Bushfire Recovery Program 2020–2021: Priority actions for threatened species in Bulburin National Park

South East Queensland

2023

Queensland Government

Prepared by: Threatened Species Operations, Department of Environment and Science

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Front cover: Rainforest burnt in Bulburin National Park. (Photo: T. B. Churchill)

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Executive summary

The bushfires of late 2019 to early 2020 had extensive ecological impacts across eastern Australia. The most fire-impacted threatened species in Queensland were prioritised for recovery efforts through an expert evaluation process led by the Department of Environment and Science (DES), in collaboration with the Australian Government's 'Wildlife and Threatened Species Bushfire Recovery Expert Panel'. In March 2020, the Queensland Bushfire Recovery Program was established with assistance from the Australian Government's Bushfire Recovery for Wildlife and their Habitats initiative to implement recovery projects across strategic locations, including Bulburin National Park (NP). At this park, three threatened species were identified as the most fire-impacted: the silver-headed antechinus *Antechinus argentus*; the ringed thin-tailed gecko *Phyllurus caudiannulatus*; and the Bulburin nut *Macadamia jansenii*.

It was recognised that whilst the conservation status of invertebrate fauna was poorly documented, many endemic taxa were likely impacted by the fires and worthy of recovery efforts. Accordingly, in collaboration with Queensland Museum specialists, seven insect and eight spider species were identified for targeted surveys.

Recovery actions were undertaken between May 2020 and June 2021, including:

- **Post-fire assessment**—detailed spatial evaluation of fire extent and severity, and the associated ecological impacts, to guide the survey of priority species and on-ground efforts to reduce threats to their recovery.
- **Ecological survey**—field assessment of the status of priority species by experts using best-practice techniques, to set a baseline to track recovery and to compare to pre-fire data, where available.
- **Reduce threats to recovery**—on-ground actions to reduce the risk to priority species and their habitats from future unplanned fires, invasive weeds and pest animals.
- **Recommendations and guidance**—assessment of the information and insights gained from the previous actions to provide recommendations for reducing threats, ecological monitoring and research.

The post-fire assessment (Melzer *et al.* 2020) documented that 7,542 hectares (ha) burned across Bulburin NP, which represented 22% of the total park area. Fire severity was predominantly low to moderate (89% of the burnt area), with impacts ranging from scorched understorey to partial canopy scorch. Almost 10% of the area burnt was at high severity, with significant impacts to the tree canopy. For a given level of fire severity, the ecological impacts can vary across different vegetation types based on their fire-tolerance. Fire severity was therefore incorporated with the fire-sensitivity of vegetation to spatially quantify the 'potential ecological impact' (PEI) (Laidlaw *et al*. 2022), which revealed a moderate to catastrophic level of impact for the fire-sensitive rainforest ecosystems (Melzer *et al.* 2020). A total of 2,116ha of rainforest burnt (23% of the rainforest on park) with slow recovery, structural and compositional changes and loss of rainforest-dependent species of significant concern (Melzer *et al.* 2020).

Silver-headed antechinus surveys were guided by a potential habitat model (see Laidlaw & Butler 2021) based on previous records, which estimated that a third of suitable habitat had burnt during the 2019–2020 fires in Bulburin NP (Melzer *et al.* 2020). Two surveys were conducted a year apart, which confirmed their presence at both burnt and unburnt sites, successful breeding post-fire and capture rates comparable to pre-fire surveys. To sustain ongoing support for their recovery it is recommended to continue monitoring, control introduced predators, manage fire and weeds to protect rainforest habitats and undertake research to understand habitat preferences and distribution.

Survey sites for the ringed thin-tailed gecko were identified using a habitat model, which calculated that 28% of this habitat in Bulburin NP was burnt (Melzer *et al.* 2020), including many critical habitat features such as large fig trees and fallen logs. The species was only detected in burnt sites where particular habitat features (e.g. fig trees) remained unburnt. The mobility of this species suggests a capacity to recolonise rainforest with low severity burns. Recommendations include sustained monitoring, protecting rainforest and habitat features from fire and reducing the impacts of feral pigs and weeds.

Of the eight priority invertebrate species, only four were recorded during the post-fire surveys in Bulburin NP. All species are flightless and geographically restricted in their range, limiting their capacity to recolonise burnt rainforest habitats. Recovery requires protecting rainforest habitats from fire and weed incursion and impacts from pigs and cane toads. The Bulburin pelican spider *Austrarchaea aleenae* was significantly impacted by the fires. Individuals were found on both unburnt sites and half of the burnt sites, with the latter being a male and a juvenile, indicating dispersal to burnt localities. Population recovery depends on unburnt remnant patches of leaf litter microhabitats, which are at risk from even low severity fires. Post-fire recovery requires ongoing protection of their rainforest habitats from fire, weed incursions and damage by feral pigs. These actions will also support the Bulburin flat ground spider *Desognaphosa bulburin*, which is only known from Bulburin NP.

An estimated 15% of the modelled potential habitat of the Bulburin nut was burnt within Bulburin NP during the 2019–2020 bushfires (Melzer *et al.* 2020). Four of the five pre-existing populations were assessed for post-fire survival and

regeneration, with the fifth population not impacted by the 2019–2020 fires. Of the two sites where Bulburin nut had been reintroduced, one was fire-impacted and therefore surveyed. There was a range of impacts across sites, from mature tree mortality through to no effect due to the patchiness of the fire. Based on pre-fire surveys, the impacts could be quantified, with 35 trees (17.5% of total population) killed by the fire, the majority being seedlings but also three mature trees over 6m tall. Surviving Bulburin nut trees were found to be reshooting from the base, and germination from seed was recorded. Protecting the populations from fire and invasive weeds is critical, as well as ongoing monitoring to track the post-fire recovery of wild populations and research to understand how to sustain the genetic diversity of Bulburin nut populations.

In addition to the existing park management program, actions were undertaken to reduce key threats to the initial post-fire recovery of priority species. To reduce the risk from future fires, a critical 5.9km fireline was upgraded to enhance QPWS capacity to control bushfires, particularly associated with the Bulburin nut. To reduce the impacts of habitat damage, weed incursions and seedling loss due to wandering cattle, a 5.7km cattle-exclusion fence was established between Bulburin NP and a neighbouring property. The threat of predation on the priority gecko and antechinus species was reduced through targeted baiting of foxes and wild dogs across the park. Potential impacts on the recovery of priority species from the spread of high-biomass grasses was reduced through control efforts by Gidarjil Indigenous Land and Sea Rangers, and from lantana by park rangers. The release of biological control agents with Bundaberg Regional Council aimed to reduce the spread of cat's claw creeper *Dolichandra unguis-cati*, with ongoing releases planned.

A range of project lessons are outlined with forward recommendations, including applying the National Disaster Risk Reduction Framework for protecting life and property to the context of protecting wildlife, to sustain ongoing investment to reduce the key threats to the recovery of threatened species, and to mitigate the increasing risk of extinctions due to climate change. To more effectively prioritise and guide conservation and threat management actions, there is an urgent need to improve the availability of high-quality ecological data. To enhance the ability to provide recovery actions for wildlife, especially amidst a broad-scale natural disaster, it is important to build capacity in the relevant specialist ecological and technical skills and maintain relationships with external specialists to expedite assessment of wildlife impacts to implement the most appropriate recovery actions. Ongoing investment is necessary to sustain best-practice methodologies and embrace more cost-effective technologies to support ecological monitoring.

1 Context

1.1 2019–2020 bushfires

The Australian bushfire season of 2019–2020 was extraordinary in terms of its extent, duration and intensity. The year of 2019 was the hottest and driest on Australian records and the Forest Fire Danger Index exceeded all previous values (Bureau of Meteorology 2020). Over 24 million ha burned, impacting at least 37 ecological communities and 330 species listed as nationally threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA) (Binskin *et al*. 2020) and almost three billion mammals, reptiles, birds and frogs (WWF 2020). Fire-sensitive communities such as rainforests experienced an historic increase in fire severity (Collins *et al*. 2021), with associated wildlife having limited capacity to recover. At least 20 nationally threatened species have been pushed closer to extinction and the long-term ecological consequences of these fires are of serious concern (Woinarski *et al*. 2020).

Quantifying the impact on invertebrates is difficult given inadequate knowledge of their taxonomy, distribution and ecology. Only a third of species are considered described, yet an analysis of the fire impacts on known taxa found that they contributed 95% of fauna species with a distributional overlap of 50% or more with the fires (Marsh *et al*. 2021). Moreover, 382 invertebrate taxa had their entire known range burnt (Marsh *et al*. 2022). The fires are estimated to have caused the extinction of 700 invertebrate species (Lee 2020) and fire impacts can persist for many decades (Henry *et al*. 2022).

In Queensland, over 7.7 million ha burned (Queensland Reconstruction Authority, 2020), which included more than 1.6 million ha of protected areas and 12,000ha of Ramsar wetlands (Threatened Species Operations 2020). At least 648 threatened species were impacted, including 631 listed as threatened under the state *Nature Conservation Act 1992* (NCA) and 266 listed under the EPBCA, of which 21 were Critically Endangered (Threatened Species Operations 2020). In southern Queensland, the preceding extensive drought (Bureau of Meteorology 2020) had already reduced habitat condition and availability of water and food resources, exacerbating fire impacts on wildlife. Normal refugia of gullies, rocky outcrops and rainforests were unpredictably burnt (e.g. Hines *et al*. 2020), which would have had significant consequences for wildlife during the fire, as well as for their post-fire recovery.

1.2 Queensland Bushfire Recovery Program

In January 2020, DES initiated a desktop process to evaluate the spatial extent of the fires relative to the likely habitat for species listed as threatened under the NCA. For species with the greatest area of burnt habitat, experts interpreted the potential fire impacts and the main threats to their recovery. These outcomes were then compared to a broader scale study by the Commonwealth Wildlife and Threatened Species Bushfire Recovery Expert Panel for species listed as Threatened under the EPBCA. An agreed list of priority species and ecological communities then qualified for emergency support under Phase 1 of the Australian Government's $200 million Bushfire Recovery for Wildlife and their Habitats package.

In March 2020, the Australian Government supported DES through Phase 1 Emergency Response funding of $1.5 million for the delivery of prioritised actions through to June 2021. The Department established the Queensland Bushfire Recovery Program, led by Threatened Species Operations unit within the Queensland Parks and Wildlife Service (QPWS). The first phase of the program included four projects representing strategic locations of fire-impacted threatened species: Gondwana Rainforests of Australia World Heritage Area; Coastal wallum-heath of the Cooloola area; Oakview and Nangur National Parks; and Bulburin National Park.

This report documents the implementation of recovery actions through the fourth project for the priority threatened species in Bulburin National Park (NP) between May 2020 and June 2021.

1.3 Prioritisation of threatened species

The species classified as threatened under the NCA and/or EPBCA were prioritised for recovery efforts based on the overlap of their modelled habitat with the fire extent, alongside expert evaluation of likely fire impacts and post-fire threats (Threatened Species Operations 2020). Three species were identified in Bulburin NP, with a conservation status that ranged from Vulnerable in Queensland to Endangered at both the state and national level (Table 1). The extent of likely habitat burnt was greatest for the endemic Bulburin nut (30%), followed by the ringed thin-tailed gecko (16%) (Table 1). Whilst the silver-headed antechinus was identified as having only 4% of its habitat impacted (Table 1), the additional and significant impacts of 2018 bushfires elsewhere within its range elevated concerns for its ongoing conservation and accordingly, it was included as a priority species.

Table 1: The species prioritised for recovery actions, with the area of their statewide modelled habitat impacted by the 2019-20 bushfires (Threatened Species Operations 2020) and their conservation status under the NCA and EPBCA (V - Vulnerable; E – Endangered).

	Species	**Common name**	**Impacted Habitat** (per. Ha)	**% Habitat Impacted**	**NCA**	**EPBCA**
Class Mammalia	*Antechinus argentus*	Silver-headed antechinus	1,261	4	E	E
Class Reptilia	*Phyllurus caudiannulatus*	Ringed thin-tailed gecko	1,123	16	V	-
Order Proteales	*Macadamia jansenii*	Bulburin nut	202	30	E	E

The Commonwealth's Expert Panel acknowledged that the conservation status of invertebrate fauna was poorly documented and that many endemic taxa were likely impacted by the 2019–2020 fires and worthy of recovery efforts. In collaboration with experts from the Queensland Museum, invertebrate species with restricted distributions and other attributes that can make them vulnerable to fire were identified as priority species for this project (Table 2).

Table 2: Invertebrate taxa prioritised for post-fire surveys during Phase 1 in Bulburin NP for which impacted habitat data were not available for the prioritisation process.

Order	**Species**	**Common name**
Insects		
Coleoptera	*Castelnaudia* sp. nov.	predatory ground beetle
	Cerabilia monteithi	predatory ground beetle
	Cerabilia amaroides	predatory ground beetle
	Nurus nox	burrowing predatory ground beetle
Hemiptera	*Neophloeobia bulburina*	flat bug
	Granulaptera remota	flat bug
Orthoptera	Gen nov. sp nov.	king cricket
Spiders		
Araneomorphae	*Austrarchaea aleenae*	Bulburin pelican spider
	Desognaphosa bulburin	Bulburin flat ground spider
	Birrana bulburin	Bulburin ground hunting spider
	Heteropoda bulburin	Bulburin huntsman spider
	Molycria bulburin	Bulburin ground spider
	Wugigarra bulburin	Bulburin daddy long-legs
Mygalomorphae	*Namea calcaria*	open-holed trapdoor spider
	Namea callemonda	open-holed trapdoor spider

1.4 Priority recovery actions

This project aimed to deliver actions that aligned to expert advice to protect and support the ongoing recovery of priority threatened species, predominantly in the notophyll vine forest (rainforest):

- **Post fire assessment**—detailed spatial evaluation of fire extent and severity, and the associated ecological impacts, to guide the survey of priority species and on-ground efforts to reduce threats to their recovery.
- **Survey priority threatened species**—expert field assessment of the status of priority species using best-practice techniques to set a baseline to track recovery and to compare to pre-fire data, where available.
- **Reduce threats to recovery**—on-ground actions to reduce the risk to priority species and their habitats from future fires, invasive weeds and pest animals.
- **Identify ongoing priorities**—assessment of the information and insights gained from the previous actions to provide recommendations for ecological monitoring, reducing threats and ecological research.

This report documents the implementation of these actions across Bulburin NP between May 2020 and June 2021 for the initial emergency response phase of the Queensland Bushfire Recovery Program.

2 Post-fire assessment

A post-fire assessment was undertaken by DES to document the 2019–2020 bushfires, clarify the fire extent and evaluate the patterns of fire severity and ecological impacts (Melzer *et al*. 2020). Two separate bushfires occurred in the southern and northern sections of the park, which burnt between the 26 November 2019 and 6 February 2020, and from 9–16 December 2019, respectively (Melzer *et al*. 2020). Summary results from the post-fire assessment report have been reproduced below, and data utilised to provide background context for this report (refer to Melzer *et al*. 2020 for the full analysis, and the details and caveats of the remote sensing methodology).

