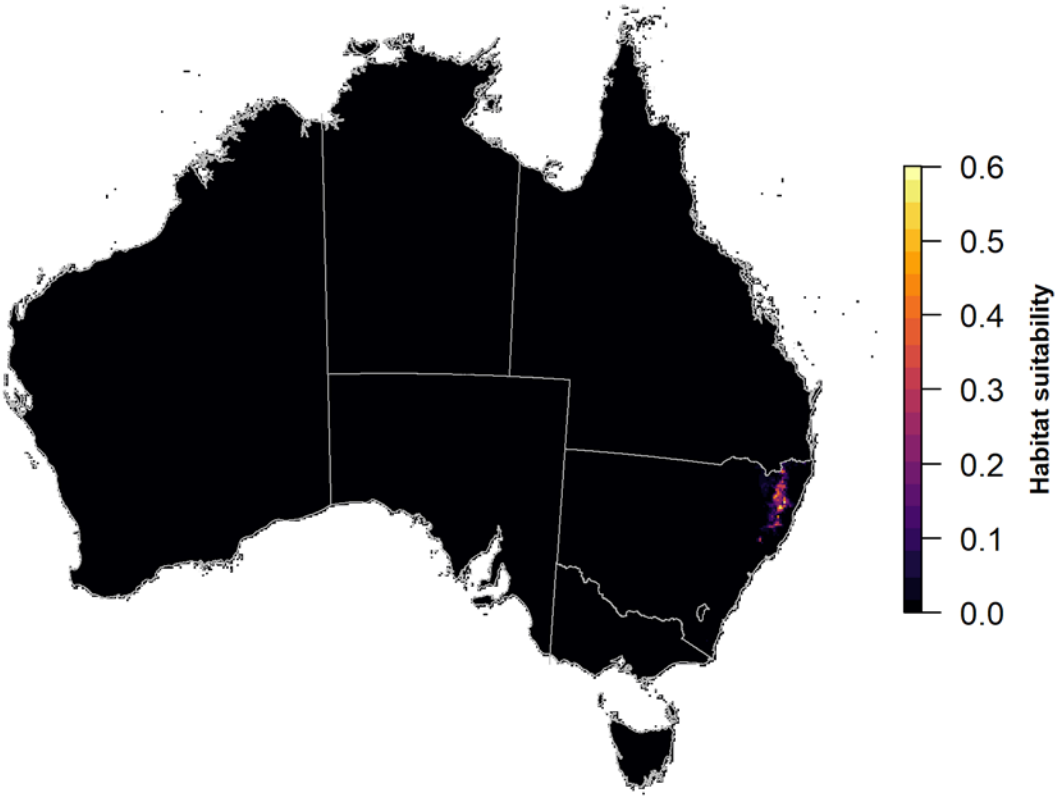
|---|
| Taxonomic group: Frogs |
| Scientific name: *Litoria subglandulosa* |
| EPBC listed status: Not listed |
| State: NSW QLD |
| Description and habitat: Prefers slow flowing and small streams in upland areas (500 – 1400 m). |
| Sampling methods: Spotlighting while walking transect along stream or creek, tadpole surveys |
| Timing of surveys: Sept – March. Calling intensity increases after light rain. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

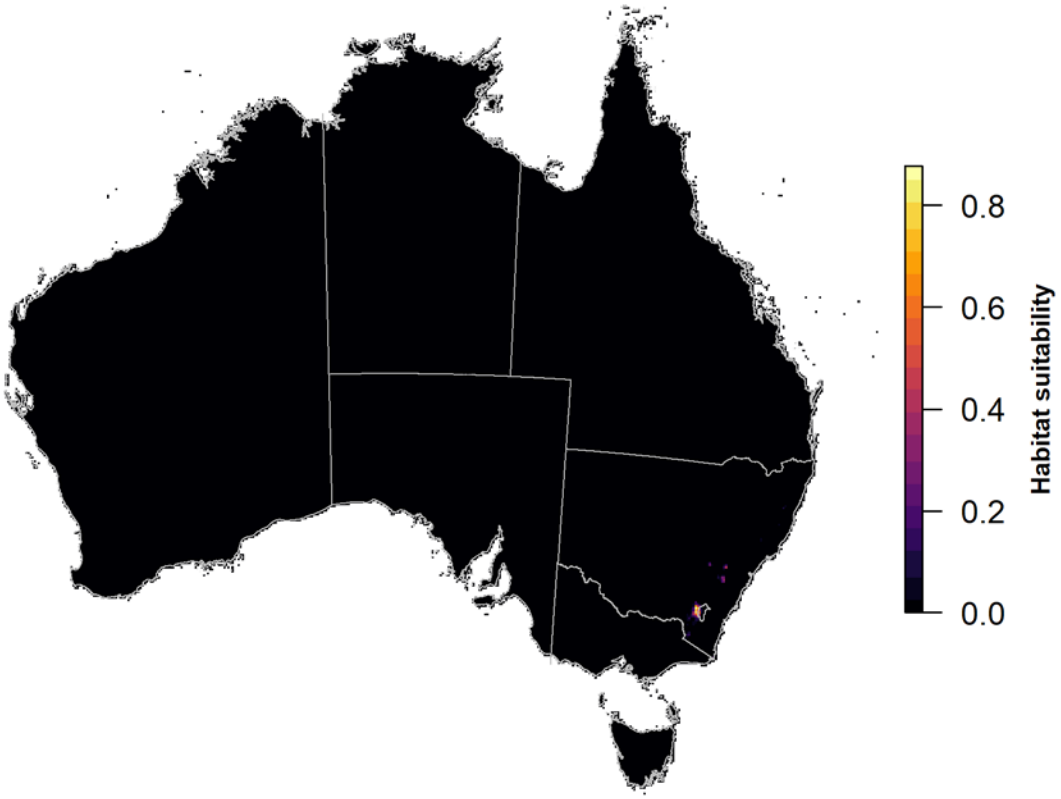
*Detectability estimates are based on surveys in unburnt areas.



## Northern Corroboree Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Pseudophryne pengilleyi* |
| EPBC listed status: Critically Endangered |
| State: ACT NSW |
| Description and habitat: Prefers to breed in sphagnum bogs and wet heath in sub-alpine areas. |
| Sampling methods: Shout response technique, active search |
| Timing of surveys: Calling period (Jan-Feb), larval period (Aug-Dec) |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Scheele et al. (2012) estimated the probability of detection after 3 surveys per day was 0.99 (SE=0.0004). National survey guidelines recommend at least two consecutive days (Department of Environment 2010). |
| References and further reading:<br>Scheele B, Driscoll D, Fischer J, Hunter D (2012) Decline of an endangered amphibian during an extreme climatic event. Ecosphere 3(10): 1-15.<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.



## Peppered Tree Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Litoria piperata* |
| EPBC listed status: Vulnerable |
| State: NSW |
| Description and habitat: Known to occupy open forest and wet sclerophyll forest |
| Sampling method: Spotlighting, focusing on streamside vegetation and on exposed rocky shelves and banks. |
| Timing of surveys: Call period (Nov-Mar), Larval period (Nov-Mar) |
| Single visit detection probability: No estimates available |
| Minimum survey effort: A minimum of four nights under ideal conditions, covering a range of stream structures (pools, riffles, stretches) (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>NSW National Parks and Wildlife Service (2001) Yellow-spotted Bell Frog (Litoria castanea) and Peppered Tree Frog (Litoria piperata) recovery plan. NPWS, Hurstville, NSW.<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

*Detectability estimates are based on surveys in unburnt areas.

## Pugh's Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Philoria pughi* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Usually found in streams or temporary pools in high rainfall rainforest. |
| Sampling methods: Conduct call surveys for calling males around headwaters of small streams and soaks. Listen for calling males during the day. Diurnal surveys along transect following stream. Tadpole surveys unsuitable. |
| Timing of surveys: Oct - Jan |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Hines H, Mahony M, McDonald K (1999) An assessment of frog declines in wet subtropical Australia. In 'Declines and disappearances of Australian frogs'. (Ed. A. Campbell) pp. 44-63. (Environment Australia: Canberra).<br><br>Knowles R, Mahony M, Armstrong J, Donnellan S (2004) Systematics of sphagnum frogs of the Genus *Philoria* (Anura: Myobatrachidae) in eastern Australia, with the description of two new species. *Records of the Australian Museum* 56, 57-74<br><br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

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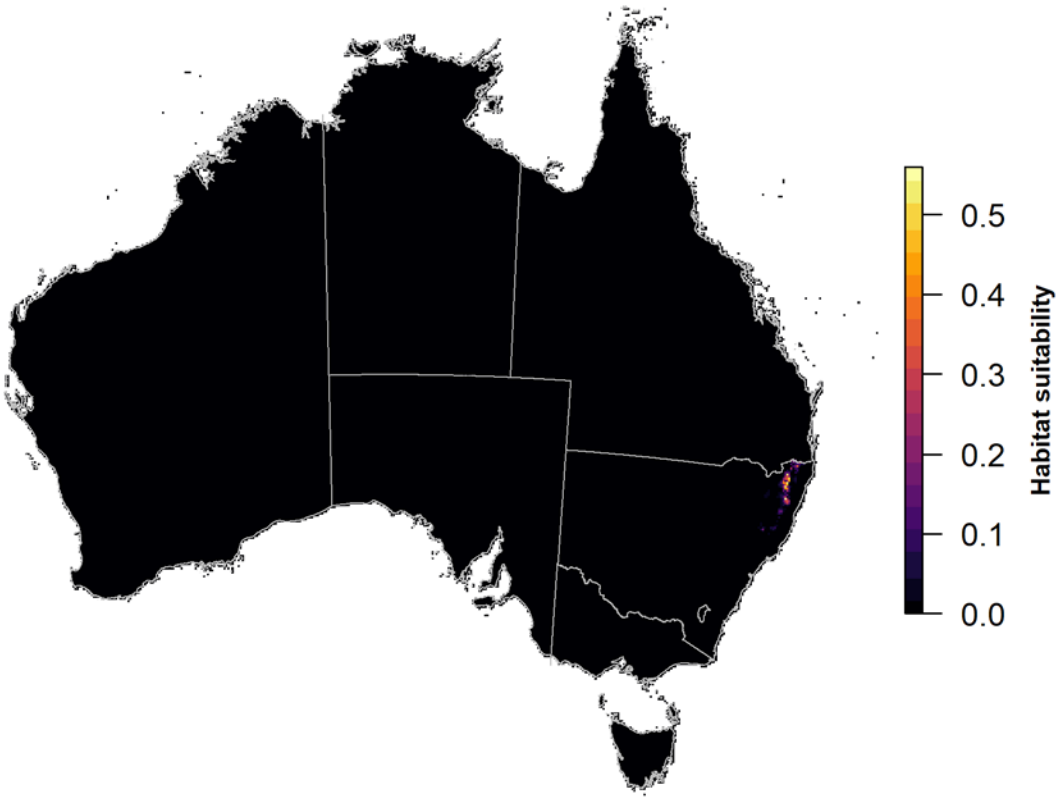

## Richmond Range Sphagnum Frog

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|---|
| Taxonomic group: Frogs |
| Scientific name: *Philoria richmondensis* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Inhabits montane moist forest and subtropical rainforest where there are seepage areas beside seasonal or permanent stream (Willacy et al. 2015). |
| Sampling method: Call surveys around headwaters of small streams or soaks. Diurnal stream transects, acoustic monitoring. Tadpole surveys unsuitable. |
| Timing of surveys: Oct - Dec |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Willacy, R.J., Mahony, M., Newell, D.A., (2015) If a frog calls in the forest: Bioacoustic monitoring reveals the breeding phenology of the endangered Richmond Range mountain frog (*Philoria richmondensis*). Austral Ecology 40, 625-633.<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

*Detectability estimates are based on surveys in unburnt areas.

## Southern Corroboree Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Pseudophryne corroboree* |
| EPBC listed status: Critically Endangered |
| State: NSW |
| Description and habitat: Prefers to breed in sphagnum bogs and wet heath in sub-alpine areas. |
| Sampling methods: Shout response technique, tadpole surveys, active search |
| Timing of surveys: Jan - Feb |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Scheele et al. (2012) estimated the probability of detection after 3 surveys per day was 0.99 (SE=0.0004). National survey guidelines recommend at least two consecutive days (Department of Environment 2010) |
| References and further reading:<br>Scheele B, Driscoll D, Fischer J, Hunter D (2012) Decline of an endangered amphibian during an extreme climatic event. Ecosphere 3(10): 1-15.<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

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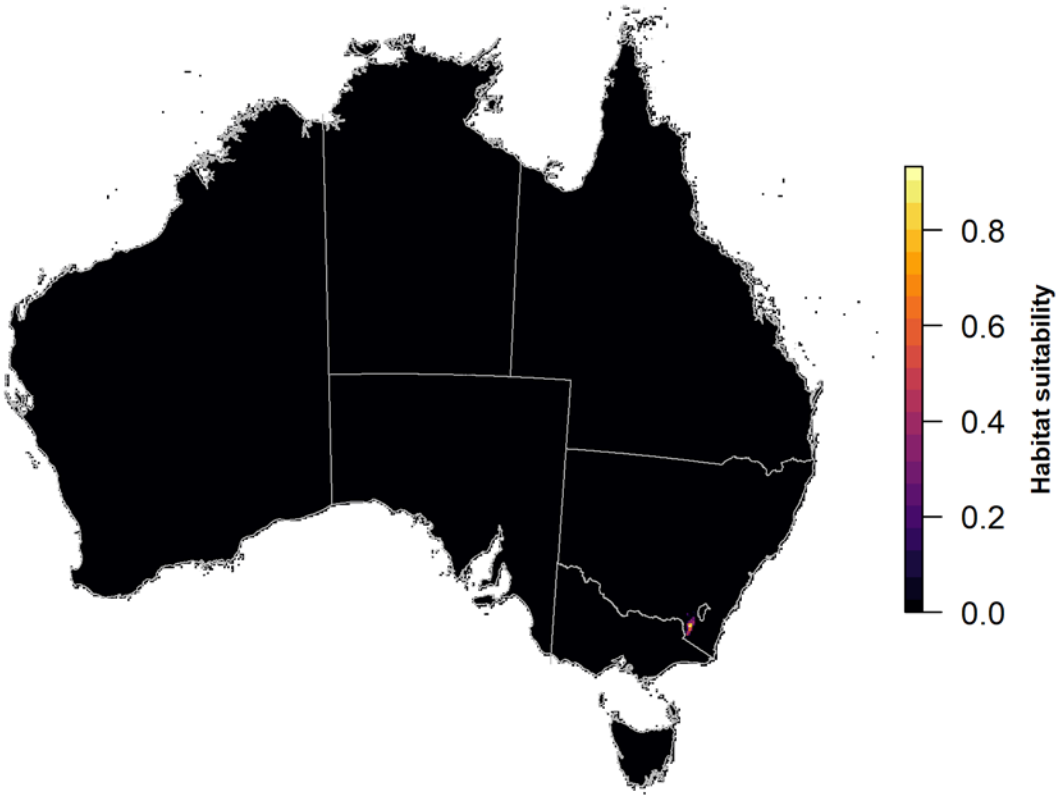

## Sphagnum Frog

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|---|
| Taxonomic group: Frogs |
| Scientific name: *Philoria sphagnicola* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Lives in extensive beds of sphagnum moss and seepages on steep slopes |
| Sampling methods: Call surveys around headwaters of small streams and soaks. Diurnal transect surveys along streams. |
| Timing of surveys: Surveys preferable morning or late afternoon in Sept - Dec |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna |

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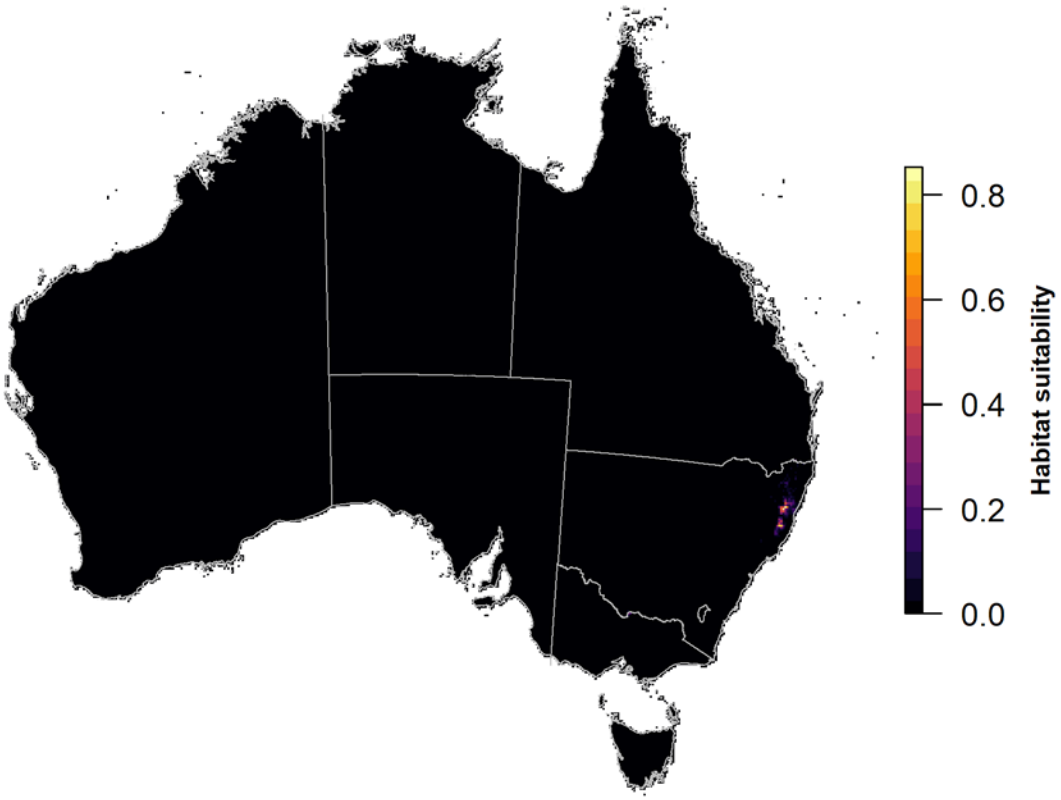

## Spotted Tree Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Litoria spenceri* |
| EPBC listed status: Endangered |
| State: NSW Vic |
| Description and habitat: The species is found almost exclusively in association with rock habitats along streams. It occurs along steep banks, especially in steeply dissected country or gorges with numerous rapids and waterfalls. |
| Sampling methods: Spotlighting, tadpole surveys |
| Timing of surveys: Call period (Oct – Dec; Feb), Larval period (Nov-Mar) |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest a minimum of 2 nights under ideal conditions (wet leaf litter), focusing on rocky shelfs and riffle areas in first to third order streams. Should be repeated on at least four separate occasions (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br>West, M. (2015) Contrasting population responses of ecologically-similar sympatric species to multiple threatening processes PhD, The University of Melbourne |