2.1 Fire extent and severity

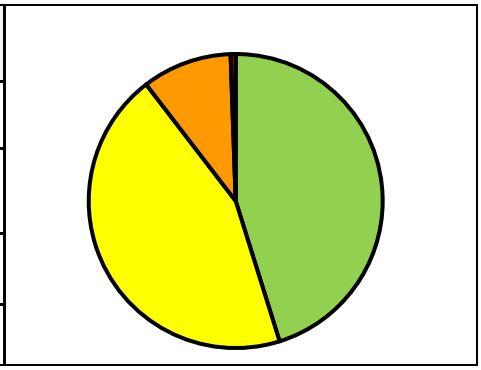
Overall, 7,542ha burned across Bulburin NP (22% of total park area) (Figure 1).

Fire severity was analysed by comparing remote satellite imagery before and after the fire event and using the scientifically derived difference to create fire severity classes from low to extreme, which were then field validated (Melzer *et al*. 2020). These classes reflect the level of impact to vegetation strata, which were then quantified (Table 3) and mapped (Figure 1) for the 2019–2020 bushfires in Bulburin NP.

Fire severity varied with a predominance of low (45%) and moderate (44%) levels that impacted the understorey and canopy, respectively (Table 3). Almost 10% of the area burnt was at high severity with even greater fire impacts to the canopy, and less than 1% (42 ha) burnt at an extreme level with complete consumption of all vegetative strata (Table 3; Figure 1).

Table 3: The area burnt in Bulburin NP across four classes of fire severity, and the relative proportion of each class of the total area burnt (colour coded by fire severity class). Data from Melzer *et al*. (2020).

Fire severity class	Description of effect on vegetation	Area (ha)
Low	Canopy and subcanopy unscorched, shrubs may be scorched, fire sensitive low shrubs may be killed.	3407
Moderate	Partial canopy scorch, subcanopy partially or completely scorched, and/or fire sensitive tall shrub or small tree layer mostly killed.	3349
High	Full canopy scorch to partial canopy consumption, subcanopy fully scorched or consumed.	744
Extreme	Full canopy, subcanopy and understorey consumption.	42



2.2 Potential ecological impacts

The ecological consequences of a fire at a given level of severity can vary with the type of vegetation, according to its sensitivity to fire. The native fauna associated with different vegetation communities has typically evolved a comparable level of fire tolerance, with those species endemic to fire-sensitive ecosystems, such as rainforests, more at risk from fire impacts. Spatially integrating this information with different fire severity classes has enabled the prediction of 'Potential Ecological Impact' (PEI) across a burnt landscape (see Laidlaw *et al*. 2022), such as Bulburin NP (Melzer *et al*. 2020; Figure 1). As a result, surveys of fire-impacted wildlife and recovery actions on the ground can be better directed to where they are most needed.

Bulburin NP includes a diverse range of ecosystems, with those that were fire impacted dominated by eucalypt woodlands to open forests (4,488ha: 21% of park total), rainforests (2,116ha: 23%) and wet eucalypt open forests (915ha: 27%) (Figure 2; Melzer *et al*. 2020). The eucalypt woodlands have a fire-adapted canopy and understorey, and as a result, the burnt areas were mostly classified as having limited or no PEI (Figure 2). Wet eucalypt open forests have a fire-adapted canopy, although the understorey can include fire-sensitive plant species, with some areas being classified as having high or catastrophic PEI (Figure 2). Whilst these ecosystems are adapted to an occasional high intensity fire, the preceding drought conditions would have made high fire severity, and the loss of large trees, more likely—with the associated risk of losing important habitat features, such as nesting hollows (Melzer *et al*. 2020).

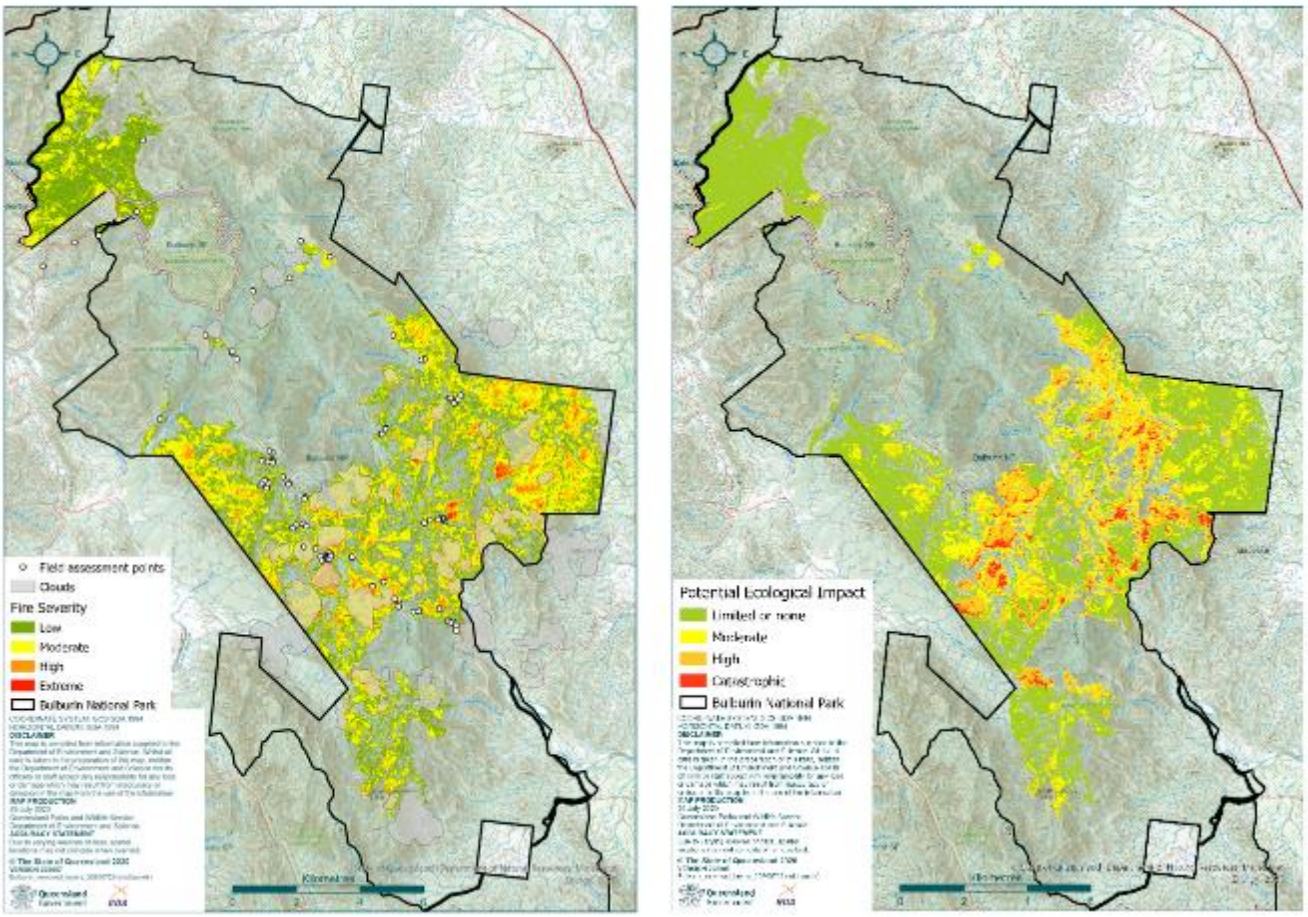


Figure 1: Distribution of the 2019–2020 fires in Bulburin NP: across four classes of fire severity (left) and Potential Ecological Impact (right). Reproduced from Melzer *et al*. (2020).

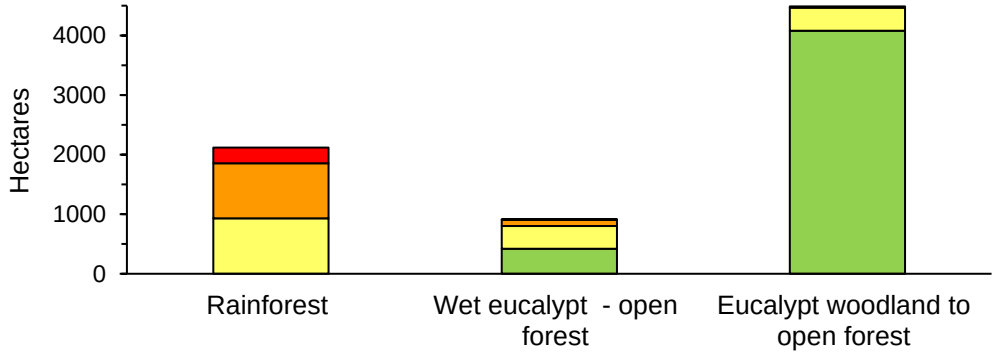


Figure 2: Area burnt across three ecological communities and Potential Ecological Impacts of limited/none (green shading), moderate (yellow shading), high (orange shading) and catastrophic (red shading), based on fire severity and fire-tolerance of the vegetation. Data from Melzer *et al*. (2020).

The fires that impacted the rainforests in Bulburin NP resulted in a moderate to catastrophic PEI, due to the high fire-sensitivity of both the canopy and understorey (Figure 2). Even at low severity, fire can significantly impact rainforests, with the loss of seed banks, ground cover and increased risk of weed incursions. At higher levels of fire severity, impacts can be catastrophic due to the loss of canopy trees and microclimates suitable for regeneration or germination, resulting in very slow recovery with structural and compositional changes, or no recovery and permanent loss of rainforest species (Melzer *at al*. 2020). A 12ha area of narrow stream-fringing communities were also impacted by the 2019–2020 fires in Bulburin NP with moderate (8ha) to high (4ha) PEI ratings. This community includes fire-adapted species such as *Eucalyptus tereticornis* and the highly fire-sensitive species *Casuarina cunninghamiana* for which the loss of trees, including large old trees, was likely and the post-fire germination rate is typically poor.

3 Priority threatened species

3.1 Silver-headed antechinus

3.1.1 Conservation context

The silver-headed antechinus *Antechinus argentus* is listed as Endangered under both the NCA and the EPBCA, and an approved Conservation Advice has been prepared for the species (Threatened Species Scientific Committee 2018). The silver-headed antechinus was first described in 2013 and is distinguished from its closest relatives, the yellow-footed antechinus *A. flavipes* and buff-footed antechinus *A. mysticus*, principally by differences in pelage and genetics (Baker *et al.* 2013). In general appearance, this small marsupial carnivore is most similar in appearance to *A. flavipes* but with the fur of its head, neck and shoulders being silvery (rather than grey), and its rump, flanks, upper hindfeet and underside of the tail base appearing a more subtle olive-buff, not orange-toned (Baker *et al.* 2013).

The silver-headed antechinus is mostly nocturnal and scansorial, feeding on a broad range of invertebrate prey (Mason *et al.* 2015). The species is endemic to central-eastern and south-eastern Queensland, where at the commencement of this project, it was known only from three isolated, high-elevation locations: Kroombit Tops NP, Blackdown Tableland NP and Bulburin NP (Mason 2018). These uplands are quite temperate, with much cooler and moister climates than the surrounding subtropical lowlands. At Kroombit Tops, it occurs in open forest dominated by *Eucalyptus montivaga* and *Corymbia trachyphloia* with a grassy, ferny or shrubby understorey (Baker *et al.* 2013), although detector dogs also identified the species within wet sclerophyll forest dominated by *Eucalyptus saligna* and simple notophyll vine forest (A.M. Baker unpublished data). At Blackdown Tableland, the silver-headed antechinus is found in open forests of *Eucalyptus sphaerocarpa* and *Eucalyptus mensalis* with a grassy to shrubby understorey (A. Baker & E. Mason unpubl. data). In Bulburin NP, it has been recorded in *Eucalyptus acmenoides* and *Syncarpia glomulifera* open forest with a dense grassy to shrubby understorey, as well as in various rainforest communities (H.B. Hines & I.C. Gynther unpublished data). Comprehensive knowledge of the species' range (especially its historic distribution) and habitat preferences is lacking because no genetic material exists from early captures of antechinuses in montane areas of central-eastern and south-eastern Queensland, and early museum specimens are now faded, making identification based on pelage characteristics impossible.

Based on captures of silver-headed antechinus in 2017 at two open forest sites on the Dawes Range in Bulburin NP, as well as the existence of historical records of '*Antechinus flavipes*' from high-elevation rainforest sites within Bulburin NP that are likely to have represented *A. argentus* (H.B. Hines unpublished data), a targeted survey was conducted in May 2019 to improve knowledge of the species' current distribution and habitat associations within this protected area. In partnership with the Queensland University of Technology, the University of Queensland and Canines for Wildlife, and with funding provided by the Commonwealth's National Endangered Species Program, seven rainforest sites in Bulburin NP were surveyed using a combination of Elliott trapping, camera trapping and detector dogs. Site selection was guided using a potential habitat model for the silver-headed antechinus (M. Laidlaw unpublished data), using existing confirmed records of the species from across its range, to predict areas most likely to support suitable silver-headed antechinus habitat (NESP Threatened Species Recovery Hub 2021; see Laidlaw & Butler 2021). To test and refine the potential habitat model, survey sites were chosen to encompass a range of habitats predicted with high, medium and low potential suitability. This 2019 fieldwork produced captures of 17 individuals from four of the seven survey sites and provided the first confirmed records of silver-headed antechinus from rainforest in Bulburin NP (S. Batista, I.C. Gynther, H.B. Hines, L. Baker & A.M. Baker unpublished data).

As a result of the 2019–2020 fires, an estimated 33% of the modelled potential habitat of the silver-headed antechinus in Bulburin NP was burnt (Table 4; Melzer *et al.* 2020). Of the area of burnt potential habitat in Bulburin NP, the proportions within the relative fire severity classes 'low', 'moderate', 'high' and 'extreme' were 45%, 44%, 11% and 0.2%, respectively (Melzer *et al.* 2020). Potential fire-impacts include those at the time of fire (death of individuals, loss of den or nest sites and loss of invertebrate prey), as well as longer-terms impacts that likely include increased predation (particularly by cats and foxes) due to the loss of vegetation cover and other shelter, and habitat degradation resulting from post-fire weed invasion (especially ecosystem-changing weeds such as *Lantana camara* and high-biomass grasses). Further warming due to projected climate change (Hoskin *et al.* 2013), together with an associated increased frequency of extreme fire weather days (Lucas *et al.* 2007), are likely to represent important future threats to conservation of the silver-headed antechinus. Of particular concern are those areas of potential habitat within fire-sensitive rainforest communities that burnt at moderate or higher severity, where ecosystem recovery is likely to take many decades in the absence of further fires (areas of high to catastrophic Potential Ecological Impact [PEI]; Melzer *et al.* 2021; Laidlaw *et al.* 2022).

Table 4: Area of modelled potential habitat (PH) of the silver-headed antechinus and the estimated proportion burnt within Bulburin NP derived from the post-fire assessment (from Melzer *et al*. 2020).

Total PH within Bulburin NP (ha)	% Qld PH in Bulburin NP	Total PH burnt (ha)	% PH burnt in Bulburin NP
2,832	16.5	928	33

3.1.2 Survey sites and methods

Following the 2019–2020 bushfires, a survey for silver-headed antechinus was conducted from 25–31 May 2020 to establish if the species persisted in Bulburin NP, and if so, to inform an assessment of fire-impacts by comparing survey results with baseline data from the previous year.