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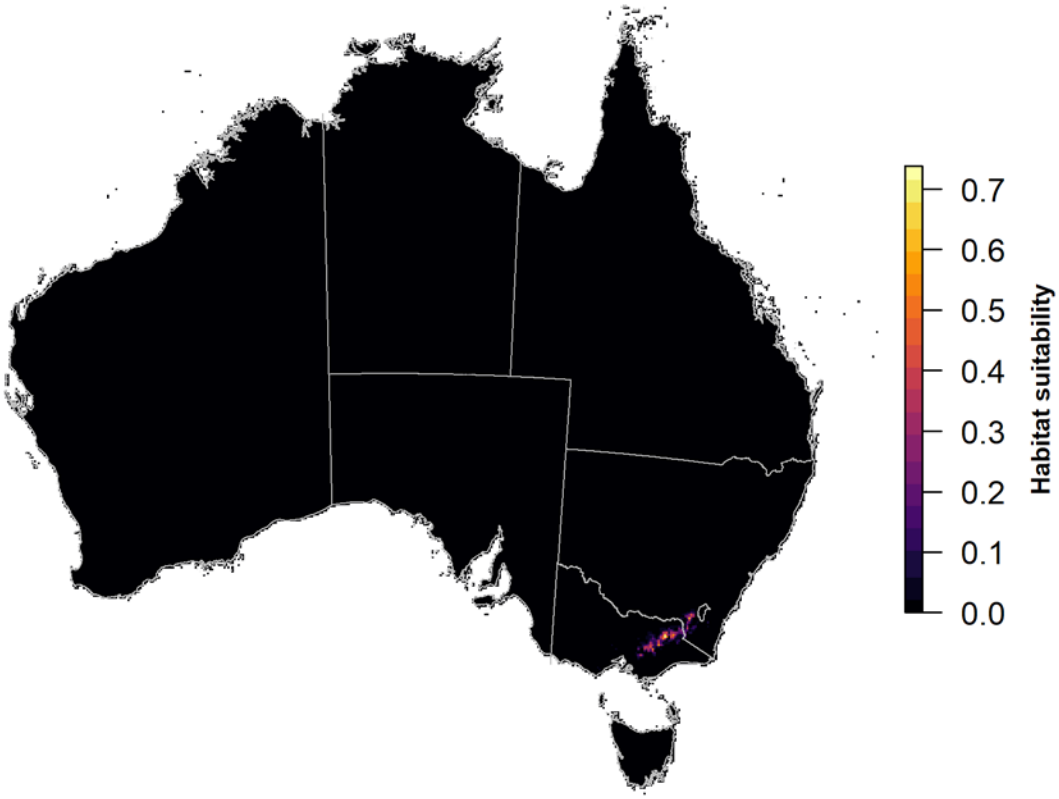

## Stuttering Frog, Southern Barred Frog

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Mixophyes balbus* |
| EPBC listed status: Vulnerable |
| State: NSW QLD Vic |
| Description and habitat: Typically found in permanent streams free from any disturbance with a thick canopy and relatively simple understorey. |
| Sampling methods: Spotlighting with call playback while walking transect along stream or creek, tadpole surveys. |
| Timing of surveys: Sept - April |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest a minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions (Department of Environment 2010). |
| References and further reading:<br>The Australian Government's Department of Environment, Water, Heritage and Arts, (2010) Survey guidelines for Australia's threatened frogs: guidelines for detecting frogs listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999<br>Cutajar TP, Rowley JL (2020) Surveying frogs from the bellies of their parasites: invertebrate derived DNA as a novel survey method for frogs. Global Ecology and Conservation 22, e00978<br>Department of Environment and Climate Change NSW (2009) Threatened species survey and assessment guidelines: field survey methods for fauna<br>Knowles R, Thumm K, Mahony M, Hines H, Newell D, Cunningham (2015) Oviposition and egg mass morphology in barred frogs (Anura: Myobatrachidae: Mixophyes Günther, 1864), its phylogenetic significance and implications for conservation management. Australian Zoologist 37(3): 381-402 |

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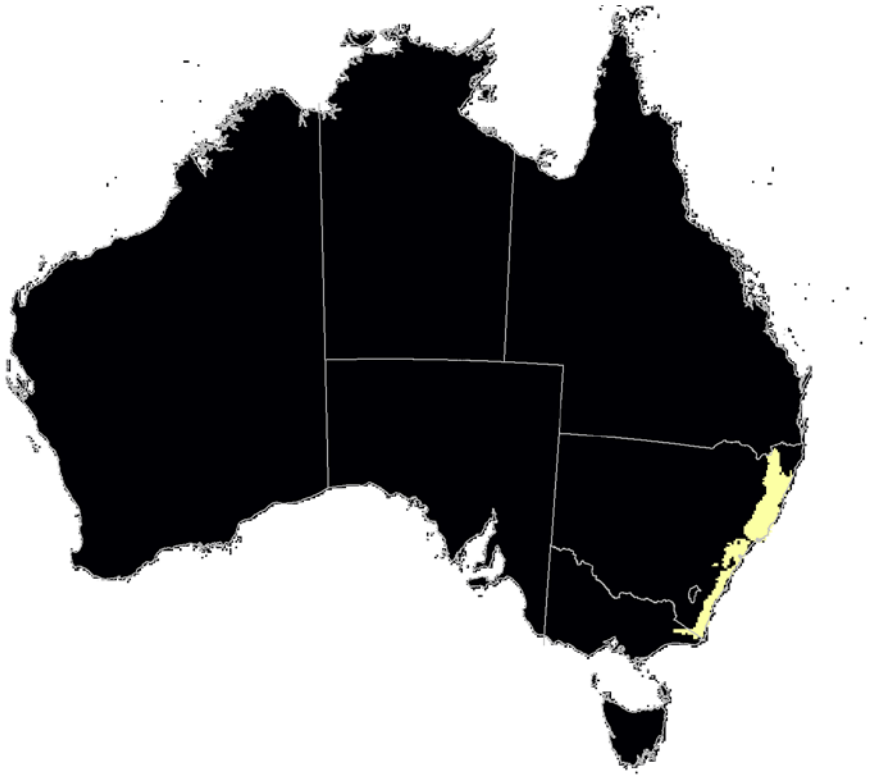

## Tyler's Toadlet

| |
|---|
| Taxonomic group: Frogs |
| Scientific name: *Uperoleia tyleri* |
| EPBC listed status: Not listed |
| State: NSW Vic |
| Description and habitat: Commonly found near water in dry forest, woodlands, shrublands and grasslands. |
| Sampling method: Call surveys, active searches |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available<br>Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018). Forest Protection Survey Program: Survey Design Summary |

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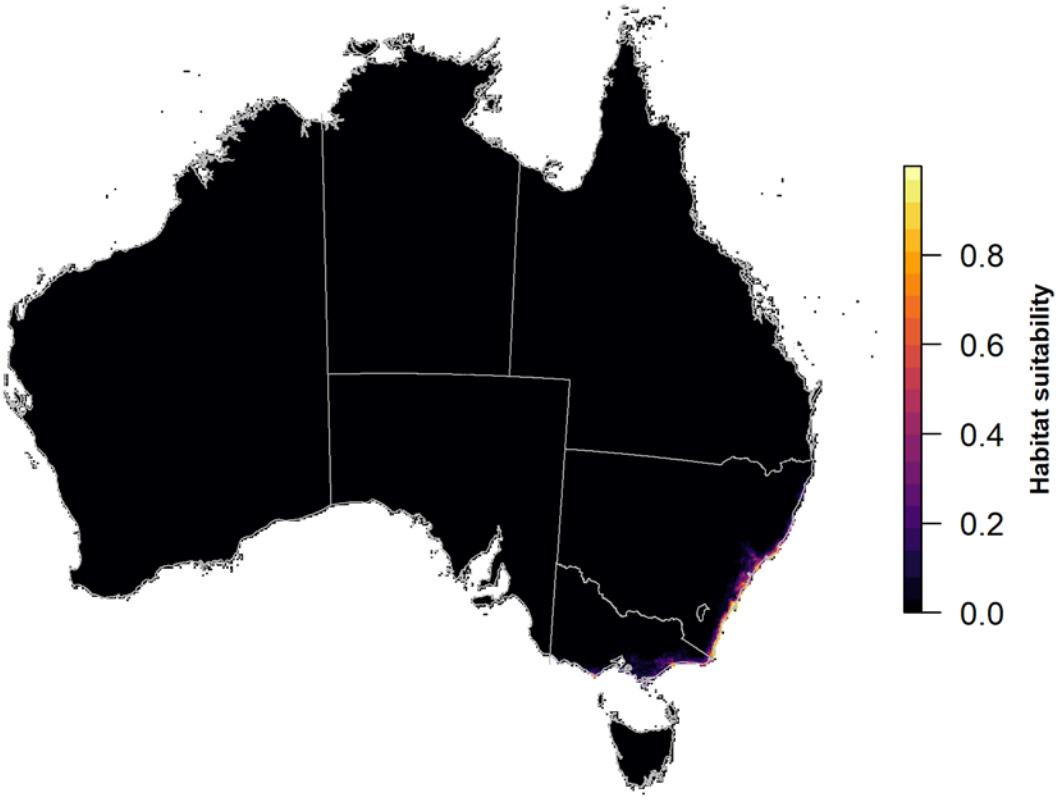

**Reptiles**

## Alpine Bog Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Pseudemoia cryodroma* |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: restricted to mountain plateaux above 1000m in Victoria |
| Sampling methods: Visual search with active hand searching. |
| Timing of surveys: Nov – April during warm weather in the mid-morning and late afternoon. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: DEWLP forest survey standards suggest approximately 2500 $m^2$ should be searched by 2 observers for 30 min. |
| References and further reading:<br>Haines M, Stuart-Fox D, Sumner J, Clemann N, Chapple DG, Melville J (2017) A complex history of introgression and vicariance in a threatened montane kink (*Pseudemoia cryodroma*) across an Australian sky island system. Conservation Genetics 18: 939 – 950<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.

## Alpine She-oak Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Cyclodomorphus praealtus* |
| EPBC listed status: Endangered |
| State: NSW Vic |
| Description and habitat: Is found in litter and under rocks in alpine fields above 1500 m in the Australian Alps. |
| Sampling methods: Visual search with active hand searching, placement of artificial cover objects such as tiles |
| Timing of surveys: Nov – April during warm weather in the mid-morning and late afternoon. |
| Single visit detection probability: No estimates available |
| Minimum survey effort: DEWLP forest survey standards suggest approximately 2500 $m^2$ should be searched by 2 observers for 30 min. |
| References and further reading:<br><br>Scroggie MP, Clemann N (2009) Handling-related tail loss in an endangered skink: incidence, correlates and a possible solution Journal of Zoology 277: 214-220<br><br>Koumoundouros T, Sumner J, Clemann N and Stuart-Fox D (2009) Current isolation and fragmentation contrasts with historical connectivity in an alpine lizard (Cyciodomorphus praeaitus) threatened by climate change. Biological Conservation 142, 992-1002.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

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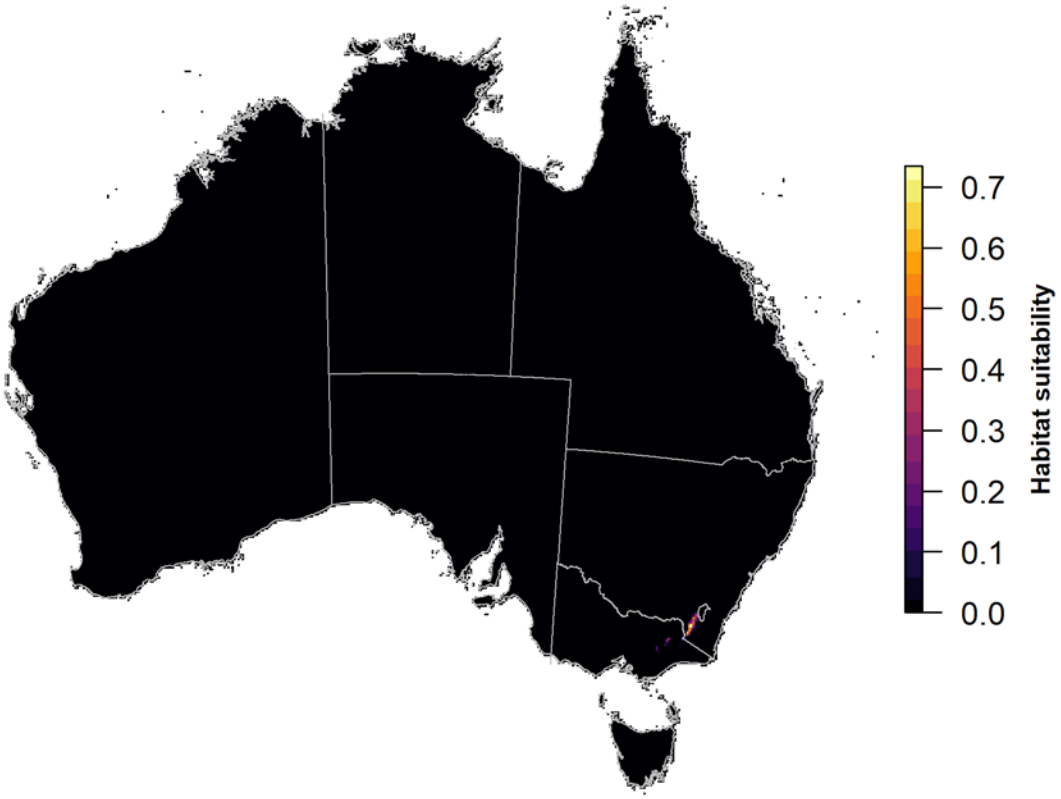

## Bell's Turtle

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Wollumbinia belli* |
| EPBC listed status: Vulnerable |
| State: NSW QLD |
| Description and habitat: Found in pools usually less than 3 m deep in small tributaries. |
| Sampling methods: Cathedral traps, fyke nets, camera trapping |
| Timing of surveys: Nov – March when species is active and feeding |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Chessman BC (2015) Distribution, abundance and population structure of the threatened western saw-shelled turtle, *Myuchelys bellii*, in New South Wales, Australia. Australian Journal of Zoology 63: 245-252<br>Fielder, D.P., D.J. Limpus & C.J. Limpus (2015) Reproduction and population ecology of the vulnerable western sawshelled turtle, *Myuchelys bellii*, in the Murray-Darling Basin, Australia. *Australian Journal of Zoology*. 62:463-476 |

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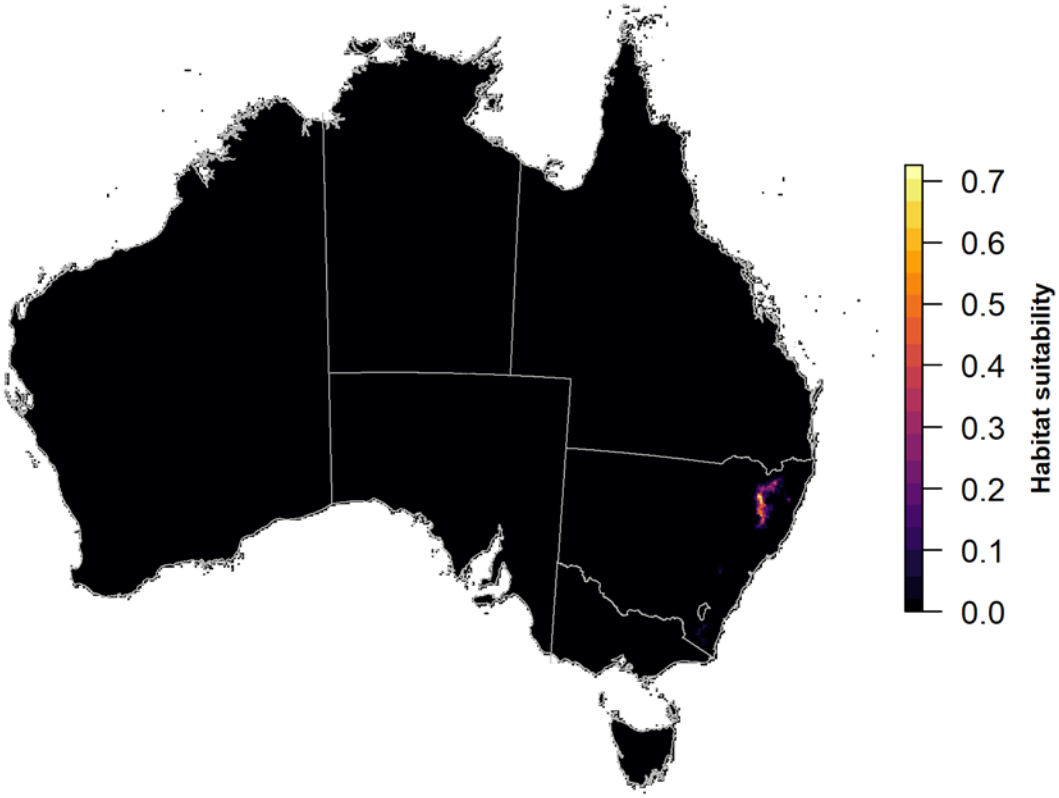

## Blue Mountains Water Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Eulamprus leuraensis* |
| EPBC listed status: Endangered |
| State: NSW |
| Description and habitat: Restricted to the middle and upper Blue Mountains west of Sydney, the Blue Mountains Water Skink is known from approximately 70 threatened highland peat swamps (Dubey et al. 2013). |
| Sampling methods: Pitfall traps, funnel traps |
| Timing of surveys: warm sunny days from Sept - April |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Dubey, S., Pike, D.A., Shine, R., (2013) Predicting the impacts of climate change on genetic diversity in an endangered lizard species. Climatic Change 117, 319-327.<br>Dubey S, and Shine R (2010) Restricted dispersal and genetic diversity in populations of an endangered montane lizard (*Eulamprus leuraensis*, Scincidae). Molecular Ecology 19: 886-897<br>Gorissen S, Mallinson J, Greenlees M, Shine R (2015) The impact of fire regimes on populations of endangered lizard in montane south-eastern Australia. Austral Ecology 40: 170-177<br>Gorisson S, Baird IRC, Greenlees M, Sherieff AN, Shine R (2018) Predicting the occurrence of an endangered reptiles based on habitat attributes. Pacific Conservation Biology 24: 12-24 |

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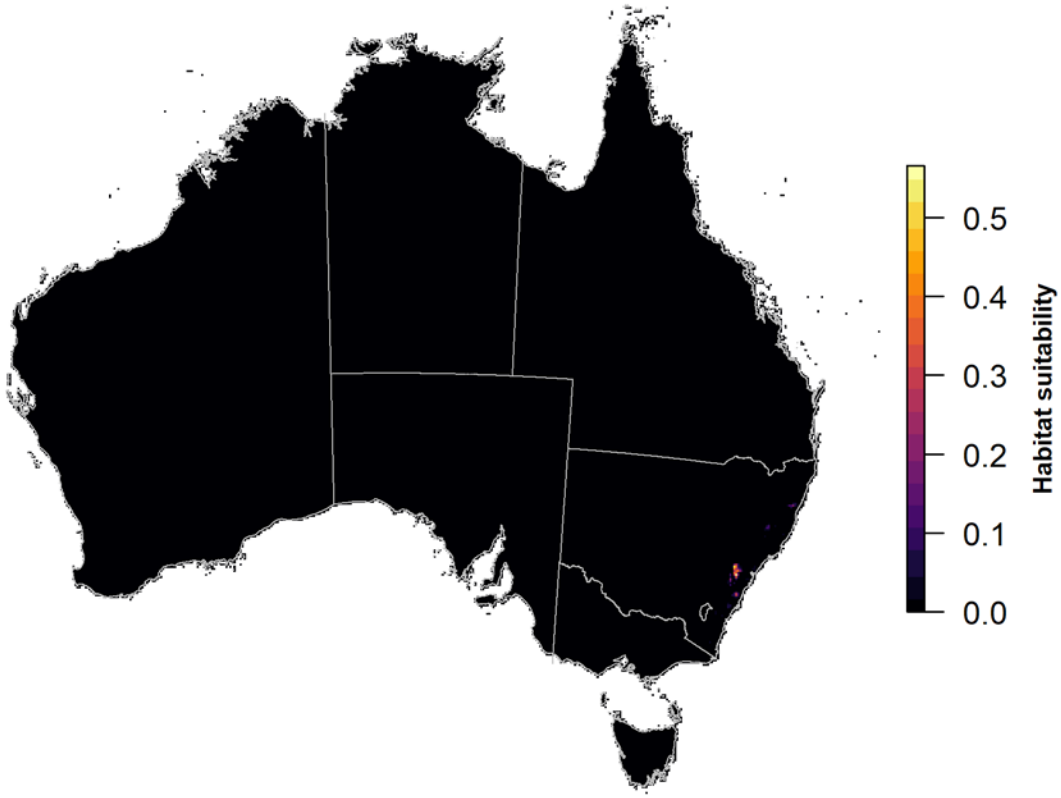

## Broad-headed Snake

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Hoplocephalus bungaroides* |
| EPBC listed status: Vulnerable |
| State: NSW |
| Description and habitat: restricted to the sandstone ranges in the Sydney Basin. It shelters in rock crevices and under flat sandstone rocks during autumn winter and spring. In summer, it can also shelter in hollows in large trees. |
| Sampling method: Area search of sheltering sites |
| Timing of surveys: No estimates available |
| Single visit detection probability: Single visit detection probability when searching a 200 x 30 m site equal to 0.25 ± 0.04 (Goldingay and Newell 2017). |
| Minimum survey effort: Eleven repeat visits needed to achieve 0.95 probability of detection. |
| References and further reading:<br>Goldingay, R.L., Newell, D.A., (2017) Small-scale field experiments provide important insights to restore the rock habitat of Australia's most endangered snake. Restoration Ecology 25, 243-252.<br>Newell DA, Goldingay RL, (2005) Distribution and habitat assessment of the Broad-headed Snake *Hoplocephalus bungaroides* Australian Zoologist 33(2) 168-179<br>Penman TD, Pike DA, Webb JK, Shine R (2010) Predicting the impact of climate change on Australia's most endangered snake, *Hoplocephalus bungaroides*. Diversity and Distribution 16: 109-118<br>The Australian Government's Department of Environment, Water, Heritage and Arts (2011) Survey guidelines for Australia's threatened reptiles: guidelines for detecting reptiles listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

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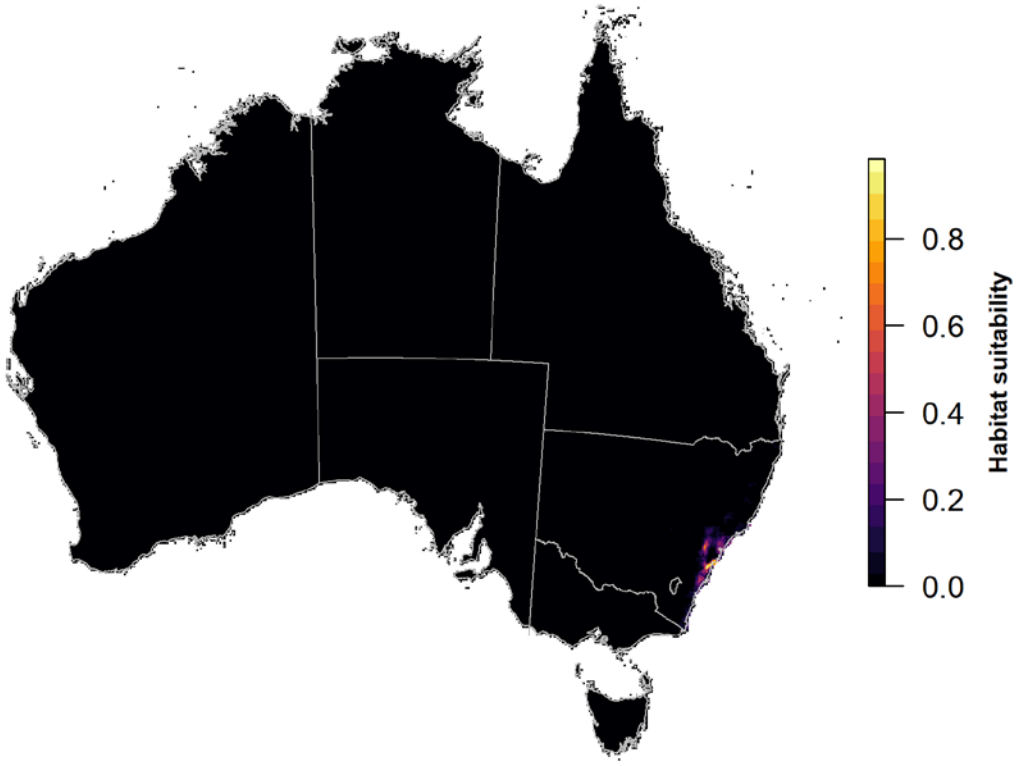

## Broad-tailed Gecko

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Phyllurus platurus* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: inhabits rocky areas in the Sydney basin including boulders, rock faces or small rock crevices, but can also naturally be found on trees including. |
| Sampling method: Active search |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Mo, M (2014) Habitat selection of the Broad-tailed Gecko Phyllurus platurus in an urban Sydney bushland remnant. Australian Zoologist 37(1): 95-101<br>Brown, D (2012). A guide to Australian Geckos and Pygopods. Reptile Publications |

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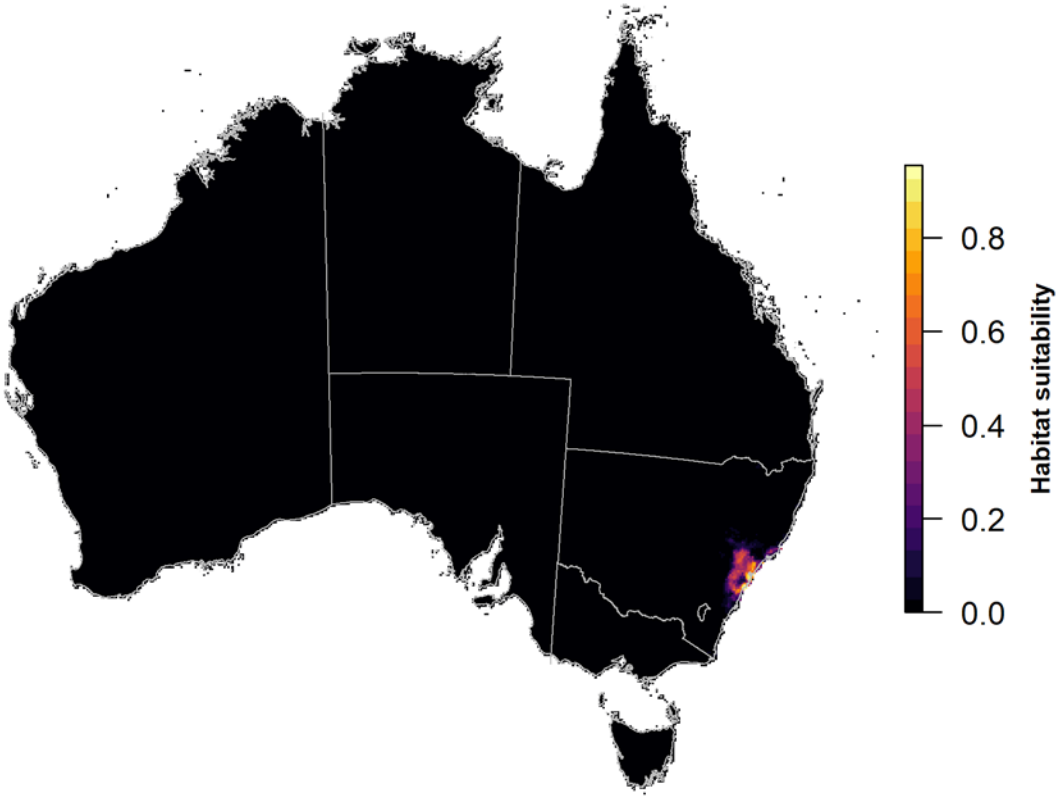

## Georges' Snapping Turtle

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Wollumbinia georgesi* |
| EPBC listed status: Critically Endangered |
| State: NSW |
| Description and habitat: A short-necked freshwater turtle endemic to the Bellinger Catchment on the north coast of NSW. |
| Sampling methods: Cathedral traps, active search (snorkelling) |
| Timing of surveys: No estimates available |
| Single visit detection probability: Detectability for 1 day of active searcher (diving) equal to 0.59 (Chessman et al. 2020). |
| Minimum survey effort: Four days of diving gives 0.97 detection probability. |
| References and further reading:<br><br>Chessman, B.C., McGilvray, G., Ruming, S., Jones, H.A., Petrov, K., Fielder, D.P., Spencer, R.J., Georges, A., (2020) On a razor's edge: Status and prospects of the critically endangered Bellinger River snapping turtle, *Myuchelys georgesi*. Aquatic Conservation-Marine and Freshwater Ecosystems 30, 586-600.<br><br>Blamires, S. J., & Spencer, R.-J. (2013) Influence of habitat and predation on population dynamics of the freshwater turtle *Myuchelys georgesi*. *Herpetologica*, *69*, 46–57. |

*Detectability estimates are based on surveys in unburnt areas.

## Glossy Grass Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Pseudemoia rawlinsoni* |
| EPBC listed status: Not listed |
| State: ACT NSW SA Tas Vic |
| Description and habitat: No data available |
| Sampling method: Active search |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading: |

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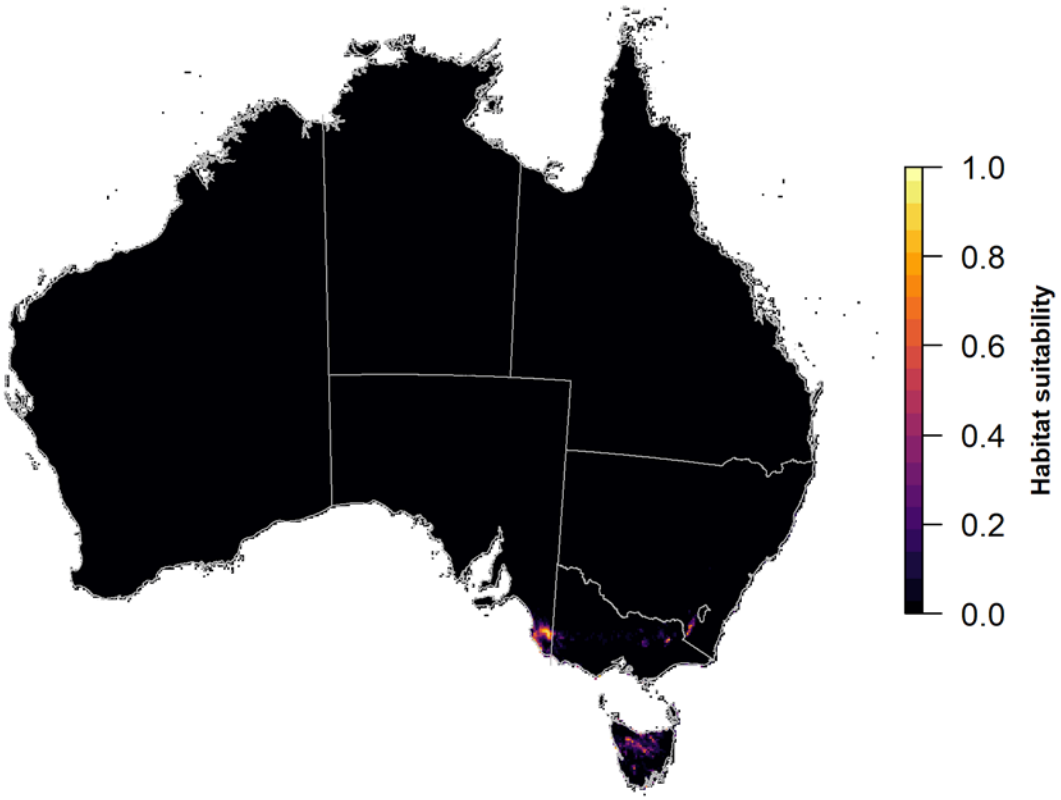


## Granite Leaf-tailed Gecko

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Saltaurius wyberba* |
| EPBC listed status: Not listed |
| State: NSW QLD |
| Description and habitat: Distributed in rocky outcrops and rainforest in south-east Queensland and northern NSW. |
| Sampling methods: Active search, spotlighting |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Brown, D (2012) A guide to Australian Geckos and Pygopods. Reptile Publications |

*Detectability estimates are based on surveys in unburnt areas.

## Guthega Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Liopholis guthega* |
| EPBC listed status: Endangered |
| State: NSW Vic |
| Description and habitat: Known from the Snowy Mountains in the vicinity of Mt Kosciuszko, New South Wales (NSW), and from the Bogong High Plains in Victoria. Usually found in close association with rock outcrops and shrubs where it excavates burrows. |
| Sampling method: Active search for individuals or burrows |
| Timing of surveys: Summer |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Atkins Z, Clemann N, Robert KA (2015) Does shelter site selection aid persistence of a threatened alpine lizard? Assessing Liopholis Guthega populations a decade after severe fire in southeastern Australia. Journal of Herpetology 49: 222-229<br><br>Sato CF, Schroder M, Green K, Michael DR, Osborne W, Lindenmayer DB (2014) Managing ski resorts to improve biodiversity conservation: Australian reptiles as a case study. Ecological Management & Restoration 15, 147–154 |

*Detectability estimates are based on surveys in unburnt areas.

## Kaputar Rock Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Egernia roomi* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Known only from the rocky summit area of the Nandewar Range between 1360 and 1489 m elevation. |
| Sampling method: Active search |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Sadlier RA, Frankham GJ, Beatson CA, Eldridge MDB, Rowley JJL (2019) Genetic evidence in support of the recognition of the Kaputar Rock Skink, one of New South Wales' most range-restricted vertebrate species. Records of the Australian Museum 71, 183-197 |

*Detectability estimates are based on surveys in unburnt areas.

## Kate's Leaf-tail Gecko

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Saltuarius kateae* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: The Kate's Leaf-tail Gecko is restricted to rocky outcrops at the southern end of the Richmond Range in NSW. |
| Sampling methods: Active search, spotlighting |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Brown, D (2012) A guide to Australian Geckos and Pygopods. Reptile Publications |

*Detectability estimates are based on surveys in unburnt areas.

## Long Sunskink

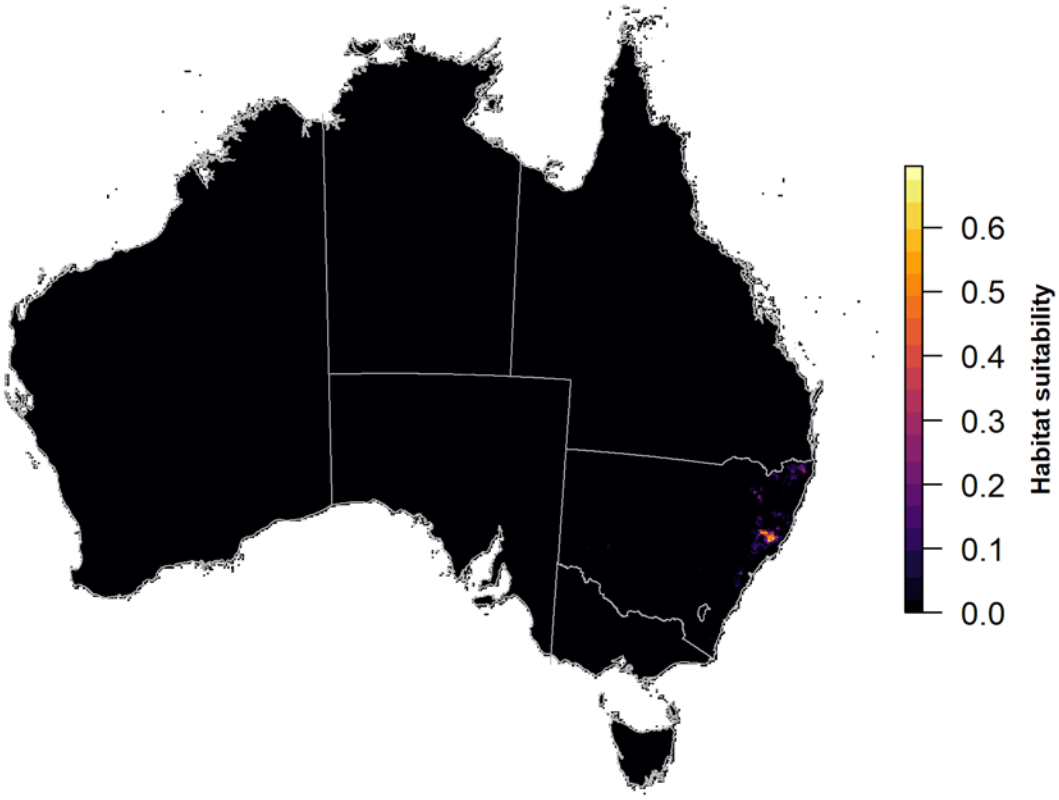
| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Lampropholis elongata* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: No data available |
| Sampling methods: Active search, funnel traps, pitfall traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading: |

*Detectability estimates are based on surveys in unburnt areas.

## Manning River Helmeted Turtle

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Myuchelys purvisi* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Prefers relatively shallow, clear, continuously fast-flowing rivers with rocky and sandy substrates. Shelters under boulders and submerged logs. |
| Sampling methods: Cathedral traps, active search (snorkelling) |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Chessman, B.C., McGilvray, G., Ruming, S., Jones, H.A., Petrov, K., Fielder, D.P., Spencer, R.J., Georges, A., (2020) On a razor's edge: Status and prospects of the critically endangered Bellinger River snapping turtle, *Myuchelys georgesi*. Aquatic Conservation-Marine and Freshwater Ecosystems 30, 586-600. |

*Detectability estimates are based on surveys in unburnt areas.