A second post-fire survey was conducted from 31 May to 5 June 2021 to provide additional data on the species and its response to disturbance from the bushfires two years earlier. Although both these surveys were conducted in collaboration with QUT, UQ and Canines for Wildlife, only the trapping effort and results from Bulburin NP for which DES staff were responsible are presented here.

The surveys involved transects of size A Elliott traps, baited with a mixture of rolled oats, peanut butter, golden syrup and peanut oil. These transects were set within burnt and unburnt subtropical rainforest or open forest, although in 2020 one site targeted woodland (also comprising areas of both burnt and unburnt habitat). The rationale for site selection was either to re-survey locations at which silver-headed antechinus captures were made during the pre-fire survey in 2019 or to further test the potential habitat model by sampling areas where the species was predicted to occur with differing probabilities (Figure 3). At these sites, the trapping methodology mostly involved either three transects of 25 Elliott traps each or six transects of 20 traps each, although in 2021 just two transects of 25 traps were established at one site. At almost all sites, trapping was conducted over two nights; the single exception was three consecutive nights of trapping conducted at a site in 2020. The total trapping effort for the 2020 and 2021 surveys was 1,200 Elliott trap-nights and 700 Elliott trap-nights, respectively (Table 5), giving a combined total of 1,900 trap-nights over the two years.

Table 5: Elliott trapping effort at each site and in total for the 2020 and 2021 surveys in Bulburin NP. Habitat type includes an indication of the degree to which the site was burnt during the 2019–2020 bushfires. [1]As recorded in the Queensland Government's WildNet database (where each site title is prefaced with 'Bulburin NP').

Site title[1]	Habitat type	Elliott trap-nights		
		2020	2021	Combined
C05	Minimally burnt rainforest	150	-	150
02	Burnt open forest	360	150	510
03	Burnt open forest	240	-	240
C11	Burnt & unburnt rainforest	150	150	300
C12	Burnt rainforest	150	150	300
C09	Burnt and unburnt woodland	150	--	150
Polmaily 01	Unburnt rainforest	-	100	100
Polmaily 02	Unburnt rainforest	-	150	150
Total		**1,200**	**700**	**1,900**

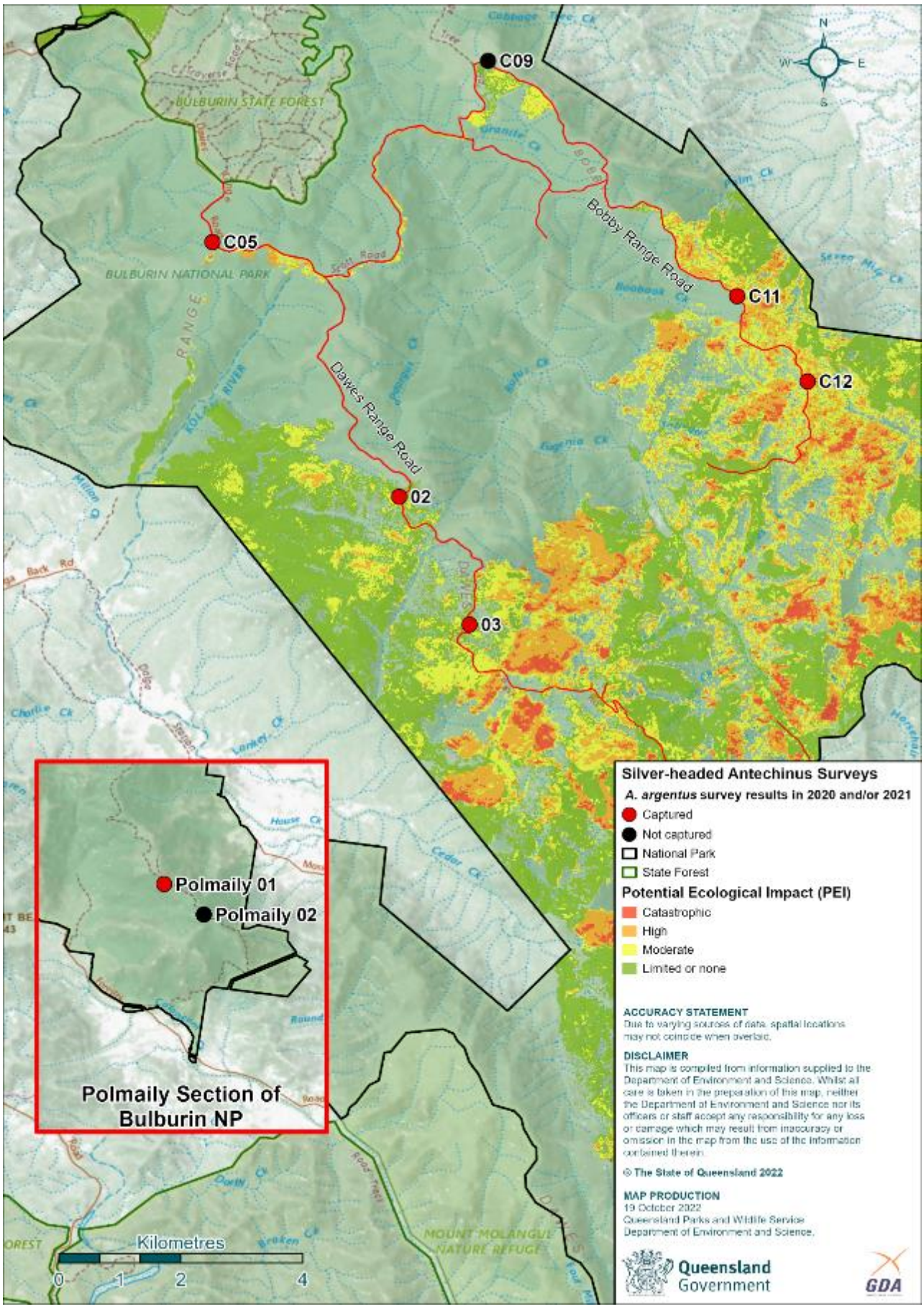


Figure 3: Sites (denoted by centroids) at which trapping was conducted during the 2020 and 2021 surveys of silver-headed antechinus, with survey results and Potential Ecological Impact shown. Inset refers to the geographically separate Polmaily section of Bulburin NP.

3.1.3 Survey results

Silver-headed antechinus survived the 2019–2020 bushfires in Bulburin NP, with the species being captured at both unburnt and burnt sites during the subsequent two years (Figures 3 and 4; Table 6). A total of 15 individuals was captured in 2020 and 18 individuals in 2021 (Table 6). These results are comparable to the total of 17 individuals captured from 889 trap-nights employed across seven sites in May 2019, prior to Bulburin NP experiencing the 2019–2020 bushfires (S. Batista, I.C. Gynther, H.B. Hines, L. Baker & A.M. Baker unpublished data).

Table 6: Sites at which Elliott trapping yielded captures of silver-headed antechinus individuals during the 2020 and 2021 surveys in Bulburin NP. [1]As recorded in the Queensland Government's WildNet database (where each site title is prefaced with 'Bulburin NP'). [2]Numbers in brackets represent the number of recaptures and dashes indicate sites not surveyed that year.

Site title[1]	**Habitat type**	**No. of *Antechinus argentus* trapped[2]**	
		2020	2021
C05	Minimally burnt rainforest	3 (0)	–
02	Burnt open forest	3 (0)	5 (1)
03	Burnt open forest	3 (0)	–
C11	Burnt & unburnt rainforest	2 (0)	6 (1)
C12	Burnt rainforest	4 (0)	4 (1)
C09	Burnt and unburnt woodland	0	–
Polmaily 01	Unburnt rainforest	–	3(1)
Polmaily 02	Unburnt rainforest	–	0
Total no. of individuals		**15**	**18**
Total no. of captures		**15**	**22**

Figure 4: A male silver-headed antechinus captured during the 2021 surveys in Bulburin NP. (Photo: M. Sanders).

In 2020, trapping conducted at two rainforest sites that were surveyed the previous year (i.e. before the bushfires) found silver-headed antechinus still present, despite the fact that half of the habitat at one of these sites (C11) had experienced low or moderate fire severities (Figure 5A). Fire resulting from a back-burn conducted from the road edge (as part of bushfire suppression efforts) had also affected part of the second rainforest site (C05); however, the area burnt was relatively small (<1ha) and mostly involved low to moderate fire severities. An additional rainforest site (C12) in Bulburin NP was trapped for the first time in 2020, with silver-headed antechinus being captured there despite the majority of the site having burned at low to moderate fire severity, with some sections at high severity. Most of the two open forest sites (02 and 03) where silver-headed antechinus was trapped in 2020 experienced low or moderate fire severity in the 2019–2020 fires (Figure 5B).

Figure 5: Sites in Bulburin NP where silver-headed antechinus was captured in May 2020 and impacted by the 2019–2020 bushfires: A) Burnt rainforest at site C11; B) Burnt open forest at site 02. (Photos: I. Gynther).

Trapping in 2021 at two of these same burnt rainforest sites (C11 and C12) and one of the burnt open forest sites (02) found the species to be persisting. Furthermore, the capture of first-year individuals during this second survey confirmed that the silver-headed antechinus had also bred successfully post-fire.

Rainforest habitats are particularly sensitive to fire, and the burnt rainforest sites found to be utilised by the silver-headed antechinus in Bulburin NP were categorised in the low to moderate and moderate to high 'Landscape' Potential Ecological Impact (Landscape PEI) classes, as determined by the relative proportion of different PEI classes within an area with a 250m radius (Figure 6). By contrast, the two burnt sites within open forest that were occupied by the silver-headed antechinus had a Landscape PEI classification of limited to low (Figure 6) due to these vegetation communities being fire adapted. No areas of high to catastrophic Landscape PEI class were surveyed.

In 2021, trapping in the Polmaily Section of Bulburin NP, which had not been impacted by fires during 2019–2020, yielded four captures of three individuals at the site referred to as Polmaily 01 (Figure 3). As silver-headed antechinus had not been recorded from this separate, northern, upland section of the national park previously, the discovery of this new population increased the known area of occupancy of the species.

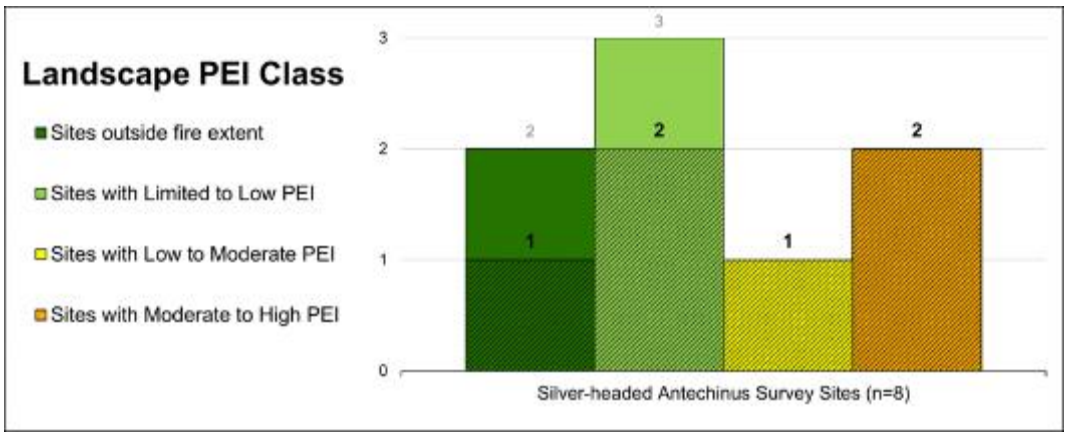


Figure 6: Numbers of survey sites in each of the Landscape PEI classes in Bulburin NP following the 2019–2020 bushfires. Hatched areas and bold numbers indicate the six sites where *Antechinus argentus* was captured during the 2020–21 post-fire surveys.

3.1.4 Discussion

The two surveys detailed here confirmed that the silver-headed antechinus survived the prolonged period of drought and the subsequent 2019–2020 fires in Bulburin NP, demonstrating that the species possesses a remarkable resilience (Baker *et al.* 2021; NESP Threatened Species Recovery Hub 2021). It was found to be utilising both burnt and unburnt rainforest and burnt open forest habitats. Furthermore, the results of the project show that the species has persisted in rainforest habitat even after this has experienced significant damage from fire, including areas classed as having moderate to high PEI ratings.

Data from the trapping program also established that the silver-headed antechinus population successfully bred after the 2019–2020 fires.

The existence of a new, isolated population of the species in the Polmaily section of Bulburin NP was established, which enhances the long-term conservation prospects for the species.

The findings from this collaborative project have provided important knowledge for conservation management of this Endangered antechinus.

3.1.5 Recommendations

Reducing key threats

- Protect the fire-sensitive upland rainforest habitats from fire.
- Maintain the health of open forest habitats through appropriate fire management.
- Reduce impacts of pigs to rainforest and open forest habitats.
- Reduce impacts of feral predators, especially cats and red foxes.

  Initiate camera-trap monitoring of sites occupied by *A. argentus* and implement a control program, as required.
- Reduce the impacts of ecosystem-changing weed species to rainforest and open forest habitats.

  Weed impacts to unburnt refugia and the recovery of burnt habitats are of concern, as is the associated elevated risk of fire, particularly higher severity fire.

Ecological monitoring

- Continue population monitoring, particularly of fire-affected sites, to assess longer-term population trends.
- Implement a monitoring program to assess post-fire habitat regeneration, especially in fire-affected rainforest habitats at higher elevations.

Ecological research

- Implement a broader survey program within Bulburin NP to identify occupied sites and key locations for targeted conservation action, as well as to refine knowledge of habitat preferences of *A. argentus*.

3.2 Ringed thin-tailed gecko

3.2.1 Conservation context

The ringed thin-tailed gecko *Phyllurus caudiannulatus* is listed as Vulnerable under the NCA and not currently listed under the EPBCA. The species is only known from a single population in rainforest within Bulburin NP.

The ringed thin-tailed gecko is a relatively small, prickly gecko with a snout-vent length of 103mm and a long cylindrical tail with 5-6 pale bands (bands are missing in regenerated tails; Figure 7) (Couper *et al.* 1993). The species is typically found sheltering in tree hollows/cavities (e.g. Figure 8), large hollow logs or rock piles, within notophyll vine forest (predominantly Regional Ecosystem 12.12.16). Unlike other species within the genus, the ringed thin-tailed gecko can also be observed moving across the forest floor in areas well away from rocky substrates.

An estimated 28% of the modelled potential habitat (see Laidlaw & Butler 2021) of the ringed thin-tailed gecko in Bulburin NP was burnt during the bushfires of 2019–2020 (Table 7; Melzer *et al.* 2020), including many critical habitat features. Potential habitat modelling incorporated environmental characteristics from existing, confirmed records of the species in order to predict suitable habitat for the ringed thin-tailed gecko (see Laidlaw & Butler 2021). A closely related species, the Oakview leaf-tailed gecko *Phyllurus kabikabi*, was also threatened by fires during the same summer bushfire season at Oakview NP.

Table 7: Area of modelled potential habitat (PH) of the ringed thin-tailed gecko and the estimated proportion which burnt within Bulburin NP (from Melzer *et al*. 2020).