## Moritz's Leaf-tailed Gecko

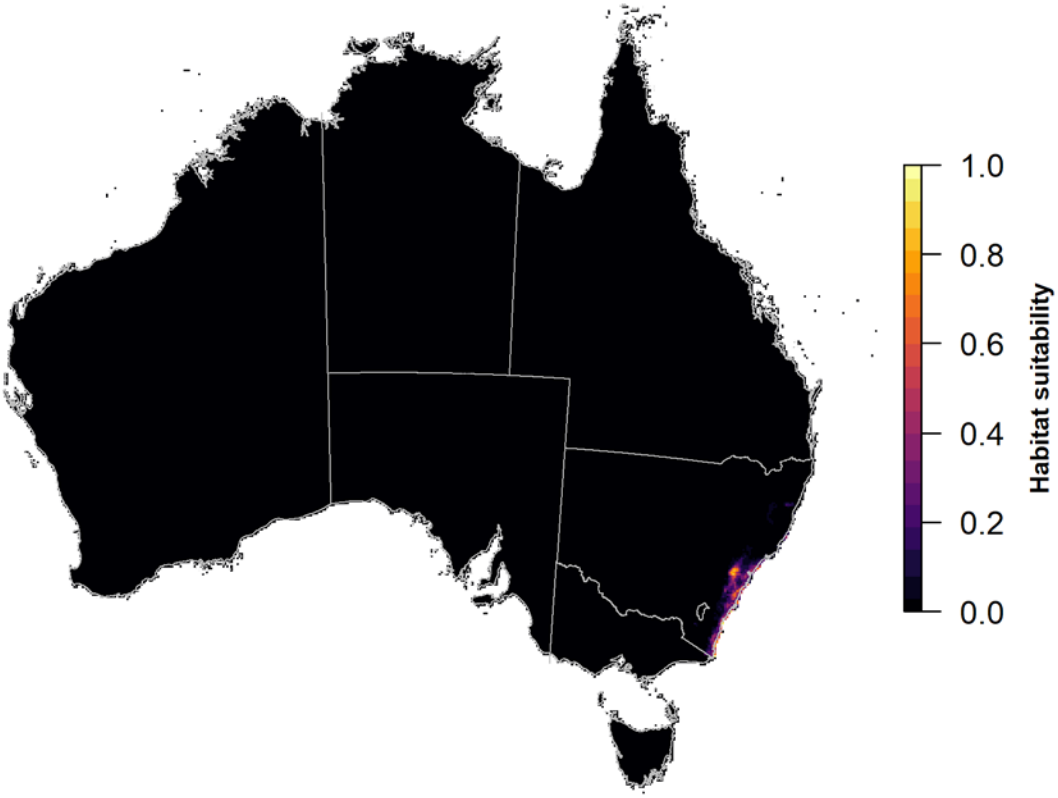
| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Saltuarius moritzi* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Widespread south of the Clarence River, from coastal areas west through the rocky gorge systems of the New England Tableland. |
| Sampling methods: Active search, spotlighting |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Brown, D (2012) A guide to Australian Geckos and Pygopods. Reptile Publications |

*Detectability estimates are based on surveys in unburnt areas.

## Mustard-bellied Snake

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Drysdalia rhodogaster* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Recorded in the Blue Mountains, around Wollongong, and along the South Coast of NSW |
| Sampling method: Active search |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Cabrelli, A.L., Stow, A.J., Hughes, L., (2014) A framework for assessing the vulnerability of species to climate change: a case study of the Australian elapid snakes. Biodiversity and Conservation 23, 3019-3034. |

*Detectability estimates are based on surveys in unburnt areas.



## Nangur Spiny Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Nangura spinosa* |
| EPBC listed status: Critically Endangered |
| State: QLD |
| Description and habitat: Occurs in two locations within southeast Queensland (Borsboom et al. 2010). |
| Sampling method: Area search for burrows |
| Timing of surveys: No estimates available |
| Single visit detection probability: Hannah (1997) detected 24 burrows and 36 individuals over a 6 day period. |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Borsboom, A.C., Couper, P.J., Amey, A., Hoskin, C.J., (2010) Distribution and population genetic structure of the critically endangered skink *Nangura spinosa*, and the implications for management. Australian Journal of Zoology 58, 369-375.<br>The Australian Government's Department of Environment and Resource Management (2010) Recovery plan for the Nangur spiny skink *(Nangura spinosa)*. Report to the Department of Sustainability, Environment, Water, Population and Communities, Canberra. Department of Environment and Resource Management, Brisbane.<br>Hannah, D., Agnew, G., Hamley, B. and Hogan, L. (1997) New information on the narrowly-restricted skink *Nangura spinosa*. *Memoirs of the Queensland Museum* 42(1): 90. |

*Detectability estimates are based on surveys in unburnt areas.

## Oakview Leaf-tailed Gecko

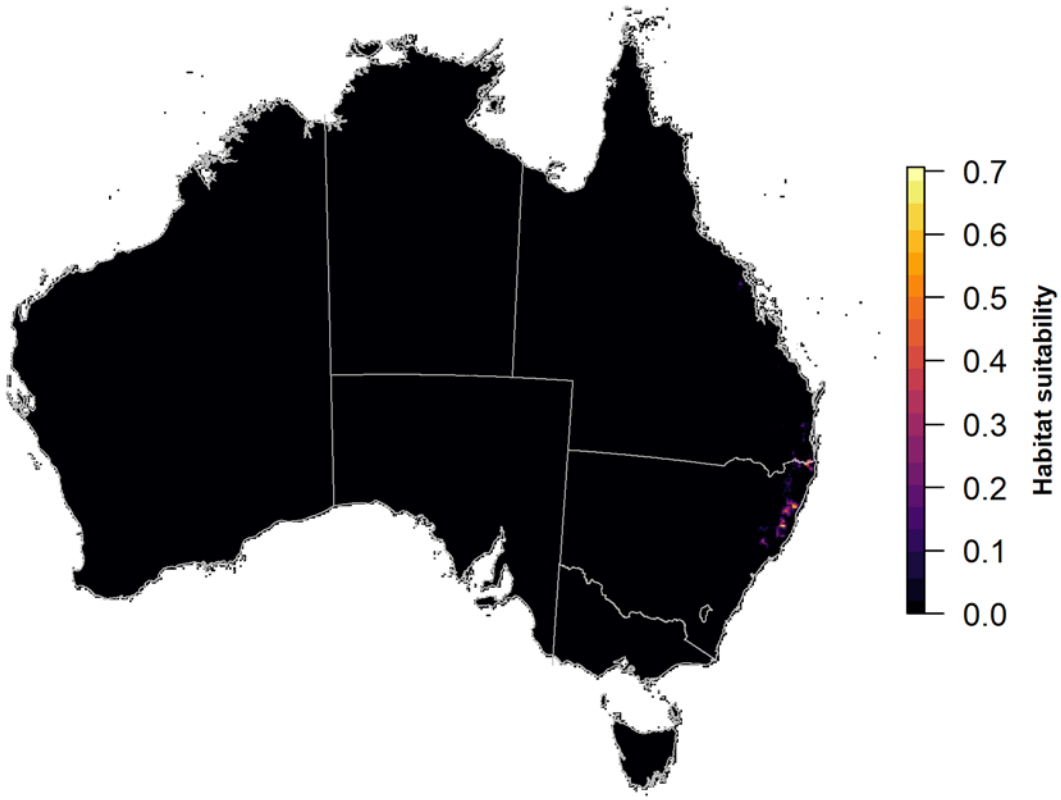
| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Phyllurus kabikabi* |
| EPBC listed status: Not listed |
| State: QLD |
| Description and habitat: Found in vibe thickets with granite boulders in Oakview National Park in Queensland. |
| Sampling methods: Active search, spotlighting |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Couper, P.J., Hamley, B. & Hoskin, C.J. (2008) A new species of *Phyllurus* (Lacertilia: Gekkonidae) from the Kilkivan district of south-eastern Queensland. *Memoirs of the Queensland Museum* 52(2): 139-147. Brisbane. ISSN 0079-8835.<br>Brown, D (2012) A guide to Australian Geckos and Pygopods. Reptile Publications |

*Detectability estimates are based on surveys in unburnt areas.

## Rainforest Cool-skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Harrisoniascincus zia* |
| EPBC listed status: Not listed |
| State: NSW QLD |
| Description and habitat: Found in coastal northern NSW and adjacent parts of southern Queensland. |
| Sampling methods: Active search, funnel traps, pitfall traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Daly G and Hoye G (2016) Survey of the reptiles of the montane forests near Dorrigo on the north coast of New South Wales. Australian Zoologist 38, 26-42 |

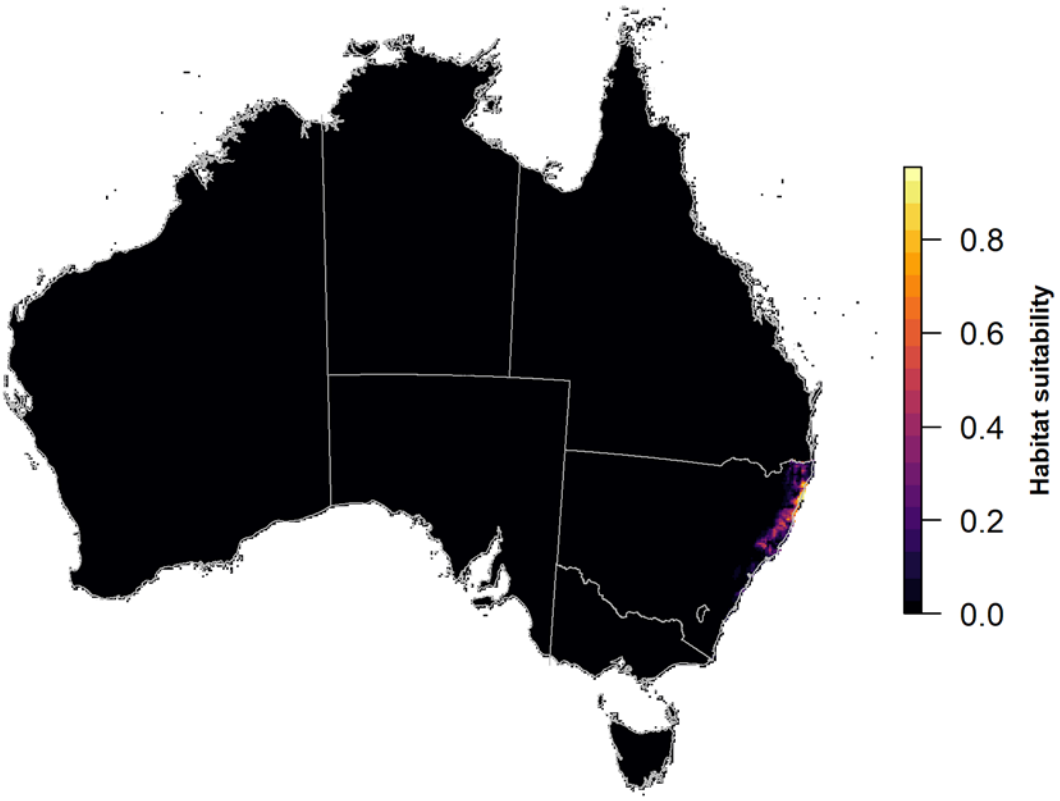
*Detectability estimates are based on surveys in unburnt areas.



## Red-tailed Calyptotis

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Calyptotis ruficauda* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: Known to the Lower North Coast of NSW in wet and dry sclerophyll forest and adjacent rainforest. Is found under logs, stones and surface litter. |
| Sampling methods: Active search, funnel traps, pitfall traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Mo (2015) An outlying location for the Australian skink *Calyptotos ruficauda* in far northern New South Wales, and some observation in plantations on cleared farmland. Queensland Naturalist 53 1-3 |

*Detectability estimates are based on surveys in unburnt areas.



## Ringed Thin-tail Gecko

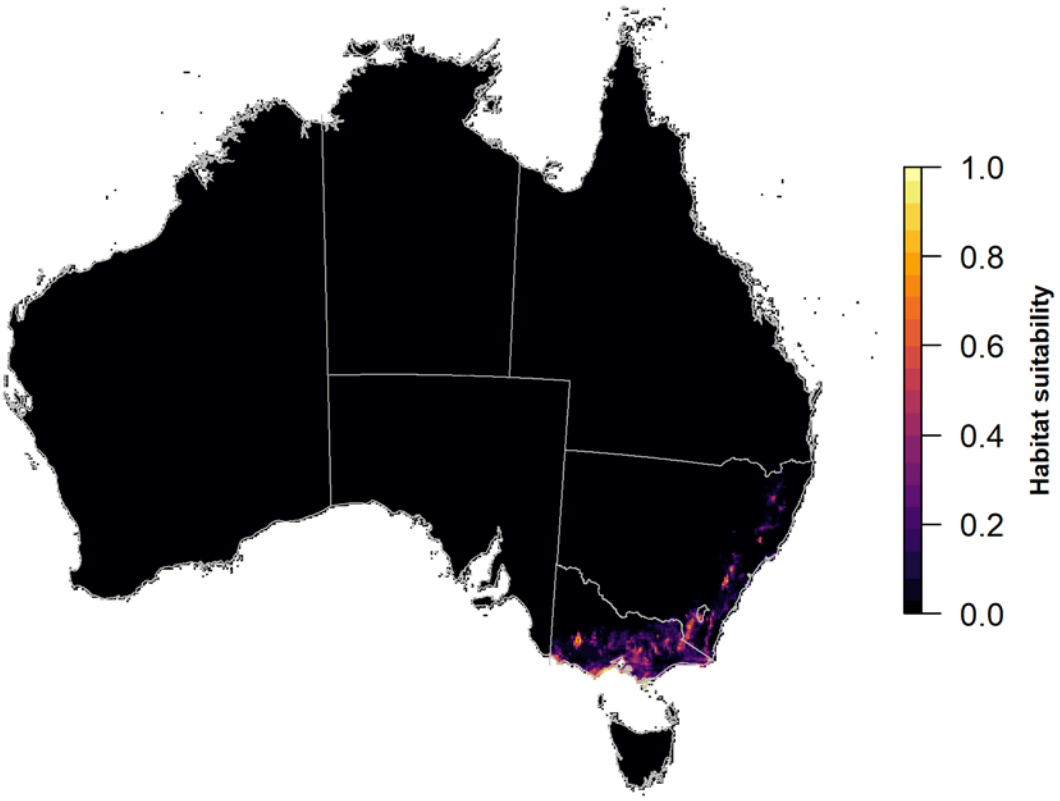
| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Phyllurus caudiannulatus* |
| EPBC listed status: Not listed |
| State: QLD |
| Description and habitat: Found in dense rainforest in the Dawes Range and Many Peaks Range in southeastern Queensland. |
| Sampling methods: Active search, spotlighting |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Brown, D (2012) A guide to Australian Geckos and Pygopods. Reptile Publications |

*Detectability estimates are based on surveys in unburnt areas.

## Southern Water-skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Eulamprus tympanum* |
| EPBC listed status: Not listed |
| State: NSW SA Vic |
| Description and habitat: Usually found beside small creeks. Basks on rocks and logs and shelters under rocks, logs and cracks in fallen timber. |
| Sampling methods: Active search, funnel traps, pitfall traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Hodges KM, Rowell DM, Keogh JS (2007) Remarkably different phylogeographic structure in two closely related lizard species in a zone of sympatry in south-eastern Australia. Journal of Zoology 272: 64-72 |

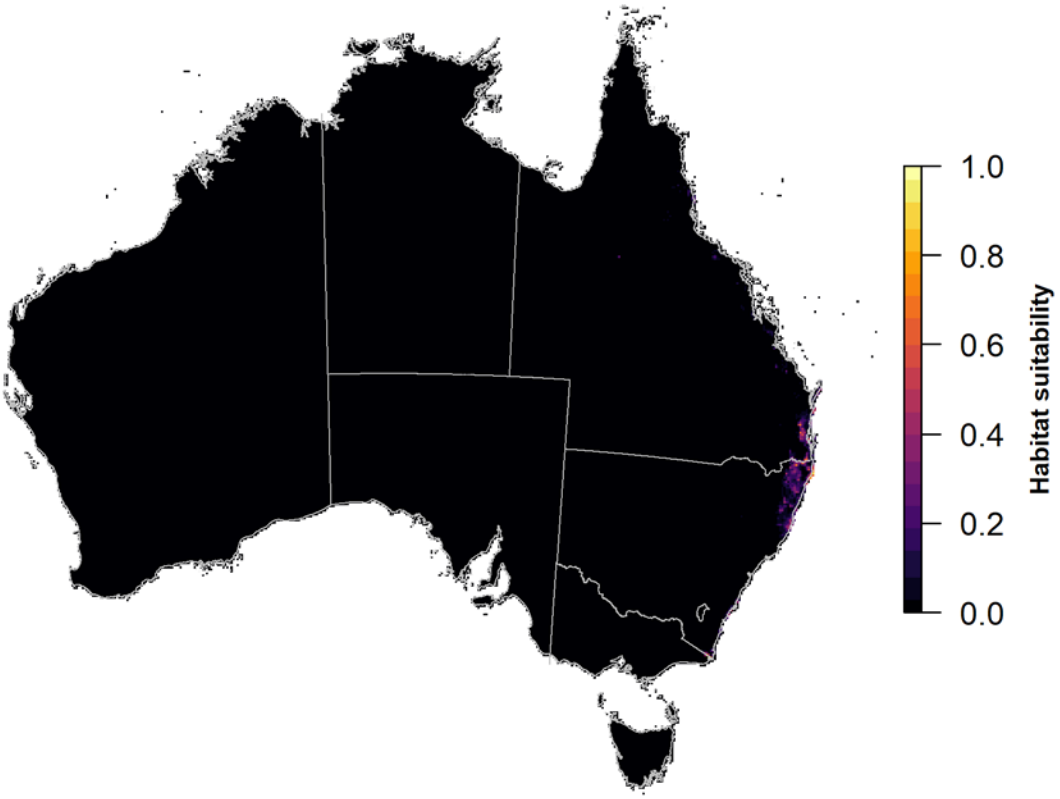
*Detectability estimates are based on surveys in unburnt areas.



## Three-toed Snake-tooth Skink

| |
|---|
| Taxonomic group: Reptiles |
| Scientific name: *Coeranoscincus reticulatus* |
| EPBC listed status: Vulnerable |
| State: NSW QLD<br>Description and habitat: Occurs in subtropical rainforest, wet sclerophyll forest Due to its burrowing habits it is seldom seen.<br>Sampling methods: Pitfall traps, active search, funnel traps |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading: |

*Detectability estimates are based on surveys in unburnt areas.