Total PH within Bulburin NP (ha)	% Qld PH in Bulburin NP	Total PH burnt (ha)	% PH burnt in Bulburin NP
7,251	84	2,045	28

3.2.2 Survey sites and methods

Sites were selected on 8 October 2020 by incorporating historic ringed thin-tailed gecko records within suitable rainforest habitat that was both burnt and unburnt.

Nocturnal spotlighting surveys were conducted by three teams over five nights from 2–7 November 2020. Nocturnal surveys were a combination of area searches of 1ha for 1 person-hour (typically two people for 30 minutes) and longer road transects of 500m for 1 person-hour (typically two people for 30 minutes) (see Appendix 1 Table A1.1 for details). Surveys were observational, using head torches to detect eye-shine or visually detect ringed thin-tailed geckos as per the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland* (Eyre *et al.* 2022).

Diurnal reconnaissance and assessment of the survey sites were conducted (time permitting) to identify habitat features such as fig trees, dead stags, rocky areas and large fallen logs. Habitat features such as fig trees and dead stags were also repeatedly targeted to monitor detectability of the species throughout the survey period.

3.2.3 Survey results

A total of 32 sites was surveyed with the detection of 25 ringed thin-tailed geckos. Approximately 2km of nocturnal transects were conducted along roads in burnt ringed thin-tailed gecko habitat and 4.9km in unburnt habitat. Nocturnal area searches covered approximately 12ha of burnt and 19ha of unburnt rainforest habitat (Appendix 1 Table A1.1). The ringed thin-tailed gecko was detected throughout all notophyll vine forests within Bulburin NP, from low altitude on Pine Creek to the higher altitude areas. The species was also detected on both the eastern Bobby and western Dawes Ranges in both burnt (six geckos from five of 15 sites; 33% of survey sites) and unburnt (19 geckos from nine of 17 sites; 52% of survey sites) survey sites where suitable habitat features remained unburnt.

Habitat features previously occupied by ringed thin-tailed geckos, such as large logs and dead stags, were burnt in the 2019–2020 bushfires. At burnt sites, geckos were only found on unburnt portions of microhabitat features, such as fig trees with minimal scorching.

Figure 7: Ringed thin-tailed geckos: pale bands on the original tail (left) are absent in regenerated tails (right). (Photos, left to right: H. Hines; B. Revell).

Figure 8: Fig trees (*Ficus* spp.) are significant habitat features for ringed thin-tailed geckos, often being occupied by many individuals in sympatry with the rough-throated leaf-tailed gecko *Saltuarius salebrosus*.

3.2.4 Discussion

The ringed thin-tailed gecko has persisted following the 2019–2020 fires. This species was detected in 33% of the burnt areas surveyed, although only where large fig trees remained intact following a low to moderate fire severity, or because the fig tree was protected from fire impacts. The abundance of ringed thin-tailed geckos has likely decreased within burnt areas, with detection rates higher at unburnt sites (2.1 geckos per site) than at burnt sites (1.2 geckos per site). Critical habitat structures such as fig trees, large stags and large fallen logs are known to support high densities of ringed thin-tailed geckos (Wilson & Swan 2010). The loss of these habitat features during the 2019–2020 fires would almost certainly be responsible for high levels of mortality across the entire area of burnt rainforest but particularly in the moderate to high fire severity areas. The post-fire regeneration of these important habitat structures in rainforests will be a slow process dependent upon the ongoing exclusion of fire and encroachment of weeds. Once the burnt rainforest regenerates and critical habitat features re-establish, it is likely that ringed thin-tailed geckos will recolonise these areas due to their mobility (which is greater than other species in the genus *Phyllurus*). The capacity for recolonisation will rely on suitable rainforest condition and connectivity that allow geckoes to move safely across the rainforest floor. Reducing threats such as weed incursion, predation by cats or foxes and ground disturbance by pigs is therefore important.

It is worth noting that the critical habitat features required by the ringed thin-tailed gecko occur in notophyll vine forest that rarely burns. However, given the fire impacts of the 2019–2020 fires, there is an increasing need for active fire management in surrounding forests to ensure protection of rainforests, especially during droughts. It is very likely that climate change will produce more severe fire-weather events in the Bulburin NP region, with the magnitude of this change being difficult to predict given uncertainties in rainfall projections (Dowdy *et al.* 2015).

The ringed thin-tailed gecko is very challenging to detect in the field due to its small size and cryptic nature, making population monitoring using established systematic survey techniques difficult. The surveys and assessments reported here have highlighted the importance of habitat features within the landscape, and it is recommended that these should form the basis of a future monitoring strategy.

3.2.5 Recommendations

Reducing key threats

- Protect the notophyll vine forest from fire.

  Future fire presents a threat to the notophyll vine forest habitats and the critical habitat features required by the ringed thin-tailed gecko. Fire management actions that aim to protect the ringed thin-tailed gecko habitat will also contribute significantly to protecting the Bulburin nut.

- Protect habitat features within rainforest that are important to the persistence of the ringed thin-tailed gecko.

  Habitat features for geckos include large fig trees, large stags, large fallen logs and rocky scree areas, which may be at risk from some fire management actions, such as mechanical works to enhance firebreaks.

- Reduce impacts of feral pigs to geckoes and their habitats, including rocky scree areas.

  Pigs were observed during surveys and present a threat of direct predation, with the risk higher in burnt areas where geckos are more exposed when moving across the forest floor. Indirect impacts from pigs include damage to suitable habitats and consuming the gecko's prey.

- Reduce impacts of predation by cats and foxes.

  Cats and foxes were observed during surveys and present a higher risk of predation in burnt areas where the geckos are more exposed when moving across the forest floor.

- Reduce impacts of weed species on rainforest habitats and habitat features, especially cat's claw creeper.

  Weed encroachment, especially along roads and firelines, threatens gecko habitat. Cat's claw creeper is of particular concern as it can smother the ground and critical habitat features.

Ecological monitoring

- Sustain monitoring of ringed thin-tailed geckos across Bulburin NP, using the methods adopted in this project, to track post-fire population changes. Design repeatable surveys focusing exclusively on important habitat features.

3.3 Priority insects

3.3.1 Conservation context

Seven insect species were identified in early 2020 as known or likely regional endemics and listed as priority taxa for this project: predatory ground beetles *Castelnaudia* sp. nov., *Cerabilia amaroides* and *Cerabilia monteithi*, and the predatory burrowing ground beetle *Nurus nox*; flat bugs *Granulaptera remota* and *Neophloeobia bulburina*; and the king cricket Gen nov. sp. nov. (undescribed).

Family Carabidae (ground beetles)

***Castelnaudia* sp. nov.**

Castelnaudia sp. nov. is a large, range-restricted, flightless, predatory ground beetle known only from Bulburin NP, Mount Fort William in Kalpowar State Forest and Kroombit Tops NP. This species is known from 14 adequately geo-referenced localities: 10 from Kroombit Tops, three from Bulburin NP and one from Mount Fort William.

Habitat modelling suggests that approximately one quarter of the species' Queensland distribution is within Bulburin NP, and that around a quarter of *Castelnaudia* sp. nov. modelled habitat within the park was burnt (unpublished data; see Laidlaw & Butler 2021 for methodology).

Cerabilia monteithi* and *Cerabilia amaroides

The genus *Cerabilia* occurs in Australia, New Zealand and New Caledonia, and all species are flightless (lacking the second pair of wings) inhabitants of closed forest. A total of 30 described Australian species of *Cerabilia* exist, all in the subgenus *Feronista*, and the majority are confined to the Wet Tropics bioregion of north Queensland. Only three species are known from outside the Wet Tropics, one from the central Queensland rainforests (Eungella and Blue Mountain) and two from southern Queensland rainforests, *C. monteithi* (Baehr 2007) and *C. amaroides* (Moore 1965); both of which have only been recorded from Bulburin NP to date and represent the most southerly extent of the genus in Australia (Will 2020).

Both *C. monteithi* and *C. amaroides* are highly range-restricted, flightless predatory ground beetles and were listed as priority taxa for Bulburin NP. As all Australian species of *Cerabilia* are flightless, they are largely confined to the ground layer (Will 2020). They are nocturnal and Will (2020) suggested that they are hypogeal, retreating underground during the day and emerging to forage in the leaf litter layer at night. *Cerabilia amaroides* has low dispersal ability and is known only from six specimens, all collected near the type locality close to the former site of the forestry barracks in Bulburin NP.

Prior to 2020, *C. monteithi* was known from only two moderately accurately geo-referenced locations, which represented the entire known distribution of the species. Habitat modelling prior to the surveys suggests that most of the known distribution of *C. monteithi* falls within Bulburin NP, and very little (<4%) of the modelled habitat of this species within the park was impacted by the 2019–2020 fires (unpublished data; see Laidlaw & Butler 2021 for methodology).

***Nurus nox* and *Nurus* sp. nov.**

There are currently 15 described species in the Australian endemic carabid genus *Nurus*, which is distributed from Mt Elliot south of Townsville, Queensland, south to around Armidale in New South Wales. *Nurus* species are large, flightless, ground-dwelling beetles that are largely confined to rainforests, and as a result, many species have restricted distributions (Will & Monteith 2018). All species in the genus live in deep burrows with a distinctive, specialised entrance 'stage' from which they ambush prey (Charley & Andren 2018).

Previously, *Nurus nox* (Darlington 1961) was thought to be the only *Nurus* species occurring in Bulburin NP, with the species also occurring at Mount Fort William to the southwest and Kroombit Tops to the north. However, *Nurus* specimens from Bulburin NP comprise two species, *N. nox* and an undescribed species that is very similar in appearance, which occur in close sympatry (K. Will, Essig Museum of Entomology, University of California, Berkeley unpublished data). Only *Nurus nox* is known from Mount Fort William, and only the undescribed species is known from Kroombit Tops NP.

Habitat modelling prior to the surveys suggested the majority (71%) of the distribution of *N. nox* falls within Bulburin NP and almost 30% of the modelled habitat of this species within the park was impacted by the 2019–2020 fires. Whilst habitat modelling for *Nurus* sp. nov. suggested that approximately 19% of this undescribed species' distribution is within Bulburin NP, almost none (<1%) was impacted by the 2019–2020 fires (unpublished data; see Laidlaw & Butler 2021 for methodology).

Family Aradidae (flat bugs)

Neophloeobia bulburina

Neophloeobia bulburina (Monteith 1997) is a highly range-restricted, flightless flat bug known only from Bulburin NP and nearby Mount Fort William to the south-west (Monteith 1997). It is one of eight described species in the genus, which is distributed from the Wet Tropics bioregion of northern Queensland to northern New South Wales (Monteith 1997). Species of *Neophloeobia* are completely wingless (apterous) and live on the forest floor in rainforest, occupying the outer surface of the bark on the underside of relatively newly fallen (less than about a year old) branches and twigs (Monteith 1997).

Habitat modelling, albeit based on very little data, suggested around 60% of the species' known Queensland distribution is within Bulburin NP, and approximately 21% of *N. bulburina* modelled habitat within the park was burnt (unpublished data; see Laidlaw & Butler 2021 for methodology).

Granulaptera remota

Granulaptera remota (Monteith 1997) is a highly range-restricted, flightless flat bug known only from Bulburin NP (Monteith 1997). Species of *Granulaptera* are completely wingless (apterous) and live on the forest floor of rainforest, occupying the outer surface of the bark on the underside of relatively newly fallen (less than about a year old) branches and twigs (Monteith 1997). Like other flat bugs, they likely feed on the hyphae of fungi responsible for the decay of wood.

Prior to 2020, *G. remota* was known only from seven adult specimens from two adequately geo-referenced localities in Bulburin NP. Habitat modelling, albeit based on very few records, suggested that the vast majority (90%) of the known distribution of *G. remota* is in Bulburin NP, and around 21% of the species' modelled habitat within the park was impacted by the 2019–2020 fires (unpublished data; see Laidlaw & Butler 2021 for methodology).

Family Anostostomatidae (king crickets)

Gen. nov. sp. nov. (Anostostomatidae)

This is an undescribed, highly range-restricted, wingless species of king cricket currently known only from Bulburin NP. The species belongs to an undescribed genus (listed as *New genus A* in Monteith & Field 2001) that includes about 20 species (all undescribed). Most species in this undescribed genus occur in mountain rainforests along eastern coastal Australia from Cape York to northern New South Wales (Monteith & Field 2001). The undescribed species from Bulburin NP is unusual because the males have flattened hind tibiae with enlarged spines (Monteith & Field 2001). Another undescribed species that has flattened hind tibiae in males occurs near Brooyar, west of Gympie (specimens in the Queensland Museum).

The undescribed king cricket from Bulburin NP is currently known from only two localities and all known specimens were collected in long-term pitfall traps that were run continuously for a full year in 1975 and 1976 (Queensland Museum records).

Habitat modelling, albeit based on very little data, suggested that approximately 90% of the species' known Queensland distribution is within Bulburin NP, and that around 36% of this species' modelled habitat within the park was impacted by the 2019–2020 fires (unpublished data; see Laidlaw & Butler 2021 for methodology).

3.3.2 Survey sites and methods

Survey sites were stratified with respect to fire severity to represent a range of bushfire impacts in rainforest: unburnt, moderately burnt and severely burnt. Ground-truthing of fire severity mapping involved examination of sites for habitat type and extent, canopy cover, indications of recent burning such as charring, fallen but not decomposed trees and shrubs, regrowth, leaf litter cover, and weediness (native and non-native) (R. Melzer pers. comm.). Unburnt sites were typified by closed canopy; no evidence of charring; only historically fallen decomposing trees and shrubs; no sapling regrowth; dense ground cover of ferns, herbs and small shrubs; thick, moist and decomposing leaf litter; suspended leaf litter; no bare soil; and no weeds. Moderately burnt sites were typified by some limited canopy; charred stumps; some fallen but not decomposed trees and shrubs; some sapling regrowth; little charcoal, with little bare soil; some dry, undecomposed leaf litter; and some weeds. Severely burnt sites were typified by no canopy; many charred stumps; many fallen but not decomposed trees and shrubs; extensive sapling regrowth; charcoal on bare soil; little or only dry, undecomposed leaf litter; and dense, high weeds.

Six survey sites were selected in notophyll vine forest to represent each fire severity category (unburnt, moderately burnt and severely burnt) at each of two locations: eastern Bobby Range, on Bobby Range Road, and the western Dawes Range, on Dawes Range Road (Figure 9; Appendix 2). Sites were sampled from 3–9 November 2020. Standardised survey methods were used at each site: leaf litter extraction; bark sprays (spraying tree trunks with insecticide); Malaise traps; unbaited pitfall traps; baited pitfall traps (using dung and mushroom baits); coloured pans; hand netting; and ant collecting (refer to Appendix 2 for details).

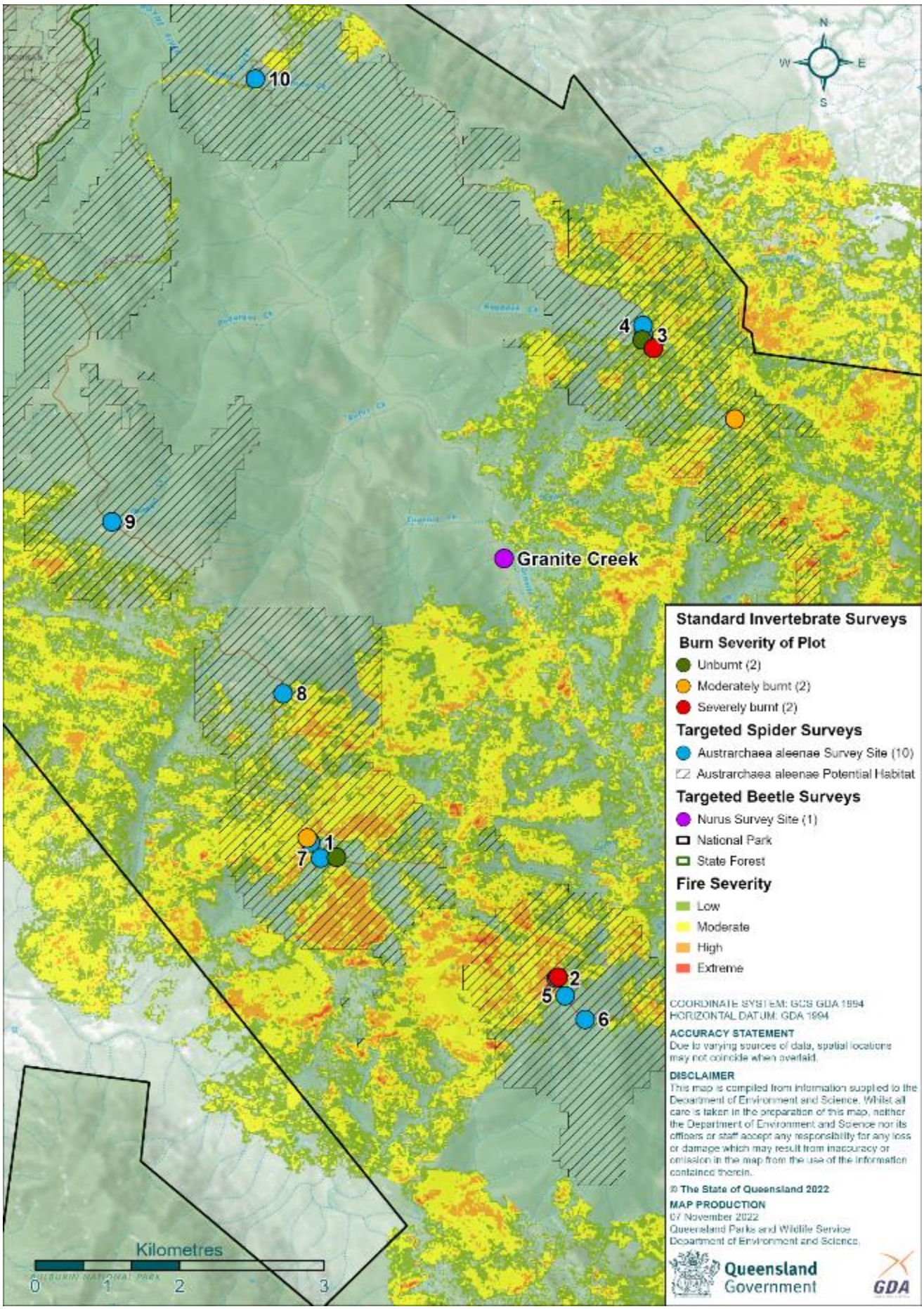


Figure 9: Location of standard invertebrate survey sites and targeted surveys for *Nurus* species and *Austrarchaea aleenae*, with *A. aleenae* modelled potential habitat and fire severity.

In addition, targeted surveys were conducted for some priority taxa. King crickets were surveyed at all three sites along Bobby Range Road using nocturnal active searching, hand collecting and fermented pineapple baits as a lure. A light sheet (using mercury vapour bulbs) was run on one night at the unburnt site on Bobby Range Road. Targeted searching for large, flightless, ground-dwelling beetles in the Australian endemic carabid genus *Nurus* required the excavation of burrows. These deep burrows have a distinctive, specialised entrance 'stage' where *Nurus* ambush prey. *Nurus* burrows were easily detected and at least one burrow in each survey site was excavated to collect its occupant beetle.

3.3.3 Survey results

Across the six invertebrate survey sites (Section 3.2.2; Appendix 2 section A2.1) only three of the seven priority species were recorded using the standardised survey methods (Appendix 2 section A2.2): *Nurus nox*, *Cerabilia monteithi* and *Granulaptera remota*. In addition, an undescribed, but recently recognised, species of predatory burrowing ground beetle in the genus *Nurus* was collected (Table 8).

Four of the seven insect species originally flagged as priority taxa were not recorded in the surveys: *Castelnaudia* sp. nov., *Cerabilia amaroides*, *Neophloeobia bulburina*, and Anostostomatidae gen. nov. sp. nov. However, these species were considered worthy of future monitoring efforts (Table 8).

Table 8: The seven priority insect species identified for this project with an additional proposed species (*), and if they were recorded (✓) or not recorded (x) during surveys in Bulburin NP.

Species	Order	Family	Recorded
Castelnaudia sp. nov.	Coleoptera	Carabidae	x
Cerabilia monteithi	Coleoptera	Carabidae	✓
Cerabilia amaroides	Coleoptera	Carabidae	x
Nurus nox	Coleoptera	Carabidae	✓
Nurus sp. nov. (undescribed)*	Coleoptera	Carabidae	✓
Neophloeobia bulburina	Hemiptera	Aradidae	x
Granulaptera remota	Hemiptera	Aradidae	✓
Gen. nov. sp. nov. (undescribed)	Orthoptera	Anostostomatidae	x

Family Carabidae (ground beetles)

Cerabilia monteithi and *Cerabilia amaroides*

Only one *C. monteithi* was extracted from leaf litter in the unburnt site on Dawes Range Road in the western Dawes Range (4 November 2020) (Figure 10). This site is approximately 8km from the nearest known locality for the species. No specimens were recorded from the unburnt habitat on Bobby Range Road, nor from any of the burnt sites in the western Dawes Range and eastern Bobby Range. No individuals of *C. amaroides* were collected from the surveys.

Figure 10: *Cerabilia monteithi* (Carabidae) (left) and *Granulaptera remota* (Aradidae) (right), both collected from the unburnt site on Dawes Range Road, western Dawes Range, Bulburin NP (Photos: G. Thompson).

Nurus nox and *Nurus* sp. nov.

As anticipated, no *Nurus* specimens were collected using the standard invertebrate survey methods employed at each site, nor through additional active searching at night or use of fermented pineapple baits employed at the Bobby Range Road sites. However, a total of eight *Nurus* specimens of both *Nurus nox* and the undescribed species of *Nurus* were excavated from burrows, seven from the invertebrate survey sites (Table 9; Figures 9, 11 and 12) and one *Nurus* sp. nov. from an additional site through targeted surveys on Bobby Range Road (Table 10).

Table 9: The number of *Nurus* beetles (Family Carabidae) excavated from burrows on invertebrate survey sites at different levels of fire severity in Bulburin NP. One *Nurus* sp. nov was collected (*), the remainder were *Nurus nox*.

Fire severity	Bobby Range Rd (5/11/2020)	Dawes Range Rd (6/11/2020)
Unburnt	1	1
Moderately burnt	2	1*
Severely burnt	1	1

Table 10: Details of an additional targeted survey site from which one *Nurus* sp. nov. was collected.

Site	Latitude	Longitude	Altitude	Description
Granite Creek	-24.569	151.531	190 m	low elevation rainforest lining Granite Creek

Figure 11: *Nurus nox* inside a burrow at a buttress tree root base in the unburnt site along Bobby Range Road, eastern Bobby Range, Bulburin NP, which was subsequently collected (Photos: C. Lambkin).

Figure 12: *Nurus nox* in the unburnt site, and *Nurus* sp. nov. (Carabidae) in the moderately burnt site from Dawes Range Road on the western Dawes Range, Bulburin NP. (Photos: C. Burwell).

Family Aradidae (flat bugs)

Granulaptera remota

Using the litter extraction survey method (refer to Appendix 2), a total of three adult *Granulaptera remota* was collected from the unburnt site on Dawes Range Road in the western Dawes Range (4 November 2020) (Figure 9). This site is approximately 3.6km from the nearest known locality for the species. No individuals of *G. remota* were recorded from the unburnt habitat on Bobby Range Road, nor from any of the burnt sites in the western Dawes Range and eastern Bobby Range.

3.3.4 Discussion

Family Carabidae (ground beetles)

***Castelnaudia* sp. nov.**

No individuals of *Castelnaudia* sp. nov. were collected during the surveys. *Castelnaudia* sp. nov. has previously been collected from two localities in Bulburin NP: Granite Creek, and the former site of the forestry barracks. As rainforest in the vicinity of the latter site did not burn in the 2019–2020 fires, the species likely persists in the park. However, due to the amount of modelled *Castelnaudia* sp. nov. habitat that burnt and the low dispersal ability of the species, it is recommended that it be retained as a priority species for further monitoring.

Cerabilia monteithi* and *Cerabilia amaroides

Although *C. amaroides* was not recorded during the surveys, the species is probably secure in Bulburin NP following the 2019–2020 fires. Species of *Cerabilia* are cryptic inhabitants of the ground layer and difficult to survey using standard invertebrate trapping methods. Of the methods employed in these surveys, leaf litter extraction was most likely to capture *Cerabilia* ground beetles. However, more direct targeted methods (see Recommendations below) are likely to yield *C. amaroides* in future surveys. It is recommended that *C. amaroides* be retained as a priority species for future monitoring, as it is known only from Bulburin NP and has low dispersal ability.

Cerabilia montheithi persists within Bulburin NP following the 2019–2020 fires. Although only recorded from unburnt habitat, there is little inference that can be made regarding the species' response to the 2019–2020 fires given the single record. All Australian species of *Cerabilia* are largely confined to the ground layer and it is suggested they retreat underground during the day and emerge to forage in the leaf litter layer at night (Will 2020). As a result, even low intensity fires that encroach into rainforest and consume the leaf litter layer may pose a threat to both *C. monteithi* and *C. amaroides*. Whilst they retreat below the surface during the day, it is unlikely to be deep enough to afford much protection from fire.

***Nurus nox* and *Nurus* sp. nov.**

This assessment reveals that both *Nurus nox* and the undescribed *Nurus* sp. nov. still persist within Bulburin NP following the 2019–2020 fires. Occupied *Nurus* burrows were present at all six sites where standardised invertebrate survey methods were conducted, regardless of impacts from the 2019–2020 fires. Although surveys were conducted many months after the fires, it is considered more likely that *Nurus* species survived the fire in situ as opposed to recolonising burnt areas post-fire. If so, the deep burrows of these flightless carabid beetles afford them protection from the direct impacts of fire, even when habitat is severely burnt. Whether *Nurus* individuals can persist long term in burnt habitat requires future monitoring. However, substantial growth of pioneer species and weeds had provided extensive ground cover at both severely burnt sites, suggesting *Nurus* beetles are likely to survive there.

Although only one species of *Nurus*, either *N. nox* or *Nurus* sp. nov., was recovered at each of the survey sites, it is suspected that the two species co-occur, which may have been revealed by the excavation of multiple burrows per site.

Family Aradidae (flat bugs)

Neophloeobia bulburina

No individuals of *N. bulburina* were collected during the surveys. Within Bulburin NP, this species was previously known from only two localities, and the former site of the forestry barracks. As rainforest in the vicinity of the latter site did not burn in the 2019–2020 fires, the species likely persists post-fire. However, given the amount of potential habitat burnt and the low dispersal ability of the species, it is recommended that it be retained as a priority species for further monitoring.

Species of *Neophloeobia* are cryptic inhabitants of the ground layer and difficult to survey using standard invertebrate survey methods. Of the standard methods employed here, leaf litter extraction was most likely to capture individuals of *Neophloebia*. However, more direct targeted methods (see Recommendations below) are likely to yield *N. bulburina* in future surveys.

Granulaptera remota

This assessment revealed that *G. remota* persisted within Bulburin NP following the 2019–2020 fires. Although recorded only from unburnt habitat, there is little inference that can be made regarding the species' response to the 2019–2020 fires given the single site record (all individuals were collected from the same leaf litter extract). *Granulaptera remota* (and *Neophloeobia bulburina*) are confined to the ground layer where they occupy the outer surface of the bark on the underside of relatively newly fallen branches and twigs (Monteith 1997). Given that they are confined to the ground, wingless and very slow moving, even low intensity fires that encroach into rainforest and consume the leaf litter layer may pose a direct threat to *G. remota* (and *N. bulburina*).

Family Anostostomatidae (king crickets)

Gen. nov. sp. nov. (Anostostomatidae)

The undescribed species of king cricket was not recorded in the surveys, but retaining the species as a priority taxon is recommended given its highly restricted range, limited dispersal abilities and amount of potential habitat that burnt. However, this species is very difficult to survey, and long-term pitfall traps are probably the only survey method likely to detect the species.

3.3.5 Recommendations

Reducing key threats

Threats to *Cerabilia monteithi*, *Cerabilia amaroides*, *Granulaptera remota* and *Neophloeobia bulburina* likely include climate change (including moisture stress impacts on rainforest), encroachment of fire into rainforest and destruction of the leaf litter layer, damage to understorey vegetation by pests (e.g. pigs, weeds), vegetation disturbance and habitat clearing.

- Protect priority insect species and their rainforest habitats from fire.
  Fires with even low severity levels can encroach into rainforest and burn the leaf litter microhabitats. As burrowers, species of *Nurus* do not appear to be directly threatened by fire, if it can be established that they persist long term in burnt habitat as, and if, it recovers.
- Protect *Nurus* species from predation by feral pigs, which can excavate their deep burrows.
- Reduce impacts of cane toads on non-burrowing carabids (e.g. *Castelnaudia* sp. nov) through predation.
- Protect the regeneration of the understorey in burnt rainforest from invasive weeds.

Ecological monitoring

- It is recommended that all seven priority species be retained for future monitoring.

Given around one quarter of modelled *Castelnaudia* sp. nov. habitat burnt within Bulburin NP, and this species has a low dispersal ability, it is recommended that it be retained as a priority species for further monitoring. The majority of *Castelnaudia* sp. nov. specimens in the Queensland Museum were collected with pitfall traps. Future surveys for the species should deploy pitfall traps more widely in the park and the use of larger diameter traps is recommended for this relatively large beetle species.

Ongoing monitoring of both *Cerabilia monteithi* and *C. amaroides* is recommended in the medium and/or long term, given longer-term threats posed by climate change and fire and the lack of information on the distribution and ecology of the species. Future surveys for these two species should dispense with the site-based approach used in the Phase I methodology and instead use a targeted search approach conducted more widely within the park. As noted by Will (2020), the most consistent method of collection is to search for *Cerabilia* species at night by raking through leaf litter, and this methodology should be adopted in future surveys.

Ongoing surveys of both species of *Nurus* are recommended in the medium and/or long term, both to monitor their persistence in burnt habitat and to further elucidate the fine-scale distribution of both species in Bulburin NP. As such, future work should revisit the six sites surveyed in Phase I, as well as searching for *Nurus* burrows more widely in the park. The two species of *Nurus* are very similar in appearance, as are their burrows; consequently, destructive excavation of burrows is necessary to establish the specific identity of their occupants. Given the high probability that the two species can co-occur at a location, there needs to be a balance between excavating sufficient burrows to determine which species are present and minimising the number of burrows destroyed. It is recommended that at a given site, burrows should be excavated until both species are recovered (the two species can be separated in the field with a hand lens) or until a maximum of four burrows has been excavated.