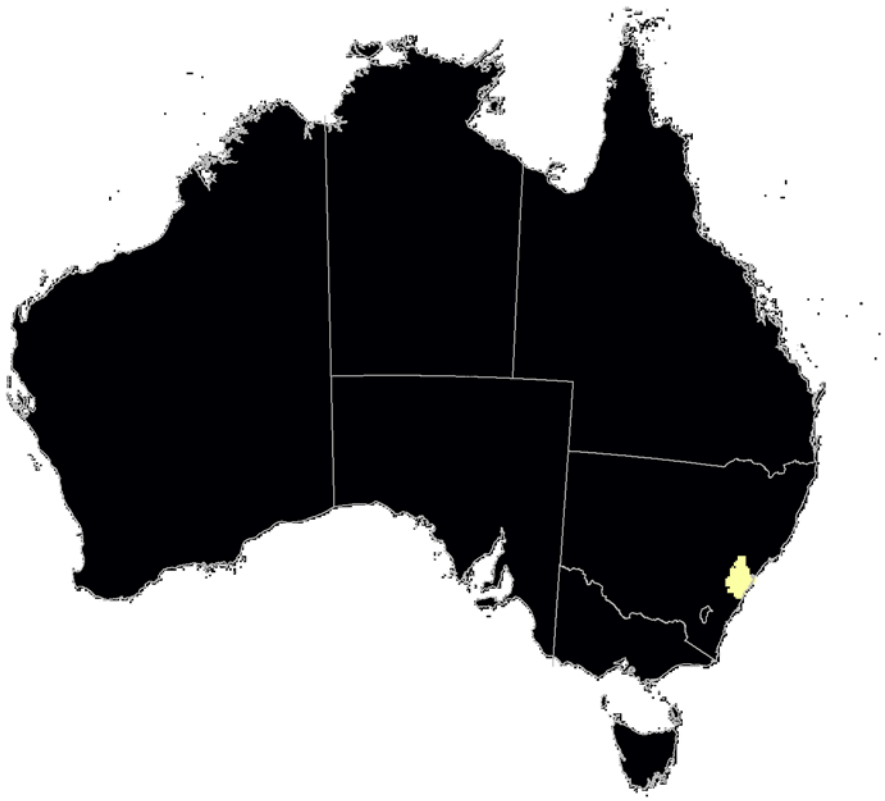


**Fish**

## Blue Mountains Perch, Hawkesbury Perch

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Macquaria sp. nov. 'hawkesbury taxon'* |
| EPBC listed status: Endangered at the species level |
| State: NSW |
| Description and habitat: Almost exclusively found in near pristine, clear streams within rugged gorges, with minimal sediment and nutrient loads, little or no instream vegetation, and among complex boulder habitat. |
| Sampling methods: Electrofishing, fyke nets, bait traps, gill nets targeting shallow to deeper water |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Lintermans, M., (2016) Finding the needle in the haystack: comparing sampling methods for detecting an endangered freshwater fish. Marine and Freshwater Research 67, 1740-1749.<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.



## Cann Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias sp. 17 'Cann'* |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: Very little information available |
| Sampling method: Electrofishing. Collection of voucher specimens needed due to taxonomic uncertainty |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.

## Clarence River Cod, Eastern Freshwater Cod

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Maccullochella ikei* |
| EPBC listed status: Endangered |
| State: NSW |
| Description and habitat: The only breeding population of the species is in the Mann-Nymboida sub-catchment of the Clarence River. Prefers clear rocky streams and rivers with low flow velocity and abundant instream cover of rocks, timber or tussocks. |
| Sampling methods: Electrofishing, fyke nets, lure fishing |
| Timing of surveys: More active at dawn, dusk and at night |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Butler GL and Rowland SJ (2009). Using underwater cameras to describe the reproductive behaviour of the endangered eastern freshwater cod *Maccullochella ikei*. Ecology of Freshwater Fish, vol. 18: 337 – 349<br>Faragher R.A., Brown, P. & Harris, J.H. 1993. Population surveys of the endangered fish species trout cod (*Maccullochella macquariensis*) and eastern cod (*M. ikei*). Report for Australian National Parks and Wildlife Service Endangered Species Program by NSW Fisheries Research Institute, Cronulla.<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.

## Dargo Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias mungadhan* |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: Known only from a small stream in the upper Dargo River system of the Gippsland region of Victoria (Raadik and Nicol 2012). |
| Sampling methods: Electrofishing, scoop nets, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>Raadik, T.A. & Nicol, M.D. (2012) Assessment of the post-fire status and distribution of the Dargo Galaxias (*Galaxias* sp. 6), affected by the White Timber Spur fire, upper Dargo River system: Black Saturday Victoria 2009 – Natural values fire recovery program. Department of Sustainability and Environment, Heidelberg, Victoria, 29 pp.<br><br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br><br>The Australian Government's Department of the Environment, Water, Heritage and the Arts. (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.

## East Gippsland Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias aequipinnis* |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: This species is only found in the Arte River system of East Gippsland, Victoria. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts. (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.

## Flathead Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias rostratus* |
| EPBC listed status: Critically Endangered |
| State: NSW SA Vic |
| Description and habitat: Little is known about this species, although historically it was collected from a variety of habitats including billabongs, lakes, swamps and rivers. |
| Sampling methods: Possibly a combination of electrofishing, seine netting and fyke netting |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts. (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.

## Honey Blue-eye

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Pseudomugil mellis* |
| EPBC listed status: Vulnerable |
| State: QLD |
| Description and habitat: Inhabits clear tannin-stained lakes, streams and wetlands where there little or no flow. Dense, aquatic vegetation is important for shelter. |
| Sampling methods: Seine nets, bait traps, dip nets |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br><br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999.<br><br>Arthington, A.H. & Marshall, C.J. 1993. Distribution, ecology and conservation of the Honey Blue-eye, *Pseudomugil mellis*, in south-eastern Queensland. Report prepared by the Centre for Catchment and In-stream Research, Griffith University, Queensland, for the Australian Nature Conservation Agency Endangered Species Program, Canberra. |

*Detectability estimates are based on surveys in unburnt areas.

## Macquarie Perch 'MDB taxa'

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Macquaria australasica* 'MDB taxa' |
| EPBC listed status: Endangered at the species level |
| State: ACT NSW Vic |
| Description and habitat: Inhabits cool, clear water of rivers, lakes and reservoirs, demonstrating a preference for slow-flowing deep rocky pools. |
| Samplign methods: Electrofishing, fyke nets, bait traps, gill nets targeting shallow to deeper water |
| Timing of surveys: March - Sept |
| Single visit detection probability: Fyke nets captured Macquarie Perch at 100% of sites; gill nets 86%. Spotlighting, boat electrofishing, backpack electrofishing and bait traps had <50% detections (Lintermans 2016). |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Lintermans, M., (2016) Finding the needle in the haystack: comparing sampling methods for detecting an endangered freshwater fish. Marine and Freshwater Research 67, 1740-1749.<br>The Australian Government's Department of the Environment, Water, Heritage and the Arts (2011) Survey guidelines for Australia's threatened fish: guidelines for detecting fish listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999. |

*Detectability estimates are based on surveys in unburnt areas.

## McDowall's Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias mcdowalli* |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: Known only from the headwaters of the Rodger River in the Snowy River National Park, East Gippsland, Victoria. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Raadik, T.A. and Nicol, M.D. (2015). Post-fire recovery of McDowall's Galaxias, and additional aquatic fauna, in East Gippsland 2014–2015. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Gippsland Region. Department of Environment, Land, Water and Planning, Heidelberg, Victoria. |

*Detectability estimates are based on surveys in unburnt areas.

## Non-parasitic Lamprey

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Mordacia praecox* |
| EPBC listed status: Not listed |
| State: NSW QLD Vic |
| Description and habitat: *Mordacia praecox* is a freshwater species of southern topeyed lamprey that occurs in south-eastern Australia. |
| Sampling methods: Electrofishing, trapping |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Moser ML, Butzerin JM, Dey DB (2007) Capture and collection of lampreys: the state of the science. Reviews in Fish Biology and Fisheries 17: 45-56 |

*Detectability estimates are based on surveys in unburnt areas.

## Oxleyan Pygmy Perch

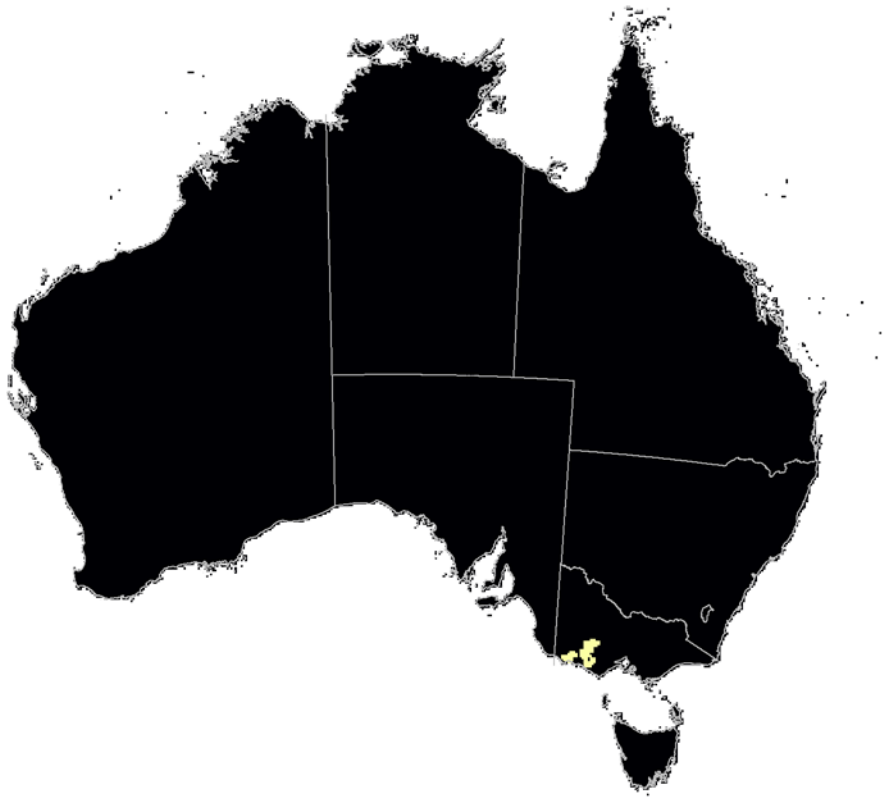
| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Nannoperca oxleyana* |
| EPBC listed status: Endangered |
| State: NSW QLD |
| Description and habitat: Has a patchy distribution confined to freshwater systems draining through sandy coastal lowlands and 'wallam' heaths (Banksia dominated heathlands) between north-eastern NSW and south-eastern Queensland. Requires slow-flowing, fresh, acidic waters with abundant aquatic vegetation. |
| Sampling methods: Trapping, electrofishing |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Ten traps found to provide precise estimates of relative abundance. Traps set for 30-60 min detected all individuals. Knight et al. (2007) recommend saturating sites with unbaited traps for at least 30 min and sampling with an electrofishing backpack. |
| References and further reading:<br>Knight, J., Glasby, T., Brooks, L., 2007. A sampling protocol for the endangered freshwater fish, Oxleyan Pygmy Perch *Nannoperca oxleyana* Whitley. Australian Zoologist 34. |

*Detectability estimates are based on surveys in unburnt areas.

## River Blackfish (south western Victoria)

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Gadopsis* sp. nov. 'Western Victoria' |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: Found in cooler, flowing streams with plenty of rock cover, fallen timber and debris. |
| Sampling methods: Electrofishing, trapping |
| Timing of surveys: No estimates available |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>Khan, M. T., et al. (2004). Habitat use and movement of river blackfish (Gadopsis marmoratus R.) in a highly modified Victorian stream, Australia. Ecology of Freshwater Fish 13(4): 285-293.<br>Koster, W. M. and D. A. Crook (2008). Diurnal and nocturnal movements of river blackfish (Gadopsis marmoratus) in a south-eastern Australian upland stream. Ecology of Freshwater Fish 17(1): 146-154 |

*Detectability estimates are based on surveys in unburnt areas.



## Roundsnout Galaxias

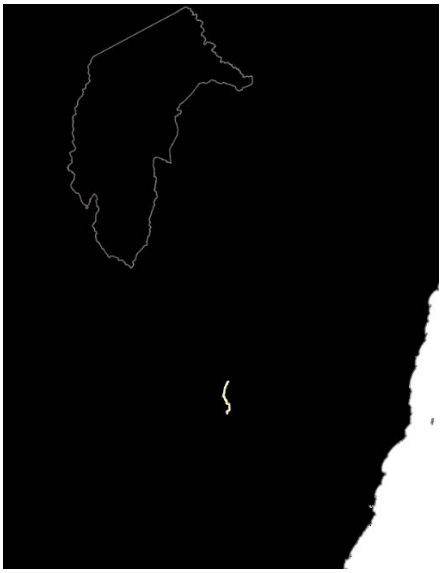
| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias terenasus* |
| EPBC listed status: Not listed |
| State: NSW Vic |
| Description and habitat: Typically found in clear water in slow to moderately flowing creeks to large rivers. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.

## Short-tail Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias brevissimus* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: The Short-tail Galaxias is restricted to upper reaches of the Tuross River system in southern, coastal New South Wales. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.



## Stocky Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias tantangara* |
| EPBC listed status: Not listed |
| State: NSW |
| Description and habitat: This critically endangered species is known only from the type locality: a single stretch of Tantangara Creek, upstream of Tantangara Reservoir, in Kosciuszko National Park, New South Wales. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.

## Swan Galaxias

| |
|---|
| Taxonomic group: Fish |
| Scientific name: *Galaxias fontanus* |
| EPBC listed status: Endangered |
| State: Tas |
| Description and habitat: Lives in freshwater streams free of other fish species except eels. Streams range in size, but are in lightly forested areas with low gradients. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: No estimates available |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.

## Yalmy Galaxias

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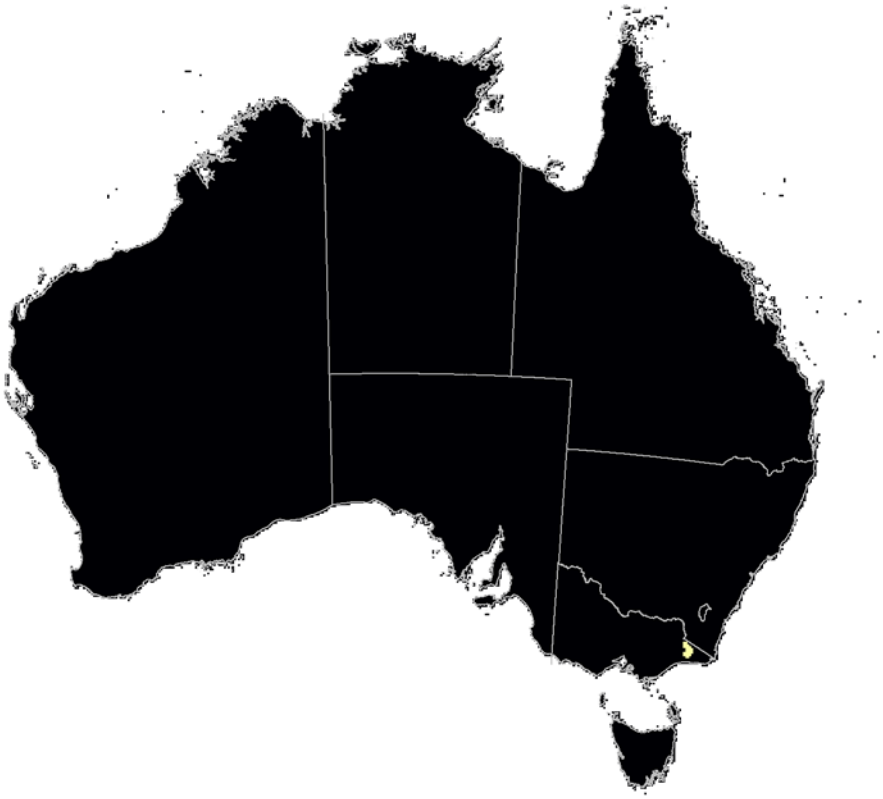
|---|
| Taxonomic group: Fish |
| Scientific name *Galaxias* sp. nov. 'yalmy' |
| EPBC listed status: Not listed |
| State: Vic |
| Description and habitat: Yalmy Galaxias is only known from very small sections of streams in East Gippsland, Victoria. |
| Sampling methods: Electrofishing, fyke nets |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: National guidelines suggest at least 30 min of backpack electrofishing is needed for streams and lake shores. One to two nights with 10 fyke nets usually adequate for detection. |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary |

*Detectability estimates are based on surveys in unburnt areas.



## Spiny crayfish

| |
|---|
| Taxonomic group: Spiny crayfish (species combined) |
| Scientific name: |
| EPBC listed status: |
| State: VIC, NSW, QLD |
| Description and habitat: At least 41 Euastacus crayfish are found in south-eastern Australia, most commonly in permanently flowing upland rivers and streams that are cool and well-oxygenated. Most species have low tolerances to salinity, high water temperatures, habitat degradation and drought. Euastacus crayfish are mostly active in winter and are often endemic to single river systems. |
| Sampling methods: Electrofishing, active burrow search, trapping |
| Timing of surveys: Jan - May |
| Single visit detection probability: No estimates available |
| Minimum survey effort: Minimum of 40 min of electrofishing for streams <4m average width or minimum 60 min for streams with >4m average width. Active searches for burrows by 2 people also recommended, with 12 box-type traps set along 2 transects for a minimum of 8 hours overnight. |
| References and further reading:<br>The State of Victoria Department of Environment, Land, Water and Planning (2018) Forest Protection Survey Program: Survey Design Summary<br>Bryant, D., Crowther, D. and Papas, P. (2012). Improving survey methods and understanding the effects of fire on burrowing and spiny crayfish in the Bunyip and South Gippsland catchments: Black Saturday Victoria 2009 - Natural values fire recovery program. Department of Sustainability and Environment, Heidelberg, Victoria.<br>Department of Sustainability and Environment Approved Standards: Spiny Crayfish Euastacus spp. 2 May 2011<br>*Detectability estimates are based on surveys in unburnt areas. |

## Section 3: Description of primary sampling methods for federally listed priority vertebrates

The choice of sampling method will be determined by the survey objective and target species. Many of the priority species can be detected using 'generic' sampling methods commonly used in inventory surveys, such as pitfall trapping, funnel trapping, cage trapping, Elliott trapping, diurnal active searches etc (Table 1). However, some species might require more specialised equipment or approaches due to their behaviour, ecology or localised habitat requirements. For example, the freshwater turtles listed should require a combination of specialised methods, such as snorkelling or seine netting. A brief description of preferred sampling methods with links to standardised protocols is presented in Table 1.