Ongoing monitoring of *Granulaptera remota* is recommended in the medium and/or long term, given longer-term threats posed by climate change and fire and the lack of information on the distribution and ecology of the species. Future surveys for this species, and for *Neophloeobia bulburina*, should use targeted surveys across a broader area within the park rather than the site-based approach used in this project. A particular technique called ‘stick brushing’ by Monteith (1997) is an effective method for sampling cryptic, wingless species of aradid bugs in rainforests. Loose material adhering to the underside of sticks and branches of an appropriate stage of decay is dislodged with a stiff brush into a container and the accumulated debris is extracted in Tullgren funnels.

Ecological research

- Further research into the distribution and ecology of *Castelnaudia* sp. nov., *Cerabilia amaroides*, *Neophloeobia bulburina*, and the undescribed Anostostomatidae in Queensland.

3.4 Priority spiders

3.4.1 Conservation context

A total of eight spider species was initially identified as known or likely regional endemics and listed as priority taxa: the Bulburin pelican spider *Austrarchaea aleenae*; a flat ground spider *Desognaphosa bulburin*, a ground hunting spider *Birrana bulburin*; a huntsman spider *Heteropoda bulburin*; a ground spider *Molycria bulburin*; a daddy long-legs spider *Wugigarra bulburin*; and the open-holed trapdoor spiders *Namea calcaria* and *Namea callemonda.*

Bulburin pelican spider

The Bulburin pelican spider was considered to be the highest priority spider species for this project. Members of the family Archaeidae in Australia have high phylogenetic, taxonomic and conservation significance, and they occupy a specialised ecological niche in rainforest environments (Rix & Harvey 2012). Pelican spiders prey on other spiders in a unique and structurally complex microhabitat of leaf litter and plant debris suspended above the rainforest floor. As a result, they are not typically captured using standard spider survey methods. Pelican spiders were therefore the focus of targeted survey efforts using a specialised sampling technique to increase the likelihood of capture and gain further insights into their conservation status and requirements.

The Bulburin pelican spider is a highly range-restricted pelican spider, known only from Bulburin NP and nearby Mount Fort William (Rix & Harvey 2011, 2012). Two adequately geo-referenced locality records existed prior to 2020, although several older specimens exist in the Queensland Museum collection with the location only listed as Bulburin NP (Rix & Harvey 2011). The vast majority of the known Queensland distribution of this species is within the protected area estate, and no specific conservation actions are being undertaken.

Flat ground spider

Desognaphosa bulburin (Platnick 2002) is a highly range-restricted flat ground spider, known only from Bulburin NP (Platnick 2002). Three female specimens were known prior to 2020, all held in the Queensland Museum collection, although none was adequately geo-referenced (dating from the 1970s). No specific conservation actions are being undertaken to protect this species.

3.4.2 Survey sites and methods

Spiders were collected using the standardised methods for invertebrates across the six survey sites (see Section 3.3.2 and Appendix 2). To survey pelican spiders in suspended leaf litter, a specifically designed ‘archaeid extraction’ technique was used (Appendix 2 section A2.2). In addition, targeted surveys for archaeid spiders were conducted in suitable habitat at another 10 sites within Bulburin NP from 4–7 November 2020 (Figure 9; Table 11). Increasing the number of locality records would improve the understanding of spider distribution and provide adequate data to undertake quantitative habitat modelling (Laidlaw & Butler 2021).

3.4.3 Survey results

Across the six invertebrate survey sites (Section 3.2.2; Appendix 2 section A2.1), only two of the eight priority spider species were definitively recorded using the standardised survey methods (Appendix 2 section A2.2): *Desognaphosa bulburin* and *Austrarchaea aleenae* (Table 11).

Table 11: The eight priority spider species identified for this project and if they were recorded (✓) or not recorded (x) during surveys in Bulburin NP, alongside recommendations for their inclusion or exclusion in future monitoring.

Infraorder	Family	Species	Recorded	Recommendation
Araneomorphae	Archaeidae	*Austrarchaea aleenae*	✓	Include
	Trochanteriidae	*Desognaphosa bulburin*	✓	Include
	Zoropsidae	*Birrana bulburin*	x	Exclude: difficult to survey
	Sparassidae	*Heteropoda bulburin*	x	Exclude: strong disperser
	Prodidomidae	*Molycria bulburin*	x	Exclude: difficult to survey
	Pholcidae	*Wugigarra bulburin*	x	Exclude: likely strong disperser
Mygalomorphae	Anamidae	*Namea calcaria*	x	Exclude: difficult to survey
	Anamidae	*Namea callemonda*	x	Exclude: difficult to survey

Bulburin pelican spider

Across the invertebrate survey sites, the Bulburin pelican spider was recorded from unburnt sites on both the eastern Bobby and western Dawes Ranges (Figure 13; Table 12). This species was not recorded from the two eastern Bobby Range burnt sites, although archaeids were collected on each of the two burnt sites on the western Dawes Range (Table 12), approximately 20m from adjoining unburnt rainforest.

During additional targeted surveys, 10 Bulburin pelican spiders were also collected from other sites on both the eastern Bobby and western Dawes Ranges (Table 13). Given the paucity of existing accurately geo-referenced records (i.e. only one site for the entirety of Bulburin NP), these additional records greatly increase understanding of the species' distribution (Table 14; Figure 9). Quantitative modelling was undertaken post-survey by incorporating 21 collection records of *A. aleenae* into a potential habitat model (Table 14; see methodology in Laidlaw & Butler 2021).

Table 12: The number of Bulburin pelican spiders and age class (♂ = male; juv. = juvenile) collected on 4 November 2020, with survey duration and notes for the six invertebrate survey sites across two locations and three categories of fire severity.

Location	Fire severity	Duration hrs:mins	No.	Description
Bobby Range Road	Unburnt	02:00	1 ♂	Difficult to locate; hence 2-hour survey
	Moderately burnt	00:57	0	
	Severely burnt	00:55	0	
Dawes Range Road	Unburnt	02:00	6 juv.	Archaeidae common at site
	Moderately burnt	00:50	1 ♂	Found in burnt zone 20m from edge of unburnt zone
	Severely burnt	00:57	1 juv.	Found in burnt zone 20m from edge of unburnt zone

Table 13: Summary of Bulburin pelican spiders recorded at additional sites during targeted surveys (MR# codes denoting unique specimen identifiers).

Site	Code	Latitude	Longitude	No.	Description
1	MR281	-24.59807500	151.5111611	1 ♂	Dawes Range Road
2	MR289	-24.61199722	151.5363722	1 ♂	Dawes Range Road; adjacent to SB site (unburnt)
3	MR292	-24.54611111	151.5453361	1 ♂	Bobby Range Road; unburnt site
4	MR293	-24.54508889	151.5452722	1 juv.	Bobby Range Road
5	MR298	-24.61378611	151.5372889	1 juv.	Dawes Range Road
6	MR299	-24.61620278	151.5393139	1 juv.	Dawes Range Road
7	MR300	-24.59969167	151.5121750	1 juv.	Dawes Range Road
8	MR301	-24.58281944	151.5083444	1 ♀	Dawes Range Road
9	MR302	-24.56521111	151.4907472	1 juv.	Dawes Range Road
10	MR303	-24.51985278	151.5054861	1 juv.	Scott Road-Cabbage Tree Road

Table 14: Quantitative potential habitat modelling for the Bulburin pelican spider indicating that a substantial portion of modelled potential habitat (PH) was burnt within Bulburin NP.

Total PH within Bulburin NP (ha)	% of QLD PH within Bulburin NP	Total PH burnt (ha)	% PH burnt within Bulburin NP
2,632	84	1,377	52

Figure 13: *Austrarchaea aleenae* female (left) and male (right) from Bulburin NP. (Photos: M. Rix).

Flat ground spider

The use of standardised methods at the invertebrate survey sites collected *Desognaphosa bulburin* from unburnt habitat on the western Dawes Range on Dawes Range Road. One juvenile was captured in a dung-baited pitfall trap between 4 and 9 November 2020, while one adult female and three juveniles were captured through leaf litter extraction on 4 November 2020 (Figure 14). No individuals of *D. bulburin* were recorded from any of the eastern Bobby Range survey sites, nor from either of the burnt sites on the western Dawes Range. Potential habitat modelling was not possible for this species due to a paucity of locality records.

Figure 14: A species of flat ground spider *Desognaphosa* in the family Trochanteriidae (likely *D. yabbra*), very similar in appearance to the priority species *D. bulburin*. (Photo: R. Whyte, used with permission).

3.4.4 Discussion

Family Archaeidae (pelican spiders)

Austrarchaea aleenae

This assessment reveals that the Bulburin pelican spider was heavily impacted by the 2019–2020 fires in Bulburin NP, with 52% of modelled potential habitat in the study area burnt. Whilst pelican spiders were not recorded in either of the burnt sites on the eastern Bobby Range, the discovery of spiders in burnt habitats on the western Dawes Range after approximately one year is significant, indicating the dispersal of this species into burnt habitat from adjacent unburnt forest (approximately 20m away in both cases). Recovery of archaeid spider populations in burnt rainforest habitats will therefore depend on the severity and/or mosaic nature of the fire impacts in different areas, and the presence of nearby unburnt forest with source populations. Rainforest habitats are already of a mosaic nature throughout Bulburin NP. The discovery of many new pelican spider populations in unburnt rainforest on both the eastern Bobby and western Dawes Ranges, in addition to the occurrence of large tracts of unburnt rainforest at the northern end of the Dawes Range, suggests that the current conservation status of the Bulburin pelican spider is not critical.

The main threatening processes for the Bulburin pelican spider are climate change and increased fire frequency or inappropriate fire regimes. While the results indicate some capacity for recruitment of pelican spiders back into burnt areas from adjacent unburnt habitat, this capacity is almost certainly limited in both space and time (e.g. if fires are too frequent, large, severe and/or not patchy). It is also unclear what impact a warming climate may have on moisture stress in rainforest habitats in Bulburin NP, as pelican spiders are known to be extremely sensitive to ambient humidity. Pest animals, such as pigs, and weed incursions also threaten the integrity of understorey vegetation and the persistence of the critical suspended litter microhabitats for pelican spiders and their prey.

Flat ground spider

This assessment reveals that *D. bulburin* was likely heavily impacted by the 2019–2020 fires in Bulburin NP, with spiders only recorded from one of two unburnt survey sites. This species was not recorded from any of the burnt survey sites, suggesting low rates of recruitment of spiders into burnt habitats. Whilst these results are limited, it is likely that the 2019–2020 fires led to a significant reduction in the rainforest leaf litter microhabitat of *D. bulburin*, and that the successful recovery of populations may be a slow process. Future fires, even of low severity, therefore present a threat to the recovery of this and other litter-dependent spider species. A warming climate and predictions of more droughts are of concern given the habitat preference of *D. bulburin* for the moist litter layer of the rainforest floor. Additional threats include pigs and deer, which can cause significant impacts through trampling and disturbance of litter habitats, and weeds, which can change the understorey structure and associated litter layer.

3.4.5 Recommendations

Reducing key threats

- Protect rainforest habitats from fire.

  These species are dependent on unburnt upland rainforests in Bulburin NP. Fires of even low severity in rainforest can burn critical leaf litter microhabitats and facilitate weed incursions.

Ecological monitoring

- Ongoing monitoring of Bulburin pelican spiders to assess the threat posed by climate change and fire. The archaeid extraction method is highly effective in determining the presence or likely absence of pelican spiders.
- Ongoing monitoring of *Desognaphos*a *bulburin* given the threat posed by climate change and fire. The litter extraction method was appropriate, although pitfall trapping is not cost-effective for this species. A method similar to the archaeid extraction technique would be a more efficient approach to target this species in future surveys.

Ecological research

- Further research the fine-scale distribution, ecology, abundance and habitat requirements of *D. bulburin*.

  Existing taxonomic data indicate that the species is a short-range endemic in Bulburin NP, but additional data are required for the species or its closest relatives to support conservation assessments.
- Further research into the distribution and ecology of *Birrana bulburin*, *Heteropoda bulburin*, *Molycria bulburin*, *Namea calcaria*, *Namea callemonda*, and *Wugigarra bulburin* in Queensland.

3.5 Bulburin nut

3.5.1 Conservation context

The Bulburin nut *Macadamia jansenii* is a long-lived rainforest species growing up to 12m in height. It is thought to be insect pollinated and produces few seeds in the wild. The species is listed as Endangered under the EPBCA and was previously only known from one small population of approximately 60 individuals alongside a creek in Bulburin NP (B.H. Howard unpublished data). The Australian Government Threatened Species Strategy lists *M. jansenii* as one of 30 threatened plant species with priority for conservation and a commitment for action by 2020.

The Bulburin nut grows in Araucarian complex microphyll to notophyll vine forest (Regional Ecosystem 12.12.13) in five pre-existing populations and two reintroduced sites within Bulburin NP (Shapcott & Powell 2011), some of which was burnt during the summer bushfires of 2019–2020 (Thorley 2020).

An estimated 15% of the modelled potential habitat of the Bulburin nut was burnt during the 2019–2020 fires (Table 15; Hayward *et al.* 2020; Melzer *et al*. 2020). Potential habitat modelling incorporated characteristics derived from existing records of the species to predict areas of suitable habitat (Melzer *et al.* 2020; see Laidlaw & Butler 2021 for the methodology). As there were too few independent records for the model to be statistically significant, a simplified model derived from the regional ecosystem and elevation was used to map potential habitat.

Table 15: Area of modelled potential habitat (PH) for the Bulburin nut and the estimated proportion that burnt within Bulburin NP (from Melzer *et al*. 2020).

Total PH within Bulburin NP (ha)	% Qld PH in Bulburin NP	Total PH burnt (ha)	% PH burnt in Bulburin NP
574	86	87	15

3.5.2 Survey sites and methods

Four of five pre-existing populations of the Bulburin nut were assessed in Bulburin NP. The Tallegalla Creek (Mj4), Peraimeles Creek (Mj3), and Sarnadsky's Corner (Mj5) populations were surveyed in July 2020 for post-fire survival and regeneration (Figures 15 and 16). Fire severity mapping was recorded and a ground-truthing survey by a small team was undertaken at these previously identified sites. Fire mapping and previous site visits confirmed that the original Pine Creek population (Mj1) did not burn, so it was not resurveyed. Only one reintroduction site, 'Bulburin bottom', was surveyed on 24 July 2020.

3.5.3 Survey results

Fire severity mapping indicated that the Tallegalla Creek (Mj4) population was the least impacted by the 2019–2020 fires in Bulburin NP, with impacts predominantly recorded on the upstream (eastern) bank. Ground survey found that the fires were patchy, often with small areas burnt. As the macadamia population is also patchy, most plants avoided direct fire impacts (Figure 15; Table 16).

Mapping indicated that a larger part of the Peraimeles Creek (Mj3) population was likely to have been impacted by the fire compared to the Tallegalla Creek site (Table 16). However, ground surveys revealed that fire impacts were also very patchy at this site, with some areas scorched but not badly burnt, and other areas with evidence of higher fire severity.

At Sarnadsky's Corner (Mj5), fire severity mapping indicated there was a very hot fire just above the *M. jansenii* population extent on the eastern side of the creek, potentially impacting individual *M. jansenii* plants (Table 16). Ground surveys found that downslope from the old forestry track, the *M. jansenii* population was almost completely intact with only minimal signs of fire impacts, whilst upslope the fire burnt more severely and resulted in higher mortality. The majority of dead *M. jansenii* plants recorded from the Sarnadsky's Corner (Mj5) population were recorded in this area (Figure 15).

The Bulburin nut has been reintroduced at two locations within Bulburin NP and at two locations on the Thorn Hill property, owned and managed by Gidarjil Cultural Heritage Corporation, which were last surveyed in late 2019. Only one of these reintroduction sites, 'Bulburin bottom', appeared to be impacted by fire based on fire severity mapping and was re-surveyed in July 2020. The fire was patchy at this location with many areas unburnt or mildly burnt.

Overall, Bulburin nuts were found reshooting from the base or germinating from seed (Figure 16).

Table 16: The number and condition of Bulburin nuts surveyed across sites before and after the fires.

Category	Location					
	Pine Ck Mj1	**Peraimeles Ck** Mj3	**Sarnadsky** Mj5	**Tallegalla Ck** Mj4	**Total**	**%**
Total 2019/pre-fire	45	60	44	51	**200**	
Total 2020 post-fire	45	48	32	40	**165**	82.5
Dead 2020 from fire	0	12	12	11	**35**	17.5
Alive but impacted by fire 2020	0	19	11	24	**54**	27
Vulnerable post-fire	0	6	7	5	**18**	9
Dead 2020 from fire >1m tall	0	8	2	1	**11**	5.5
Dead from fire >6m tall	0	2	1	0	**3**	1.5

Figure 15: A large individual Bulburin nut confirmed dead (left) and an individual unaffected by fire, very healthy in appearance (right), Bulburin NP. (Photos: G. Hayward).

3.5.4 Discussion

The Bulburin nut appears to have great capacity to reshoot post-fire (Figure 16), significantly reducing the initially observed levels of mortality, with 83% of the population having survived the 2019–2020 fires. However, 9% of the overall population is still considered vulnerable to death post-fire. Overall, the 2019–2020 fires resulted in a total mortality of 35 plants; however, most of these individuals were seedlings. Only 11 plants greater than 1m tall were killed and only three of these were mature plants 6m or taller.

Of the populations that were impacted by fire (which excludes plants at Pine Creek), 120 plants survived (77%), 35% were alive but impacted by fire, 12% were still vulnerable post-fire, 7% of plants >1m tall were dead and 2% of plants >6m tall were dead. Seven new individual plants were recorded during this project.

Figure 16: Individual Bulburin nut reshooting from the base (left) and germinating from seed (right) after the 2019–2020 fires in Bulburin NP. (Photos: G. Hayward).

3.5.5 Recommendations

Reducing key threats

- Protect the Bulburin nut and suitable habitat from fire through appropriate fire management in fire-adapted ecosystems.

  The planting of insurance populations at botanic gardens is underway to mitigate the ongoing risks to Bulburin nut populations in Bulburin NP and to ensure the survival of the species.

- Reduce impacts to the known habitats from invasive weeds, particularly lantana, cat's claw creeper and high-biomass grasses.

Ecological monitoring

Long-term monitoring of in situ *M. jansenii* populations to track post-fire recovery.

Ecological research

- Collate information to support a submission to review the conservation status of the Bulburin nut.
- Assessment of the genetic diversity among populations of *M. jansenii*, with research into the extent of pollen flow between *Macadamia* cultivars and wild populations.
- Long-term monitoring of *M. jansenii* populations to assess the impacts of climate change and fragmentation on genetic population structure.

4 Reducing threats to recovery

The key threats to the recovery of the priority species in the post-fire landscape were identified by experts (Threatened Species Operations 2020). In Bulburin NP, these included the risk of future fire, pest animals and invasive plants. On-ground actions to reduce these threats were then prioritised and implemented based on the modelled habitat maps for the priority species, expert ecological knowledge, available project budget and local understanding of the threats by park managers.

4.1 Fire

The risk of future bushfires to the priority threatened species habitat was critically assessed across Bulburin NP with respect to local geographic features and prevailing weather in the bushfire season.

A major potential pathway for fire into the park was identified that would place the restricted populations of Bulburin nut at significant risk, alongside other wildlife species dependent on their unique rainforest habitat, such as the ringed thin-tailed gecko. An extensively overgrown old forestry track was therefore used to establish a critical fireline of 5.9km along a dominant north–south ridgeline (Figure 17). The fireline encircles core *Macadamia jensenii* habitat areas and will provide QPWS access to control bushfires and support ongoing post-fire recovery processes. With ongoing vegetation maintenance and annual grading, the fireline will help to protect threatened species and their habitats from future fires.

Figure 17: A 5.9km fireline created along a dominant north–south ridgeline in Bulburin NP.

4.2 Pest animals

Pest animals that were identified as primary threats to the recovery of priority threatened species and their habitats in Bulburin NP were cattle and foxes.

Cattle

The incursion of significant numbers of cattle into Bulburin NP from adjoining lands (Figure 18) presented a key threat to the recovery of *Macadamia jansenii* populations and their habitats via direct impacts to seedlings and regenerating plants, and by facilitating weed dispersal and promoting soil erosion. These threats also extended to the habitats of other priority species.

To prevent stock incursions into the park, a 5.7km cattle-exclusion fence was established in the Granite Creek area between Bulburin NP and a neighbouring freehold property. Construction included fencing, stiles, flood gates and cattle grids (Figure 18), with a deed of agreement successfully negotiated with the landowner to maintain the fence for the next 20 years.

Figure 18: The cattle-exclusion fence (lower images) erected between the park and a neighbouring freehold property to prevent cattle intrusion into Bulburin NP (above).

Foxes

The threat of predation by foxes and wild dogs to the post-fire recovery of the silver-headed antechinus across high-altitude open forests and rainforest was of significant concern. Accordingly, Canine Pest Ejectors were deployed to specifically target foxes and wild dogs in the habitat of the silver-headed antechinus to support population recovery.

4.3 Invasive weeds

Invasive weeds are a threat to the recovery of burnt habitats and were prioritised in terms of the risks they presented to the recovery of the priority threatened species in Bulburin NP.

High-biomass grasses

Exotic high-biomass grasses can readily exploit post-fire conditions by dispersing into new areas and expanding existing populations to create dense barriers to natural regeneration. Of particular concern were: guinea grass *Megathyrsus maximus*; thatch grass *Hyparrhenia rufa*; slender panic grass *Ottochloa nodosa*; and broad-leaved paspalum *Paspalum mandiocanum*. To control these species, Gidarjil Indigenous Land and Sea Rangers undertook spot spraying with an appropriate herbicide to treat a 5ha area of *Macadamia jensenii* habitat, as well as key access tracks and roadsides that served as easy pathways for new incursions into recovering plant communities.

Lantana

The existing populations of *Lantana camara* adjacent to and within the burnt rainforest communities presented a risk to priority species through incursion into new areas and by inhibiting natural regeneration, as well as elevating the fuel hazards and associated severity of future fires. Control with appropriate herbicides was therefore undertaken, with follow-up treatment planned for the warmer growing season.

Cat’s claw creeper

Cat's claw creeper *Dolichandra unguis-cati* is a perennial woody vine that can reach up to 30m and develop an extensive, tuberous root system. It is a weed of national significance, forming dense mats that outcompete native ground cover and seedlings and smother shrubs and trees to restrict their growth or cause mortality. This aggressive vine can readily take advantage of post-fire conditions, and reducing its impacts on the habitats for priority threatened species was therefore critical. A biocontrol agent for cat’s claw creeper has been established and approved for release through the Department of Agriculture and Fisheries across multiple sites in South East Queensland. The jewel beetle *Hylaeogena jureceki* was released in Bulburin NP in collaboration with Bundaberg Regional Council to treat approximately 32ha (Figure 19). During the project, a reduction of approximately 25% of the treated area covered by cat’s claw creeper was recorded. Ongoing releases of these beetles are planned to sustain impacts on cat’s claw creeper in rainforest communities, including those with Bulburin nut populations.

Figure 19: Control of cat’s claw creeper using the jewel beetle (left) at the release site (right).

5 Summary recommendations

5.1 Reducing ongoing threats to recovery

The recommendations for reducing the key threats to the ongoing post-fire recovery of priority species are summarised for future reference (Table 17). Refer to the relevant section of each priority species or group of species for further details and contact the scientific experts (Appendix 3) to seek guidance if required.

- It is essential to sustain investment in reducing the key threats to recovery.

This will optimise the returns from this significant Commonwealth funding and continue to provide ongoing conservation benefits and support for fire-impacted threatened species.

Table 17: Summary recommendations for reducing key threats arising from the post-fire surveys of priority taxa in Bulburin NP.

Recommendation	Silver-headed antechinus	Ringed thin-tailed gecko	Priority insects	Priority spiders	Bulburin nut
Fire					
Protect rainforest habitats from fire	✓	✓	✓	✓	✓
Maintain open forest habitats	✓				
Protect critical habitat features within rainforest		✓			
Pest animals					
Reduce impacts of pigs	✓	✓	✓		
Reduce impacts of cats and red foxes	✓	✓			
Reduce impacts of feral pigs		✓			
Reduce impacts of cane toads			✓		
Invasive plants					
Reduce the impacts of invasive weeds	✓	✓	✓	✓	✓
Reduce impacts of cat's claw creeper		✓			
Reduce the impacts of ecosystem-changing weeds	✓				✓

5.2 Ecological monitoring and research

The summary recommendations for ongoing ecological monitoring and ecological research across the priority taxa are summarised for easy reference (Table 18). Refer to the relevant section of each priority species or group of species for further details and contact the scientific experts (Appendix 3) to seek guidance if required.

Table 18: Summary recommendations for ecological monitoring and research for priority species arising from the post-fire surveys in Bulburin NP.

Recommendation	Silver-headed antechinus	Ringed thin-tailed gecko	Priority insects	Priority spiders	Bulburin nut
Ecological monitoring					
Continue population monitoring, particularly in fire-impacted sites	✓	✓	✓	✓	✓
Implement monitoring of post-fire regeneration in rainforests	✓				
Ecological research					
Research distribution, abundance and habitat requirements	✓	✓		✓	
Research distribution and ecology of priority species in Queensland			✓	✓	
Research and collate information to support a submission for conservation status review or listing				✓	✓

6 Lessons learnt and forward guidance

This project was completed despite significant challenges to the planning, coordination and delivery of priority actions to support the recovery of threatened species after the 2019–2020 fires. Climate change predictions are for an increasing frequency and severity of bushfires (Canadell *et al*. 2022) and other natural disasters, hence wildlife will continue to be at risk. It is therefore important to capture the project learnings, advances made and opportunities to improve the capacity to protect Queensland's threatened species.

6.1 Risk management

Risks to wildlife

The 2019–2020 fires were extensive with broad ecological impacts, including direct mortality of wildlife, loss or degradation of habitats and increased chance of predation. The probability of such events occurring and impacting wildlife is likely to increase with a changing climate, with the most vulnerable being threatened species and fire-sensitive ecosystems and species. To protect threatened species and reduce the risk of other species being listed as threatened, it is vital to:

- update the assessment of risk from bushfire to threatened species, particularly those most at risk from extinction.

Decision making

A risk-based approach was used to prioritise threatened species for recovery actions under this program. This relied on information such as conservation status, species' traits, ecological requirements and their distribution relative to the fire extent (Threatened Species Operations 2020; Legge *et al.* 2021). The methodology used was best practice, yet the availability and reliability of core data were limited. This presents a significant risk that the species prioritised and the decisions made to allocate funds or direct on-ground efforts may *not* be optimal for protecting species from decline or extinction. To improve the decision-making process and outcomes, it is important to:

- significantly enhance the capture and accessibility of reliable ecological information on threatened species.

Viral pandemic

The global spread of the Covid-19 virus led to unexpected challenges, such as the need to adopt strict and novel hygiene protocols and adapt to evolving health advice in the QPWS context. Restrictions to travel and the number of staff allowed in vehicles, accommodation facilities or in the field delayed initial efforts and made planning difficult. The establishment of, and greater familiarity with, pandemic health procedures will improve future capacity to respond concurrently to a bushfire and a pandemic. However, wildlife recovery projects can be better supported by:

- specific evaluation of the relevant health risk for field work in relatively remote localities.

6.2 Ecological data and expert services

To deliver this project, procedures and protocols had to be established to assess ecological impacts, identify priorities and implement surveys led by experts in a short timeframe. Significant improvements were made during this project and the broader program which need ongoing support and expansion to facilitate future wildlife recovery projects.

Threatened species data

This project generated a significant volume of data that will improve the ecological understanding of the priority species, as well as other non-target species in Bulburin NP. However, a centralised system to capture and secure this information with consistent protocols is lacking, resulting in external hard drives being used to store some data sets, which presents a significant business risk. Wherever feasible, data were uploaded to WildNet, pending the availability of skilled staff and time during the project. To improve knowledge and management of threatened species, to secure critical data and to support ongoing monitoring or a future emergency response, it is essential to:

- establish an information system that captures, secures and provides access to core data across QPWS business units and which seamlessly engages with relevant external systems to facilitate data sharing and collaboration
- update an assessment of the gaps in current threatened species data to prioritise data collection efforts.

Post-fire ecological assessment

To map fire severity and summarise the ecological impacts to key natural values, a new process needed to be established to provide guidance in the context of QPWS-managed protected areas (Melzer *at al*. 2020). The methodology incorporated the fire sensitivity of ecosystems in order to map the potential ecological impacts (Laidlaw *et al*. 2022), which helped to better target recovery actions towards the most fire-impacted species and ecosystems. QPWS can now more efficiently undertake post-fire assessments of protected areas. To ensure ongoing capability

for post-fire assessments, it is essential to:

- sustain the skills and capacity required for post-fire spatial and ecological analyses
- sustain base-level investment to adopt and integrate technological improvements to the methodology.

Ecological expertise

Due to the extent of the 2019–2020 fires, this project was one of four to survey 56 threatened species, in addition to invertebrates, across six protected areas. The expertise available to provide ecological guidance, lead field work, oversee projects and ensure consistency in survey methodology and data capture was limited. To improve capacity for wildlife recovery efforts, it is therefore vital to:

- recognise the unique skills that are required to plan, deliver and report on ecological surveys and assessments
- expand capacity through a mentoring and recruitment process that targets specialist ecological skill sets.

Potential habitat mapping

To inform and guide recovery actions in the absence of adequate distributional data for threatened species, a potential habitat map was generated if a minimal set of locality data was available for the spatial modelling process (Laidlaw & Butler 2021; refer to Appendix 6 in Melzer *at al*. 2020). Potential habitat maps were invaluable to help design surveys and guide on-ground efforts to reduce threats from pest animals, invasive plants or future fires. The maps for some species, such as the Bulburin nut, are not publicly available in order to protect them.

It is recommended that:

- online access to potential habitat maps for threatened species is maintained, with updates and inclusion of additional species when data are available.