Table 1: Description of primary sampling methods used to detect target species and links to standardised protocols

| Method | Description | Target species | Considerations and protocols |
|---|---|---|---|
| **Pitfall trapping** | PVC pipe or buckets sunk into the ground, so the rim is level with the surface. A drift fence erected between buckets directs small animals into the bucket traps. | Ground dwelling amphibians, reptiles, mammals, spiders | The number, dimensions (e.g., width and depth of traps) and array of pitfall traps may be influenced by the habitat being surveyed or the target species. Larger animals (e.g., snakes and goannas) can escape. Further discussion on survey protocols can be found at: https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Funnel trapping** | A soft mesh funnel shaped trap that is difficult for animals to escape from due to the shape of the entrances. | Reptiles (especially snakes), but can catch small mammals, ground-dwelling birds, invertebrates | The number and array of traps can be influenced by the habitat being surveyed or the target species. Can be added to pitfall arrays or used independently. Further discussion on survey protocols can be found at https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-reptiles-guidelines-detecting-reptiles-listed |
| **Diurnal active search** | Involves actively searching site for animals present. Can involve turning rocks and logs, looking under bark for cryptic species. | Reptiles, amphibians, small | The optimal time to conduct searches will vary depending on the season, region, target species and local weather |

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| | | mammals, invertebrates | conditions. Surveyors should be aware of observer bias. Further discussion on survey protocols can be found at https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Nocturnal spotlight search** | Involves actively searching a site during night for eyeshine (with a spotlight) or listening for activity | Reptiles, amphibians, small mammals, spiders | Surveyors should be aware of observer bias and local weather conditions. Further discussion on survey protocols can be found at: https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Box trapping** | Collapsible aluminium box traps (e.g. Elliot traps) usually baited | Mammals, but can catch reptiles, amphibians, small birds | The number and arrangement of box traps as well as the bait type will influence the ability to detect species. Further discussion on survey protocols can be found at https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Cage trapping** | Wire mesh cage with a door that closes when a baited trigger is activated | Medium sized mammals | Can have poor detectability compared to camera traps. May not be necessary if the objective is to determine if a species is present. Further discussion on survey protocols can be found at https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Diurnal area bird survey** | Active area search to provide direct census of diurnal bird occurrence or abundance | Birds | Requires highly skilled observers. Bird activity fluctuates widely, although best time to survey is typically in the morning. Time spent surveying will depend on the target species and habitat. Repeat surveys recommended over consecutive days to improve detectability. Further discussion on survey protocols can be found at: |

| | | | |
|---|---|---|---|
| | | | http://www.environment.gov.au/system/files/resources/107052eb-2041-45b9-9296-b5f514493ae0/files/survey-guidelines-birds-april-2017.pdf<br>https://birdata.birdlife.org.au/survey-techniques |
| **Point transect bird survey** | Conducting a series of point surveys along a transect at regular intervals | Birds | See points above<br>http://www.environment.gov.au/system/files/resources/107052eb-2041-45b9-9296-b5f514493ae0/files/survey-guidelines-birds-april-2017.pdf<br>https://birdata.birdlife.org.au/survey-techniques |
| **Camera trapping** | Deploying a fixed digital camera (or array of cameras) to capture images or video of target species. Cameras can be positioned vertically or horizontally depending on the target species. Cameras are usually baited but this depends on the target species. | Mammals, but can detect large reptiles, ground dwelling birds | Careful consideration should be given to the number, arrangement and placement of cameras, as well as camera model and settings. Can be left for long periods of time to increase detectability. Surveys should account for the cost and time required to process large batches of photos. The camera model should remain consistent across space and time. Meek et al. (2014) provides a good summary of camera trapping protocols. |
| **Call playback** | A species call is played to elicit a response from the target species | Birds, mammals | Often conducted during terrestrial bird surveys or before spotlighting. Local weather conditions can influence detectability https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed<br>https://birdata.birdlife.org.au/survey-techniques |
| **Echo-location call detection** | Recordings of bat calls recorded and viewed/analysed on a sonogram. | Mammals | Experienced personnel and specialised equipment required. The choice of bat detector will depend on the purpose and design of the survey. Careful consideration should be given to the local weather conditions<br>http://www.environment.gov.au/system/files/resources/2f420bf1-d9e4-44ec-a69c-07316cb81086/files/survey-guidelines-bats.pdf |
| **Scat and sign search** | Active search of plot for secondary signs of occupancy. Sign includes tracks, scratches, | Mammals, birds, reptiles | The number or incidence of sign is often used as an index of abundance. Consideration should be given to the age of the |

| | | | |
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| | feeding marks, scats, nests, roosts, hair or feathers | | sign as it might remain at a site for much longer than the species. https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-mammals-guidelines-detecting-mammals-listed |
| **Electrofishing** | Either mounted on a boat or backpack. Passes an electrical current through the water, stunning fish so they can be netting and processed | Fish, spiny crayfish | Mostly limited to freshwater https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-fish-guidelines-detecting-fish-listed-threatened |
| **Snorkelling** | Individuals located by searching the sides and bottoms of streams | Reptiles (turtles) | Water clarity influences detectability. Observer skill and experience also has a large effect on detectability. Time spent searching and number of observers influences detectability https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-fish-guidelines-detecting-fish-listed-threatened |
| **Harp trap** | Consist of vertically strung nylon lines held in an aluminium frame above a calico bag. | Mammals (bats) | Useful for detecting the presence of species whose calls cannot be separated or identified using bat detectors http://www.environment.gov.au/system/files/resources/2f420bf1-d9e4-44ec-a69c-07316cb81086/files/survey-guidelines-bats.pdf |
| **Seine netting** | | Reptiles (turtles) | Usually requires special authorisation by the relevant fishing authority. https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-reptiles-guidelines-detecting-reptiles-listed |
| **Automatic acoustic recording** | Sensors deployed remotely to record an individuals vocal behaviour | Birds, mammals, frogs | Recording quality will depend on weather conditions. Can require manual study of sound recordings unless detection is automated. Further information can found in Stowell et al. (2019) |
| **eDNA** | DNA is extracted and then amplified from water or sediment samples. | Potentially all taxonomic groups | Can only determine presence or absence. Requires advanced molecular methods and computational tools. Further information can found in Ruppert et al. (2019). |

## Section 4: Summary of post-fire surveys already underway

There is an urgent need to survey post-fire refugia to assess the immediate impact of the 2019-20 fires on threatened species and ecological communities. Fortunately, post-fire reconnaissance surveys have already been conducted for many threatened species and ecological communities across Australia. These efforts provide valuable insight into the post-fire status of some threatened species. This table summarises which vertebrates have already been surveyed (or are planned to be surveyed as of June 2020) to assess the impact of the 2019-20 bushfires. Please note this table will likely become outdated very quickly as new surveys are established.

| | | | | **Post-fire surveys already underway or planned** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Group** | **Common name** | **Scientific name** | **States were species is found** | **NSW** | **VIC** | **QLD** | **SA** | **WA** | **Birdlife** |
| Birds | Western Ground Parrot | *Pezoporus wallicus flaviventris* | WA | | | | | Yes | Yes |
| Birds | Kangaroo Island Glossy Black-Cockatoo | *Calyptorhynchus lathami halmaturinus* | SA | | | | Yes | | |
| Birds | Rufous Scrub-bird | *Atrichornis rufescens* | NSW QLD | Yes | | Yes | | | Yes |
| Birds | Regent Honeyeater | *Anthochaera phrygia* | ACT NSW QLD SA VIC | Yes | | | | | Yes |
| Birds | Eastern Bristlebird | *Dasyornis brachypterus* | NSW QLD VIC | **Yes** | | Yes | | | Yes |
| Birds | Albert's Lyrebird | *Menura alberti* | NSW QLD | Yes | | Yes | | | |
| Birds | Mainland Ground Parrot | *Pezoporus wallicus wallicus* | NSW QLD VIC | | | Yes | | | |
| Birds | Bassian Thrush (South Australian) | *Zoothera lunulata halmaturina* | SA | Yes | | | | | **Yes** |
| Birds | Black-faced Monarch | *Monarcha melanopsis* | NSW QLD VIC | | | | | | |
| Birds | Rockwarbler | *Origma solitaria* | NSW | | | | | | |
| Birds | Pilotbird | *Pycnoptilus floccosus* | ACT NSW VIC | | | | | | |
| Birds | Superb Lyrebird | *Menura novaehollandiae* | ACT NSW QLD VIC | | | | | | |
| Birds | Red-browed Treecreeper | *Climacteris erythrops* | ACT NSW QLD VIC | | | | | | |
| Birds | Gang-gang Cockatoo | *Callocephalon fimbriatum* | SA VIC NSW ACT | | | | | | |
| Birds | South-eastern Glossy Black-Cockatoo | *Calyptorhynchus lathami lathami* | VIC NSW ACT QLD | | | Yes | | | |
| Birds | Kangaroo Island Western Whipbird | *Psophodes nigrogularis lashmari* | SA | | | | **Yes** | | **Yes** |
| Birds | Kangaroo Island Southern Emu-wren | *Stipiturus malachurus halmaturinus* | SA | | | | **Yes** | | **Yes** |
| Mammals | Kangaroo Island Dunnart | *Sminthopsis griseoventer aitkeni* | SA | | | | Yes | | |
| Mammals | Hastings River Mouse, Koontoo | *Pseudomys oralis* | NSW QLD | | | Yes | | | |
| Mammals | Long-footed Potoroo | *Potorous longipes* | NSW VIC | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Mammals | Kangaroo Island Echidna | *Tachyglossus aculeatus multiaculeatus* | SA | | | | Yes | | |
| Mammals | Mountain Pygmy-possum | *Burramys parvus* | NSW VIC | Yes | | | | | |
| Mammals | Silver-headed Antechinus | *Antechinus argentus* | QLD | | | Yes | | | |
| Mammals | Broad-toothed Rat (mainland) | *Mastacomys fuscus mordicus* | ACT NSW VIC | Yes | Yes | | | | |
| Mammals | Smoky Mouse, Konoom | *Pseudomys fumeus* | ACT NSW VIC | Yes | Yes | | | | |
| Mammals | Koala (QLD, NSW, ACT) | *Phascolarctos cinereus* | ACT NSW QLD | **Yes** | Yes | | | | |
| Mammals | Parma Wallaby | *Notomacropus parma* | NSW QLD | Yes | | | | | |
| Mammals | Yellow-bellied Glider | *Petaurus australis* | NSW QLD SA VIC | | Yes | | | | |
| Mammals | Greater Glider | *Petauroides volans* | ACT NSW QLD VIC | | Yes | | | | |
| Mammals | Brush-tailed Rock-wallaby | *Petrogale penicillata* | NSW QLD VIC | Yes | | Yes | | | |
| Mammals | Long-nosed Potoroo (SE Mainland) | *Potorous tridactylus tridactylus* | NSW QLD SA VIC | | | Yes | | | |
| Mammals | Spotted-tail Quoll | *Dasyurus maculatus maculatus* | ACT NSW QLD VIC | Yes | | Yes | | | |
| Mammals | New Holland Mouse, Pookila | *Pseudomys novaehollandiae* | NSW QLD TAS VIC | | | Yes | | | |
| Mammals | Grey-headed Flying-fox | *Pteropus poliocephalus* | ACT NSW QLD SA VIC | Yes | | | | | |
| Mammals | Golden-tipped Bat | *Phoniscus papuensis* | NSW | Yes | | | | | |
| Mammals | Platypus | *Ornithorhynchus anatinus* | ACT NSW QLD SA TAS VIC | | | | | | |
| Mammals | Mainland Dusky Atnechinus | *Antechinus mimetes* | VIC, NSW, ACT | | | | | | |
| Reptiles | Blue Mountains Water Skink | *Eulamprus leuraensis* | NSW | Yes | | | | | |
| Reptiles | Georges' Snapping Turtle | *Wollumbinia georgesi* | NSW | | | | | | |
| Reptiles | Long Sunskink | *Lampropholis elongata* | NSW | | | | | | |
| Reptiles | Nangur Spiny Skink | *Nangura spinosa* | QLD | | | Yes | | | |
| Reptiles | Bell's Turtle | *Wollumbinia belli* | NSW QLD | Yes | | | | | |
| Reptiles | Manning River Helmeted Turtle | *Myuchelys purvisi* | NSW | Yes | | | | | |
| Reptiles | Broad-headed Snake | *Hoplocephalus bungaroides* | NSW | **Yes** | | | | | |
| Reptiles | Kaputar Rock Skink | *Egernia roomi* | NSW | | | | | | |
| Reptiles | Guthega Skink | *Liopholis guthega* | NSW VIC | | | | | | |
| Reptiles | Alpine She-oak Skink | *Cyclodomorphus praealtus* | NSW VIC | | Yes | | | | |
| Reptiles | Three-toed Snake-tooth Skink | *Coeranoscincus reticulatus* | NSW QLD | Yes | | | | | |
| Reptiles | Alpine Bog Skink | *Pseudemoia cryodroma* | VIC | | Yes | | | | |
| Reptiles | Southern Water-skink | *Eulamprus tympanum* | NSW SA VIC | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Reptiles | Glossy Grass Skink | *Pseudemoia rawlinsoni* | ACT NSW SA TAS VIC | | | | | | |
| Reptiles | Rainforest Cool-skink | *Harrisoniascincus zia* | NSW QLD | | | | | | |
| Reptiles | Moritz's Leaf-tailed Gecko | *Saltuarius moritzi* | NSW | | | | | | |
| Reptiles | Mustard-bellied Snake | *Drysdalia rhodogaster* | NSW | | | | | | |
| Reptiles | Red-tailed Calyptotis | *Calyptotis ruficauda* | NSW | | | | | | |
| Reptiles | Granite Leaf-tailed Gecko | *Saltaurius wyberba* | NSW QLD | | | | | | |
| Reptiles | Broad-tailed Gecko | *Phyllurus platurus* | NSW | | | | | | |
| Reptiles | Oakview Leaf-tailed Gecko | *Phyllurus kabikabi* | QLD | | | Yes | | | |
| Reptiles | Kate's Leaf-tail Gecko | *Saltuarius kateae* | NSW | | | | | | |
| Reptiles | Ringed Thin-tail Gecko | *Phyllurus caudiannulatus* | QLD | | | Yes | | | |
| Frogs | Northern Corroboree Frog | *Pseudophryne pengilleyi* | ACT NSW | Yes | | | | | |
| Frogs | Mountain Frog | *Philoria kundagungan* | NSW QLD | | | Yes | | | |
| Frogs | Pugh's Frog | *Philoria pughi* | NSW | | | | | | |
| Frogs | Sphagnum Frog | *Philoria sphagnicola* | NSW | | | | | | |
| Frogs | Peppered Tree Frog | *Litoria piperata* | NSW | Yes | | | | | |
| Frogs | Southern Corroboree Frog | *Pseudophryne corroboree* | NSW | Yes | | | | | |
| Frogs | Spotted Tree Frog | *Litoria spenceri* | NSW VIC | Yes | Yes | | | | |
| Frogs | Kroombit Tinker Frog | *Taudactylus pleione* | QLD | | | | | | |
| Frogs | Giant Burrowing Frog | *Heleioporus australiacus* | NSW VIC | Yes | | | | | |
| Frogs | New England treefrog, Glandular Frog | *Litoria subglandulosa* | NSW QLD | Yes | | | | | |
| Frogs | Tyler's Toadlet | *Uperoleia tyleri* | NSW VIC | | | | | | |
| Frogs | Littlejohn's Tree Frog, Heath Frog | *Litoria littlejohni* | NSW VIC | Yes | Yes | | | | |
| Frogs | Richmond Range Sphagnum Frog | *Philoria richmondensis* | NSW | | | | | | |
| Frogs | Davies' Tree Frog | *Litoria daviesae* | NSW | | | | | | |
| Frogs | Stuttering Frog, Southern Barred Frog | *Mixophyes balbus* | NSW QLD VIC | Yes | | | | | |
| Frogs | Giant Barred Frog | *Mixophyes iteratus* | NSW QLD | | | | | | |
| Frogs | Fleay's Frog | *Mixophyes fleayi* | NSW QLD | Yes | | Yes | | | |
| Invertebrates | Banksia Montana Mealybug | *Pseudococcus markharveyi* | WA | | | | | | |
| Invertebrates | Eastern Stirling Range Pygmy Trapdoor Spider | *Bertmainius colonus* | WA | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Invertebrates | Banksia brownii Plant Louse | *Trioza barrettae* | WA | | | | | | |
| Invertebrates | Bathurst Copper Butterfly | *Paralucia spinifera* | NSW | **Yes** | | | | | |
| Invertebrates | Alpine Stonefly | *Thaumatoperla alpina* | VIC | | Yes | | | | |
| Spiny crayfish | Arte Spiny Crayfish | *Euastacus sp. 1* | VIC | | | | | | |
| Spiny crayfish | Cann Spiny Crayfish | *Euastacus sp. 2* | VIC | | | | | | |
| Spiny crayfish | West Snowy Spiny Crayfish | *Euastacus sp. 3* | VIC | | | | | | |
| Spiny crayfish | Tianjara Crayfish | *Euastacus guwinus* | NSW | | | | | | |
| Spiny crayfish | Small Crayfish | *Euastacus spinichelatus* | NSW | | | | | | |
| Spiny crayfish | Smooth Crayfish | *Euastacus girurmulayn* | NSW | | | | | | |
| Spiny crayfish | Ellen Clark's Crayfish | *Euastacus clarkae* | NSW | | | | | | |
| Spiny crayfish | Orbost Spiny Crayfish | *Euastacus diversus* | VIC | | | | | | |
| Spiny crayfish | Hairy Cataract Crayfish | *Euastacus pilosus* | NSW | | | | | | |
| Spiny crayfish | East Gippsland Spiny Crayfish | *Euastacus bidawalus* | VIC | | | | | | |
| Spiny crayfish | Alpine Crayfish | *Euastacus crassus* | ACT NSW VIC | | | | | | |
| Spiny crayfish | Gamilaroi Spiny Crayfish | *Euastacus gamilaroi* | NSW | | | | | | |
| Spiny crayfish | Blue-Black Crayfish | *Euastacus jagabar* | NSW | | | | | | |
| Spiny crayfish | Sutton's Crayfish | *Euastacus suttoni* | NSW QLD | | | | | | |
| Spiny crayfish | Clayton's Spiny Crayfish | *Euastacus claytoni* | NSW VIC | | | | | | |
| Spiny crayfish | Bloodclaw Crayfish | *Euastacus gumar* | NSW | | | | | | |
| Spiny crayfish | Mud Gully Crayfish | *Euastacus dalagarbe* | NSW | | | | | | |
| Spiny crayfish | Many-bristled Crayfish | *Euastacus polysetosus* | NSW | | | | | | |
| Spiny crayfish | Riek's Spiny Crayfish | *Euastacus reiki* | NSW | | | | | | |
| Spiny crayfish | Small Mountain Crayfish | *Euastacus simplex* | NSW | | | | | | |
| Spiny crayfish | Jagara Hairy Crayfish | *Euastacus jagara* | NSW | | | | | | |
| Spiny crayfish | Morgan's Crayfish | *Euastacus morgani* | NSW | | | | | | |
| Fish | Yalmy Galaxias | *Galaxias sp. nov. 'yalmy'* | VIC | | | | | | |
| Fish | McDowall's Galaxias | *Galaxias mcdowalli* | VIC | | | | | | |
| Fish | East Gippsland Galaxias | *Galaxias aequipinnis* | VIC | | | | | | |
| Fish | Stocky Galaxias | *Galaxias tantangara* | NSW | Yes | | | | | |
| Fish | Dargo Galaxias | *Galaxias mungadhan* | VIC | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Fish | Short-tail Galaxias | *Galaxias brevissimus* | NSW | Yes | | | | | |
| Fish | Flathead Galaxias | *Galaxias rostratus* | NSW SA VIC | | | | | | |
| Fish | Honey Blue-eye | *Pseudomugil mellis* | QLD | | | Yes | | | |
| Fish | Roundsnout Galaxias | *Galaxias terenasus* | NSW VIC | | | | | | |
| Fish | River Blackfish (south western Victoria) | *Gadopsis sp. nov. 'Western Victoria'* | VIC | | | | | | |
| Fish | Swan Galaxias | *Galaxias fontanus* | TAS | | | | | | |
| Fish | Oxleyan Pygmy Perch | *Nannoperca oxleyana* | NSW QLD | Yes | | Yes | | | |
| Fish | Non-parasitic Lamprey | *Mordacia praecox* | NSW QLD VIC | | | | | | |
| Fish | Clarence River Cod, Eastern Freshwater Cod | *Maccullochella ikei* | NSW | | | | | | |
| Fish | Macquarie Perch 'MDB taxa' | *Macquaria australasica 'MDB taxa'* | ACT NSW VIC | Yes | | | | | |
| Fish | Cann Galaxias | *Galaxias sp. 17 'Cann'* | VIC | | | | | | |
| Fish | Blue Mountains Perch, Hawkesbury Perch | *Macquaria sp. nov. 'hawkesbury taxon'* | NSW | | | | | | |

# Section 5: Species distribution models and spatial prioritisation

## Background

Post-fire surveys are critical for assessing the immediate impact of bushfires on native species and ecological communities. Organisations might conduct a rapid inventory of plants and animals following a large intense fire to: assess the survival rate of individuals and populations (Banks et al. 2011); determine whether populations were extinguished, or at worst, species driven to extinction; identify the presence and quality of post-fire refugia to aid population recoveries (Robinson et al. 2013); measure the presence and intensity of threats (Russell et al. 2003), and; assess the response of species and communities to variations in fire characteristics, such as fire severity (Lindenmayer et al. 2013). Such information, if collected appropriately, can improve understanding of the response of species to large catastrophic disturbances and help prioritise post-fire management actions to aid recovery (Rouget et al. 2003).