6.3 Partnerships and networks

Scientific collaboration

This project was delivered in collaboration with the Queensland Herbarium, the Sunshine Coast University and the Queensland Museum, which enabled field surveys, data capture and analysis, as well as the writing of report sections to be completed (Appendix 3). The ability to secure this expertise was due to established relationships that shared common conservation concerns for the priority taxa. Amidst other work programs and an increasing chance of natural disasters, the availability of such expertise at short notice may become limited. It is therefore recommended that:

- formal agreements are established with existing partners to clarify a commitment to supporting wildlife recovery, the specific expertise that can be provided and the necessary data-sharing arrangements.
- new partnerships are sought to expand the network of species experts for other taxa and geographical localities beyond that relevant to this project.

Contract land management services

Following the 2019–2020 fires, park managers had to deliver pest and fire management actions in a short timeframe, in addition to sustaining their normal work program. Existing relationships with local partners helped to implement actions such as release of biological control agents, with an additional need to engage contractors to provide targeted weed control activities to reduce impacts. After a natural disaster, demand for contract services are high, limiting contractor availability, which is further constrained by the need to meet specific standards for protected areas to ensure that natural values are not at risk. To enhance future capacity, it is suggested that:

- networks are sustained with a range of suitably qualified local contractors, including First Nations teams, to support recovery efforts on park.

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Appendix 1: Ringed thin-tailed gecko survey effort

Table A1.1 Details of sites, methods and effort for surveys of ringed thin-tailed gecko between February 2021 and May 2022, with the number of geckos recorded (#).

Site	Site ID	Method	Burnt	Effort description	#	Notes
1	PC01	Nocturnal transect	No	~500m for 60 person-mins	0	
29	PC02	Habitat feature search	No	20 person-mins	3	Search of large fig tree and immediate surrounds. *Saltuarius salebrosus* (rough-throated leaf-tailed gecko) also found on fig tree.
				30 person-mins	1	
				20 person-mins	0	
				10 person-mins	0	
				20 person-mins	1	
4	PC03	Nocturnal transect	No	~900m for 90 person-mins	0	
2	PC03A	Nocturnal transect	No	~500m for 60 person-mins	1	*Saltuarius salebrosus* (rough-throated leaf-tailed gecko) also found during both surveys
				~500m for 60 person-mins	1	
28	PC04	Nocturnal transect	No	~1000m for 60 person-mins	0	Native forest (southern) side of road only.
5	PC05	Nocturnal transect	Yes	~500m for 60 person-mins; southern side burnt; northern side unburnt	1	Low intensity fire; on fig tree with small fire scars
			No		0	
6	PC06	Nocturnal area search	No	1ha, 60 person-mins	2	
7	PC07	Nocturnal area search	No	1ha, 60 person-mins	0	
8	PC08	Nocturnal area search	No	2ha, 120 person-mins	1	*Saltuarius salebrosus* (rough-throated leaf-tailed gecko) also found.
10	PC09	Nocturnal area search	No	1ha, 60 person-mins	0	Drier vine forest Regional Ecosystem 12.12.13
11	PC10	Nocturnal area search	No	1ha, 60 person-mins	0	Drier vine forest Regional Ecosystem 12.12.13
12	PC11	Nocturnal transect	No	~500m for 60 person-mins	0	
31	PC13	Nocturnal area search	Yes	1ha, 60 person-mins	0	Severely burnt
33	PC14	Nocturnal area search	No	1ha, 60 person-mins	2	Across road from severely burnt site PC13
15	PC15	Nocturnal transect	Yes	~500m for 60 person-mins; eastern side burnt; western side unburnt	0	Regrowth weeds on burnt side of road made searching difficult.
			No		0	
16	PC16	Nocturnal transect	Yes	~500m for 60 person-mins	0	Burnt both sides of road; variable intensity
17	PC17	Nocturnal area search	Yes	1ha, 60 person-mins	0	
18	PC19	Nocturnal area search	Yes	1ha, 60 person-mins	0	Patchily burnt
21	PC20	Nocturnal area search	No	6ha, 180 person-mins	1	
19	PC25	Nocturnal transect	No	~500m for 60 person-mins	2	
20	PC26	Nocturnal area search	Yes	1ha, 60 person-mins	0	

Table A1.1 *continued*

Site	Site ID	Method	Burnt	Effort description	#	Notes
22	PC27	Nocturnal area search	Yes	1ha, 60 person-mins	1	Inside large unburnt fig tree
23	PC29	Nocturnal area search	Yes	1ha, 60 person-mins	1	On large unburnt fig tree
24	PC28	Nocturnal area search	Yes	1ha, 60 person-mins	2	Inside large unburnt fig tree
30	PC30	Nocturnal area search	Yes	1ha, 60 person-mins	0	
25	PC31	Nocturnal area search	Yes	1ha, 60 person-mins	0	
26	PC33	Nocturnal transect	Yes	~500m for 60 person-mins	1	Low intensity fire; gecko on unburnt fig
9	PC GRANCK	Nocturnal area search	No	4ha, 240 person-mins	3	
27	PC Aa28	Nocturnal area search	No	1ha, 60 person-mins	0	
3	PC Brown Pine	Diurnal area search	No	1ha, 60 person-mins	1	Area around large fig tree surveyed
		Nocturnal area search		1ha, 60 person-mins	0	
		Habitat feature search		30 person-mins	0	Large fig tree
		Habitat feature search		30 person-mins	0	Large fig tree
13	PC scree1	Nocturnal area search	Yes	2ha, 60 person-mins	0	
14	PC scree 2	Nocturnal area search	Yes	1ha, 60 person-mins	0	

Appendix 2: Invertebrate survey sites and methods

A2.1 Invertebrate survey sites

Survey sites were selected to represent different levels of fire impacts (Table A2.1, Figure A2.1).

Table A2.1: Location of the six invertebrate survey sites on eastern Bobby Range (surveyed 3–8/11/2020) and western Dawes Range (surveyed 4–9/11/2020) across three levels of fire severity in notophyll vine forest.

Location	Site	Latitude °	Longitude °	Altitude
Bobby Range Rd	Unburnt	-24.54659167	151.5451889	625 m
	Moderately burnt	-24.55467222	151.5546722	600 m
	Severely burnt	-24.54745278	151.5463333	620 m
Dawes Range Rd	Unburnt	-24.59959444	151.5137889	690 m
	Moderately burnt	-24.59761389	151.5108222	660 m
	Severely burnt	-24.61187500	151.5365472	610 m

A2.2 Standardised invertebrate survey methods

Nine standardised methods were used to sample invertebrates at each site, as outlined below.

Archaeid extraction: spiders in the family Archaeidae were targeted by sifting leaf litter using a metal sieve for approximately 60 minutes. Accumulated litter that was suspended above ground was collected within a 30–40m radius of the centre of each invertebrate survey site. Fine material including small spiders was captured in a base plate under the sieve and was then assessed for live archaeids (Figure A2.2).

Litter extraction: leaf litter was collected (Figure A2.2) and sifted to provide two 1m^2 samples per site, which were processed in a Tullgren funnel for 24–36 hours (wetter litter was extracted for longer) to collect invertebrates.

Bark spray: the trunks of five large trees (>30cm diameter at breast height if possible) were sprayed using cans of Mortein Fast Knockdown® pyrethroid insecticide. Falling insects were collected on a rectangular sheet of rip-stop nylon at the base of each tree. After 15 minutes, material collected on the five sheets were transferred to an ethanol-filled vial using a suspended fabric funnel. This process was repeated to provide two samples per site.

Malaise trap: one trap was set at each site to target insects that fly upwards when hitting an obstruction (e.g., Diptera (flies) and Hymenoptera (bees, wasps)). The trap base was pegged to maximise the opening across an insect flight path and vegetation used to create a tunnelling effect to enhance the number of species caught over five days. The Townes-style trap was 2m long, 2m high with very fine mesh, a white roof, black walls and central barrier. A collecting jar was filled with ~300ml of 70% ethanol to kill and preserve captured insects (Figure A2.3).

Unbaited pitfall traps: 10 traps were arranged in a line 2.5–3m apart at each site and operated for five days to target ground-active invertebrates. Traps were 120ml plastic vials with a 42mm internal diameter, three-quarters filled with 70% ethanol, with a square, black, plastic cover suspended 3–4cm above the trap (Figure A2.4).

Baited pitfall traps: eight traps were set in four pairs at each site, with each pair approximately 20m from the site centre, arranged in a cross formation. Traps in a pair were separated by at least 3m with one baited with wallaby dung and the other with crushed mushrooms wrapped in Chux® kitchen cloth and suspended on wire pegs above a plastic cup (67mm internal diameter) three quarters filled with 70% ethanol. Traps were operated for five days to target dung beetles, with wallaby dung baits replaced after two or three days (Figure A2.4).

Coloured pans: nine plastic bowls (three each of blue, white, and yellow) were placed 2m apart in a line across each site and operated for two days to target flying pollinators. Each pan had an internal diameter of 14cm and held 250ml of water, with a drop of detergent to reduce surface tension and optimise insect capture.

Hand netting: one netting sample was collected over a 30-minute period at each site, targeting insects flying or resting on vegetation within a 30–40m radius of the site centre. The hand net had a 1.2m long handle and large 46cm-diameter hoop with a net bag of fine Polyganza to retain the smallest of insects (Figure A2.4).

Ant collecting: one sample was collected between 09:05 and 16:50 hrs over a 60-minute period at each site, targeting foraging ant workers and ant nests within a 30–40m radius of the site centre. Not all observed ants were collected, as the aim was to maximise the number of species collected.

Invertebrate survey sites

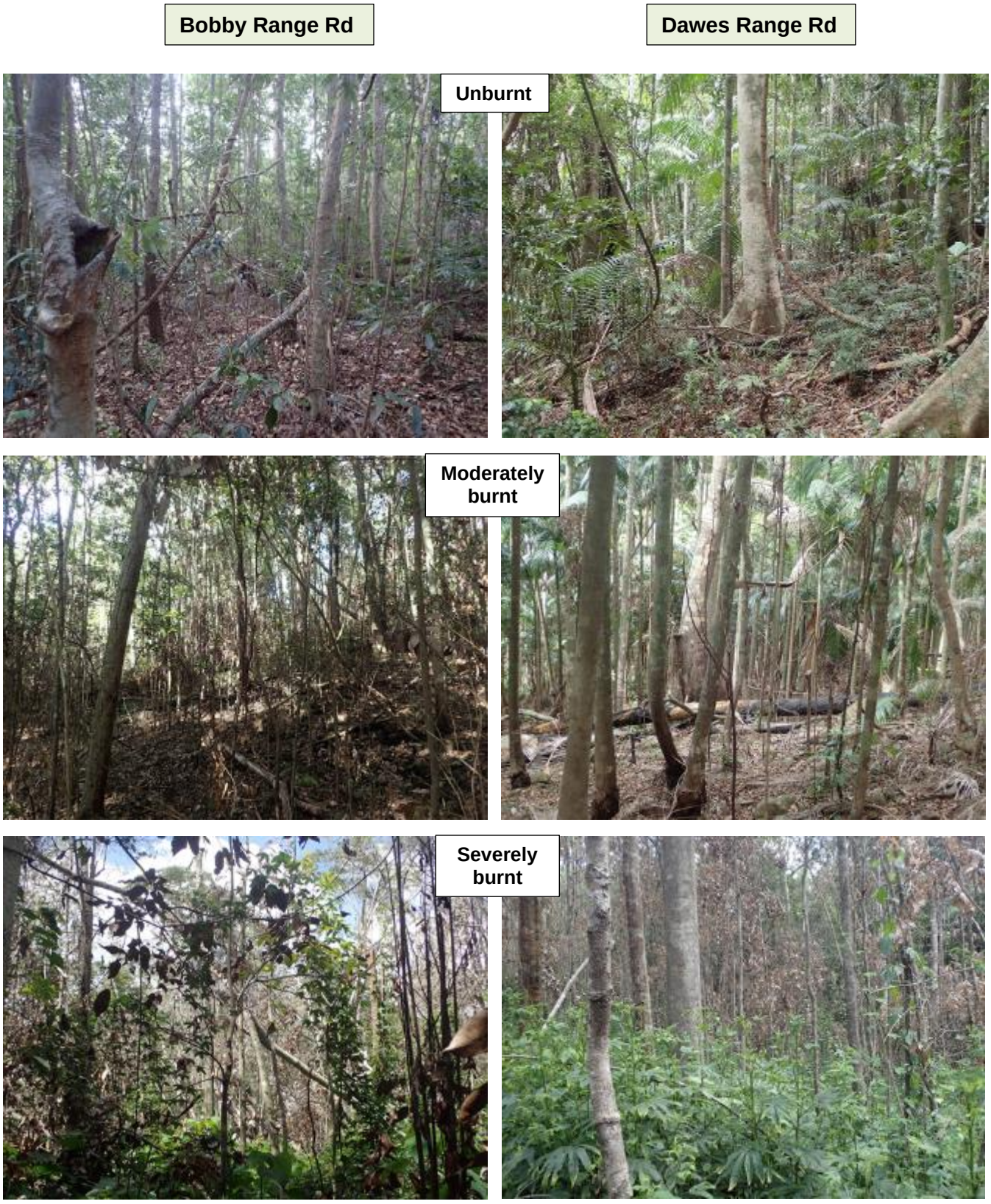

Figure A2.1. The invertebrate survey sites on Bobby Range Road and Dawes Range Road, each with sites that were unburnt, moderately burnt and severely burnt. (Photos: M. Rix, February 2020).

Figure A2.2: Sifting suspended leaf litter for spiders in the family Archaeidae (left) and collecting leaf litter for Tullgren funnel extraction (right). (Photos: C. Lambkin (left); M. Laidlaw (right)).

Figure A2.3: Malaise trap set-up (left) and insects captured in the collecting jar (right) at the severely burnt site, Dawes Range Rd, western Dawes Range, Bulburin NP. (Photos: C. Lambkin).

Figure A2.4: Invertebrate survey techniques: unbaited pitfall trap (left); baited pitfall trap – mushroom (centre left); baited pitfall trap – dung (centre right); and hand netting (right). (Photos: M. Laidlaw (left and centre left); T. Churchill (centre right); M. Rix (right)).

A2.3 Targeted invertebrate surveys

Additional methods were used to target burrowing predatory ground beetles in the genus *Nurus* and king crickets (in particular, a species in a known but undescribed genus). At least one *Nurus* burrow in each survey site was excavated to collect the resident beetle. One additional *Nurus* specimen was excavated from a burrow at a location other than the six survey sites described in section A2.1.

Targeted searching for king crickets was conducted at all three sites along Bobby Range Road. The methods used included active searching using hand collecting at night and the setting of fermented pineapple baits to attract king crickets. A light sheet (using mercury vapour bulbs) was run on one night in the unburnt site on Bobby Range Road.

Supplementary surveys targeted archaeid spiders in suitable habitat at 10 additional sites to those outlined in section A2.1. The archaeid extraction method was used as described in Section A.2.2. The archaeid records were then used for quantitative potential habitat modelling (see Laidlaw & Butler 2021).

Figure A2.5: An additional site used for targeted surveys in low-elevation rainforest at Granite Creek, Bobby Range Rd, on eastern Bobby Range, Bulburin NP. (Photo: C. Lambkin).

Appendix 3: Authors and contributors

Report context	Authors and key contributors	Department or institution
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