Fortunately, post-fire reconnaissance surveys have already been conducted for many threatened species and ecological communities across Australia (see section 4). These efforts have provided valuable insight into the post-fire status of some threatened species. However, threatened species monitoring in Australia is primarily the responsibility of state government organisations and private land management agencies, with generally no overarching coordination across jurisdictions. This makes it difficult to keep track of how and where species are being surveyed across the full extent of their range or across jurisdictional boundaries. There is a need to collate existing post-fire reconnaissance surveys to identify species and regions currently under-represented in surveys.

In this section, we conducted a gap-analysis to prioritise new regions for surveys within the fire zone to assess the immediate impact of the 2019-20 fires on 114 priority vertebrates and crayfish (plus two additional species, Tyler's Toadlet and Swan Galaxias, which were included on the preliminary priority list). More specifically, the aims of this section were threefold. Firstly, we built species distribution models to predict the pre-fire distribution of priority species, where possible, using high-resolution environmental predictor variables and up-to-date occurrence records. Secondly, we mapped the location of post-fire surveys already underway across Australia. Thirdly, we combined our species distribution models and maps of existing surveys with recently developed national fire severity maps in a spatial optimisation to identify priority regions for new surveys. This section can inform where to conduct new reconnaissance surveys to ensure adequate representation across species and regions.

## Building species distribution models

### *Data collation and screening*

We collated species occurrence records for the 116 species from four state-specific databases: 1) New South Wales BioNet Atlas; 2) Victorian Biodiversity Atlas; 3) Queensland WildNet database, and; 4) Biodiversity Databases of South Australia. Occurrence records were also collated from the Atlas of Living Australia (ALA) and Global Biodiversity Information Facility (GBIF) using the *ala4R* and *spocc* packages in R, respectively (Chamberlain 2020, Newman et al. 2020). ALA and GBIF contained a broader range of data sources, including reference specimen in museum collections, and, to a lesser extent,

opportunistic recordings from volunteers. While these data were more likely to contain quality issues (Thessen and Patterson 2011), they were nevertheless important sources of information, particularly for some less well-sampled species. Several species names were also not referenced by taxonomic checklists (e.g. GBIF Taxonomic Backbone), so synonyms were also searched for and manually merged.

We screened occurrence records using the *CoordinateCleaner* package in R (Zizka et al. 2019). Specifically, we checked for coordinate errors, including missing or invalid coordinates; equal longitude and latitude; coordinates falling into the ocean; state and national centroids; capital cities, or specimen collection institutions. We removed records dated before 1970 and those with coordinate uncertainty that was either >1000 m or unknown. A cut-off of 1970 was chosen to increase the number of species we could fit models to; however, we note that very few older records were retained due to the threshold in spatial accuracy. We then overlaid the remaining records on a 250 x 250 m raster grid of Australia and filtered records to ensure there was only one per species in a cell. Finally, records were visually inspected for any remaining outliers. Species with records in <20 grid cells were excluded from the modelling, as such few records were unlikely to support accurate and detailed distribution predictions (Guisan et al. 2017).

***Spatial covariates***

We collated a set of 52 topographic, climatic and environmental variables thought to influence the distribution of the priority species. All layers were reprojected at 250m resolution using QGIS 3.2 in the Australian Albers (GDA94) coordinate reference system. To refine our list of spatial variables, we calculated the variance inflation factor (VIF) using the *usdm* package (Naimi et al. 2014) in R to detect strong correlations between two of more predictor variables. Highly correlated variables with a correlation coefficient greater >0.7 and a VIF >10 were removed from the analysis (Naimi et al. 2014). This resulted in a total of 13 variables for inclusion: mean diurnal temperature range, isothermality, precipitation of warmest quarter, precipitation of coldest quarter, highest period radiation, radiation of wettest quarter, radiation of driest quarter, moisture index seasonality, mean aspect slope, slope, topographic wetness index, NDVI, native vegetation in neighbourhood. We added a further 3 variables after preliminary model fitting to capture environmental range limits: elevation, maximum temperature in warmest quarter, coldest temperature in coldest quarter.

***Model fitting and evaluation***

We modelled habitat suitability for the 116 species with presence-only data using *MaxNet* models (using the R package maxnet: Phillips, 2017). *MaxNet* is a regularized logistic regression model based on the interpretation of the frequently used Maxent model (Phillips et al. 2006; Elith et al. 2011) as an inhomogeneous point process model (Renner and Warton, 2013; Fithian and Hastie 2013). We used cross-validation to tune the regularisation parameter of *MaxNet*, as this is known to have a considerable impact on the model's performance (Muscarella et al. 2014). To further control for overfitting, we allowed for all features (linear, quadratic, product, hinge) on fitted response curves initially, but restricted feature types for range-restricted species that are hard to fit complex models with.

A common challenge to presence-only models is that sampling bias can be confused with occurrence intensity. To mitigate this, we used target-group-background samples (Phillips et al. 2009) when applicable (when there were more than 1000 records from the same taxa

per state with occurrence records), otherwise, we generated 10,000 random sample from the background landscape (i.e. states in which the species is found, or in the case of Kangaroo Island endemic species, Kangaroo Island). The random background samples were taken with a higher intensity towards roads and cities to take account for accessibility bias, using a 1-km resolution travel-distance-to-cities layer (Weiss et al. 2018). We evaluated the predictive performance of the models using two threshold-independent metrics calculated in a 5-fold cross-validation setting: the area under the ROC curve (AUC) (Jimenez-Valverde 2012) and the continuous Boyce index (Hirzel et al. 2006).

***Mapping species distributions***

We predicted the distribution of species across the state(s) in which occurrence data were recorded. For species with <20 occurrence records, we collated 'most likely' or 'known' range maps from the Commonwealth Department of Agriculture, Water and the Environment Species of National Environmental Significance database. Range maps for crayfish were obtained from the Geospatial & Information Analytics section of the Department of Agriculture, Water and the Environment. All predictions for crayfish and fish were clipped to a rasterized permanent stream network for Australia, obtained from the GeoScience Australia website at 250m resolution. We also masked predictions of species known only to occur on Kangaroo Island from the mainland. The predicted distribution for 65 priority species is presented in Section 2, with range maps presented for the remaining species.

**Spatial prioritisation**

We used the spatial prioritisation tool Zonation (Lehtomaki and Moilanen 2013) to identify regions for surveys throughout the landscape that ensured adequate representation of all priority species across a range of fire severity classes, while accounting for existing surveys already underway. Zonation is commonly used to address conservation planning questions, such as where to establish conservation reserves, where target habitat restoration or establish new developments. It works using a reverse stepwise heuristic which iteratively removes cells from the landscape based on their biodiversity value (in this case habitat suitability) while maintaining connectivity (Cabeza et al. 2004). This generates a hierarchical ranking of cells from 0 to 100 in the landscape, with the top ranked areas maximising the representation of all included biodiversity components (in this case priority species).

We obtained a national fire severity map at 40m resolution developed by The Remote Sensing and Landscape Science Branch, Science Economics and Insights Division, New South Wales Department of Planning, Industry and Environment. Fire severity was categorised into 5 classes ranging from 1 (unburnt) to 5 (high severity). We clipped the fire severity map to southern Australia, removed fires outside of the study region (such as the deserts of WA and SA) and reprojected the map to 250m resolution to align with the species distribution models. We created a 5km buffer of unburnt habitat around burnt cells and reclassified fire severity into three classes: unburnt (fire severity class 1 and the unburnt buffer); low severity (classes 2 and 3), and; high severity (classes 4 and 5). We then masked the distribution or range map for each species three times to create one layer for each fire severity class. For example, we made one layer predicting habitat suitability for species A in unburnt habitat, another layer predicting habitat suitability of species A in low severity habitat, and so forth.

Using the information presented in Section 4, we mapped the location of existing post-fire surveys already underway across Australia and used this map as a 'removal mask' in Zonation. We obtained the point coordinates of survey locations and reprojected them to the Australian Albers (GDA94) coordinate reference system. We rasterized these points and created a 1km buffer around each survey location. In our Zonation analysis, priorities were generated in a two-level hierarchy so that existing survey locations were 'locked in' as a higher priority than the rest of the landscape. This meant regions not yet surveyed were prioritised so that they cover as efficiently as possible the combination of species and fire severity classes that are poorly represented in existing surveys (i.e. the gaps).

We weighted species by their vulnerability to the fires using the results of a risk assessment presented by Legge et al. (2020). They used expert opinion to assess the combined risk for each species due to imperilment and pre-fire range overlap with fire extent. Species that had large amounts of their range burnt and have traits that make them more susceptible to fires (i.e. low dispersal ability) were weighted higher than others. Giving species different weightings influenced the balance achieved between features in any selected fraction of the landscape. We ran the Zonation analysis for all priority vertebrates (using the range maps for the species we could not fit models to) as well as separately for each species group.

**Results**

In total, we fitted species distribution models to 65 of 116 species (16 of 17 birds; 19 of 20 mammals; 15 of 23 reptiles; 12 of 17 frogs; 2 of 22 crayfish; 1 of 17 fish), with the number of occurrence records per species ranging from 21 to 18344. The spatial prioritisation for all species highlighted important areas distributed within or on the edge of the burnt area (cells equal to 100 have the highest priority; Figure 1 - 7). The highest ranked areas (some of which are already surveyed) included Kangaroo Island, East Gippsland, southern ACT and north-eastern NSW. Priority regions for surveys depended on whether all species are considered together, or whether each group was run separately. The species distribution models and results of the spatial prioritisation can be updated over time as new pre-fire occurrence records become available for species and when new post-fire monitoring sites are established. The spatial prioritisation could also be expanded to weight cells by accessibility (i.e. distance to nearest road or township) or by distance to the burnt/unburnt edge.

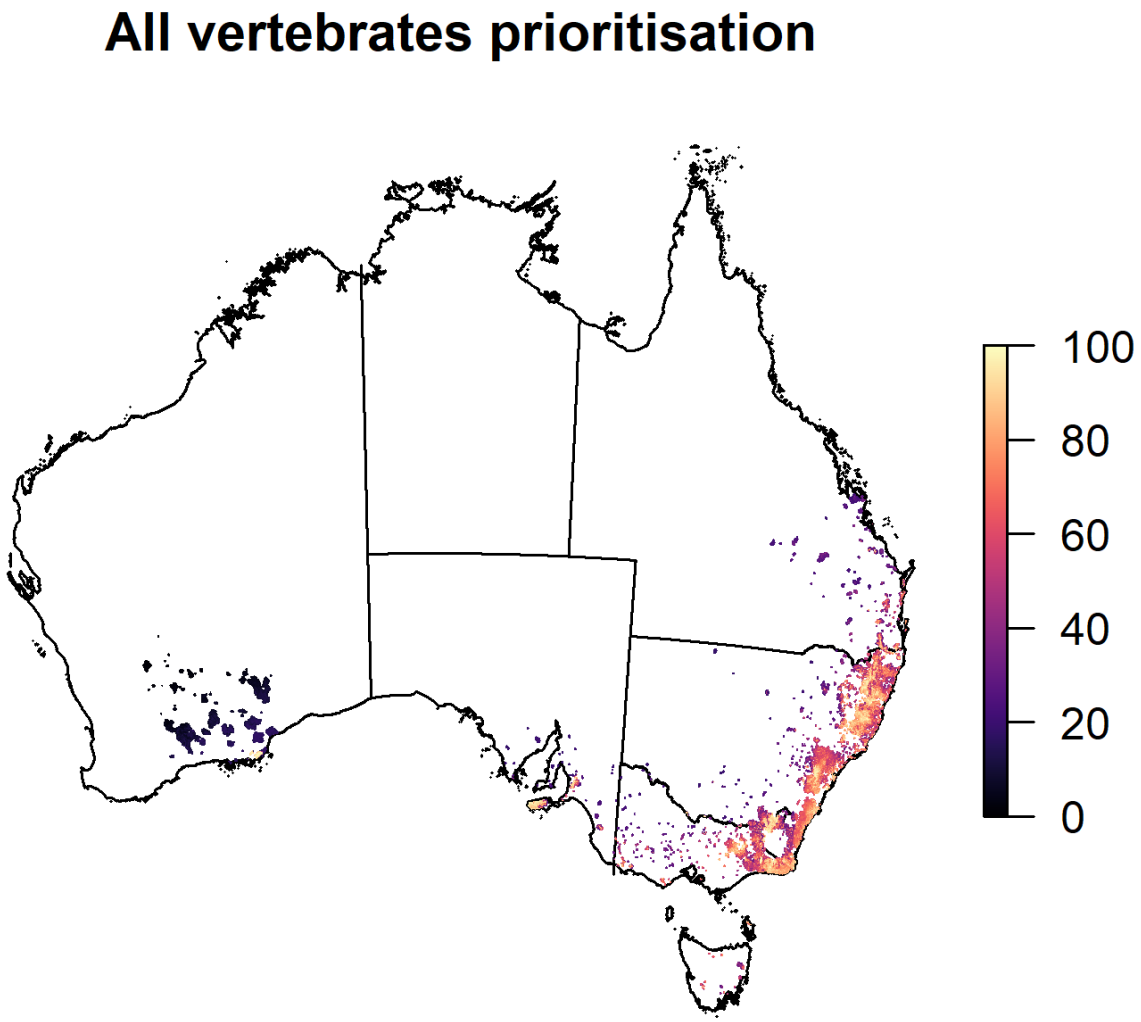


Figure 1: Priority regions for new post-fire surveys for all priority vertebrates both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

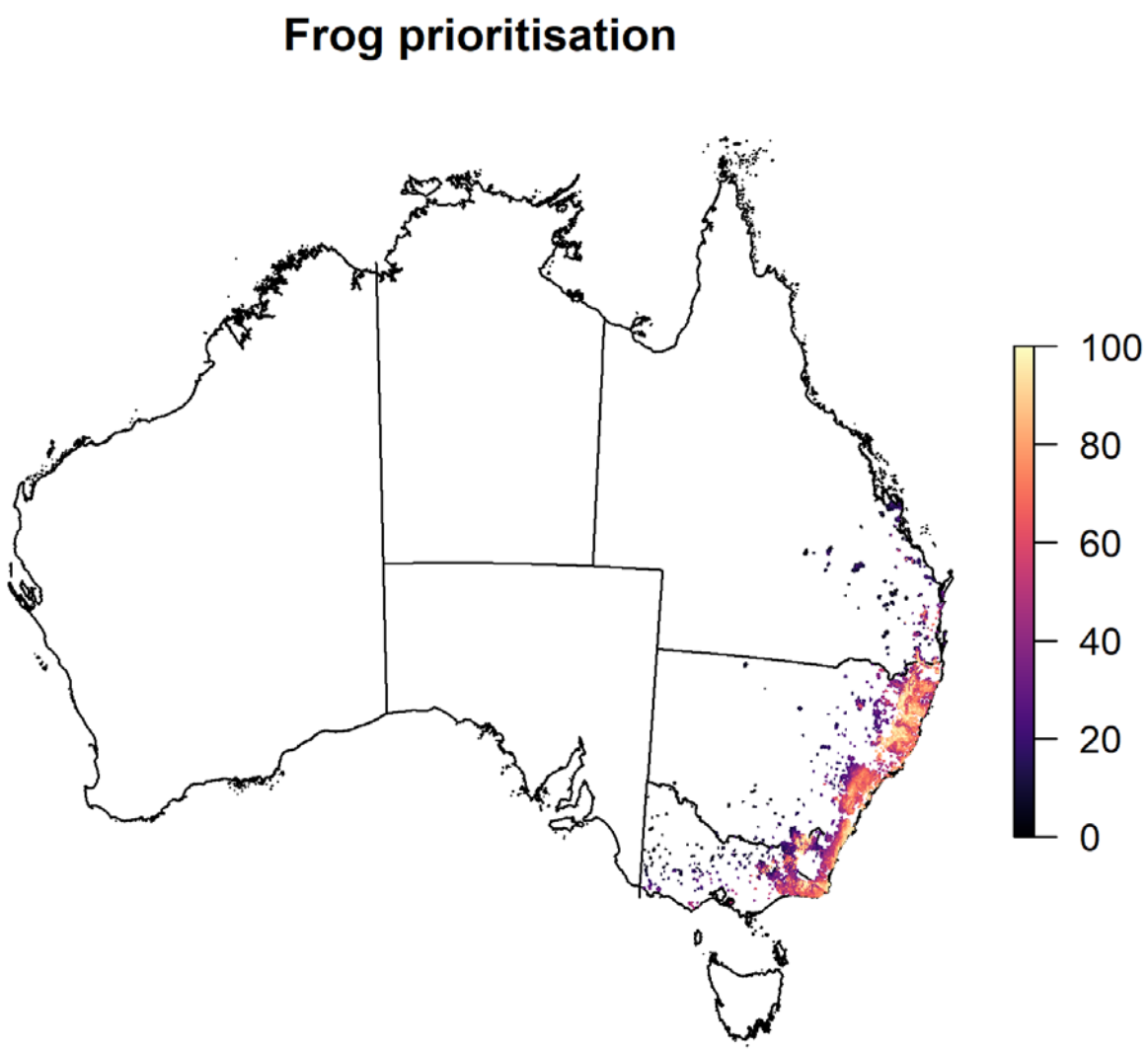


Figure 2: Priority regions for new post-fire surveys for priority frogs both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

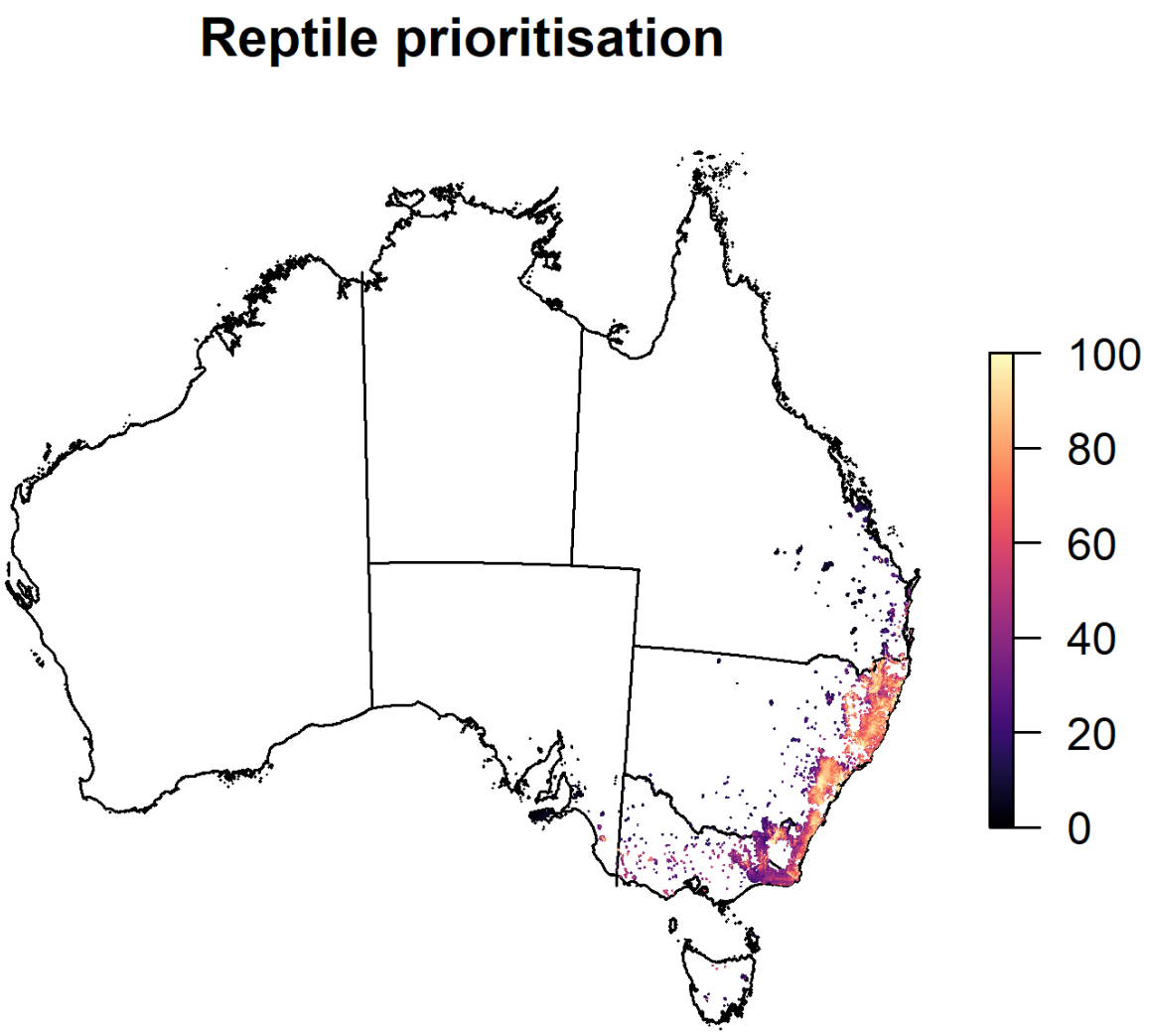


Figure 3: Priority regions for new post-fire surveys for priority reptiles both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

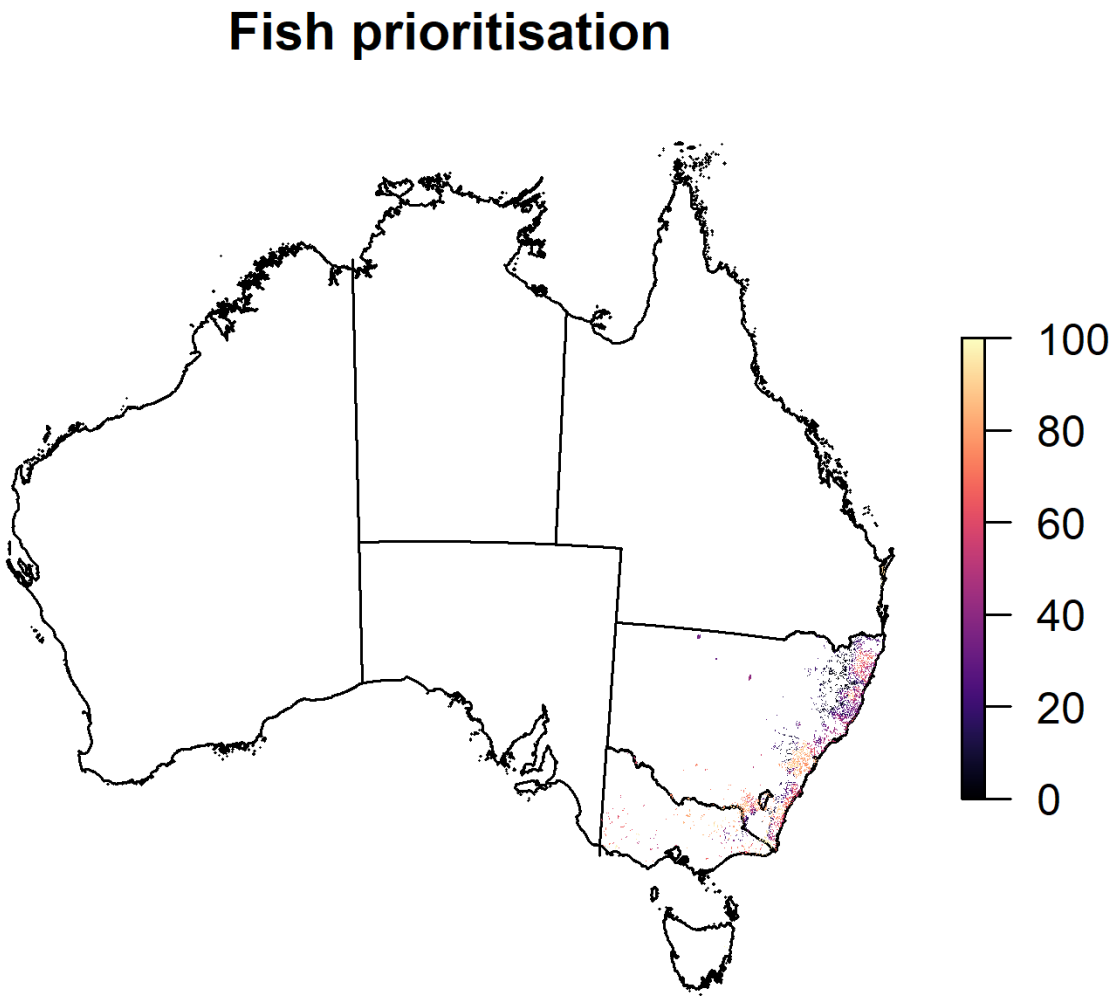


Figure 4: Priority regions for new post-fire surveys for priority fish both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

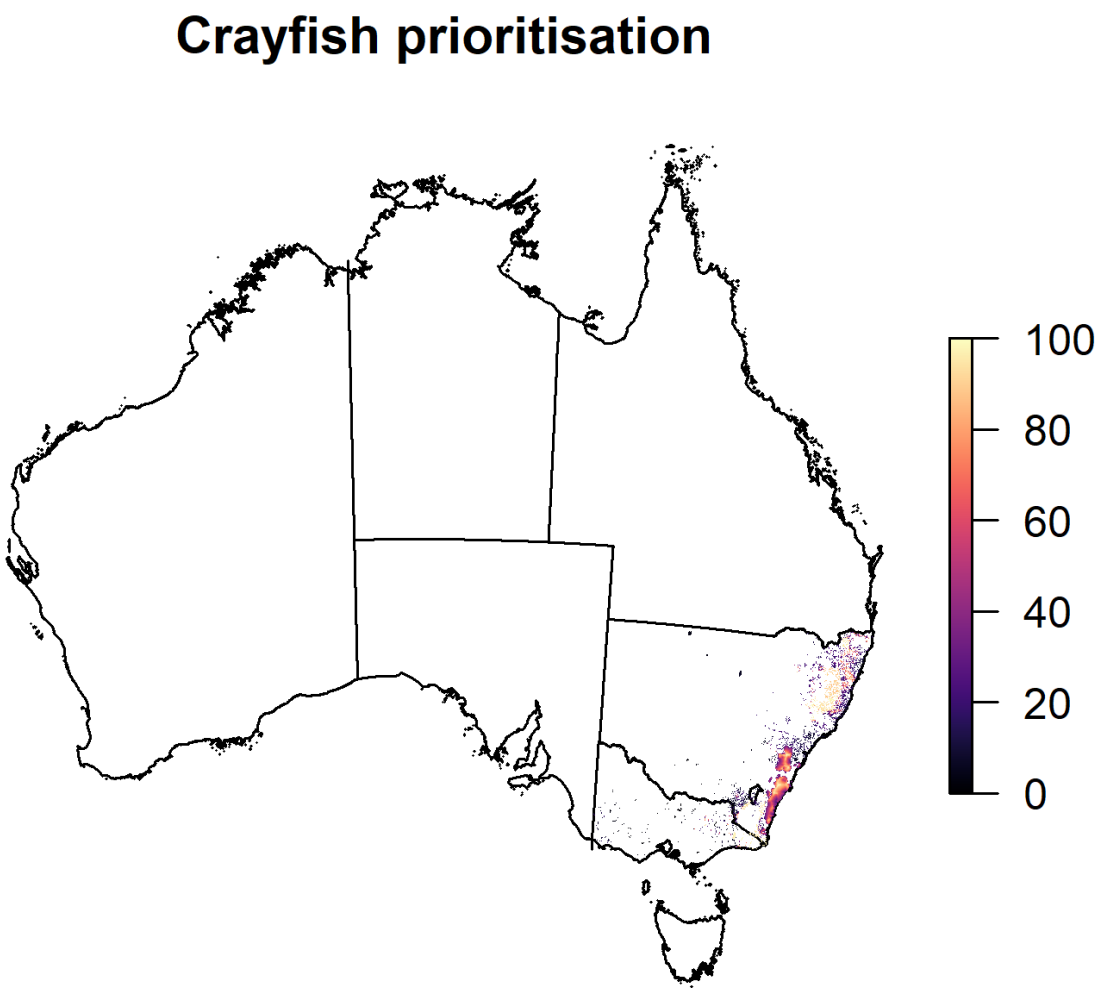


Figure 5: Priority regions for new post-fire surveys for priority crayfish both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

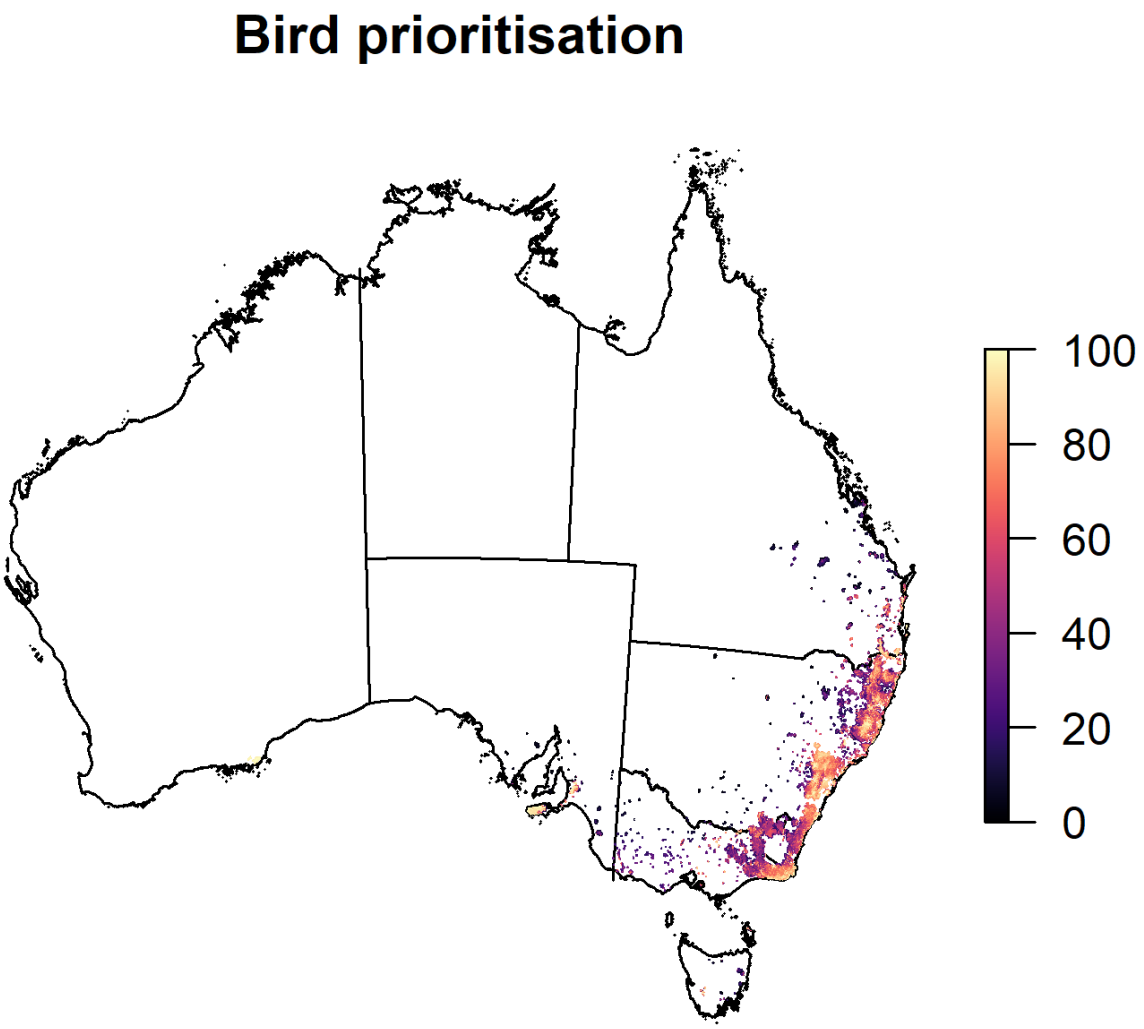


Figure 6: Priority regions for new post-fire surveys for priority birds both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

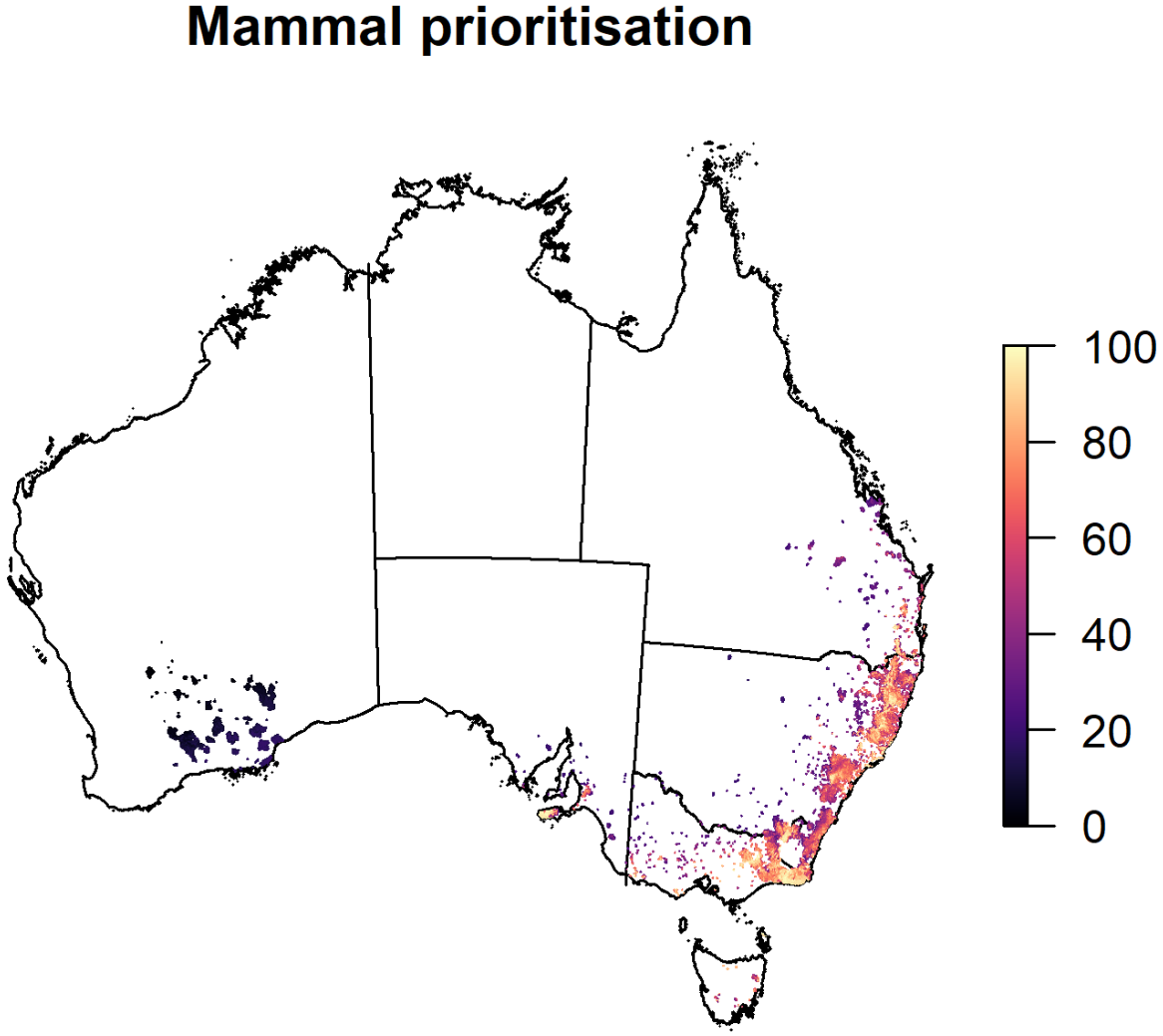


Figure 7: Priority regions for new post-fire surveys for priority mammals both in the burnt zone and within 5 km from the edge. Yellow shading represents regions of highest priority (100), purple shading represents regions of moderate priority (50), while black represents regions of lowest priority.

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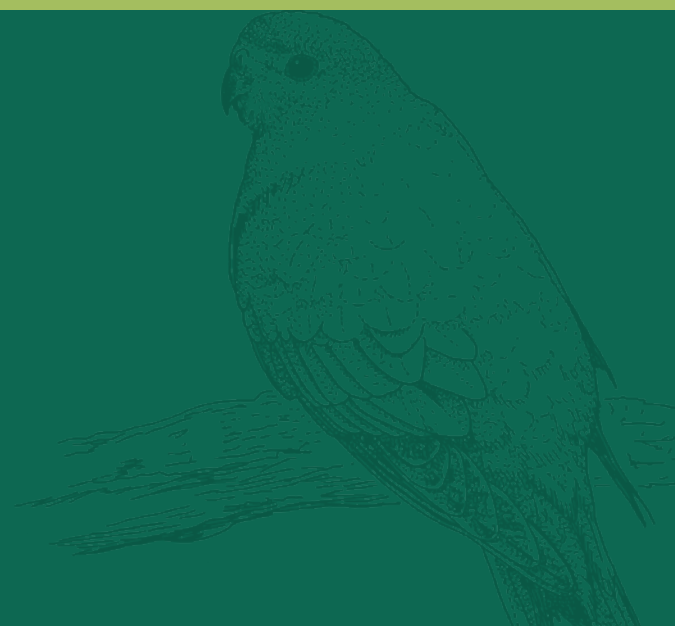

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