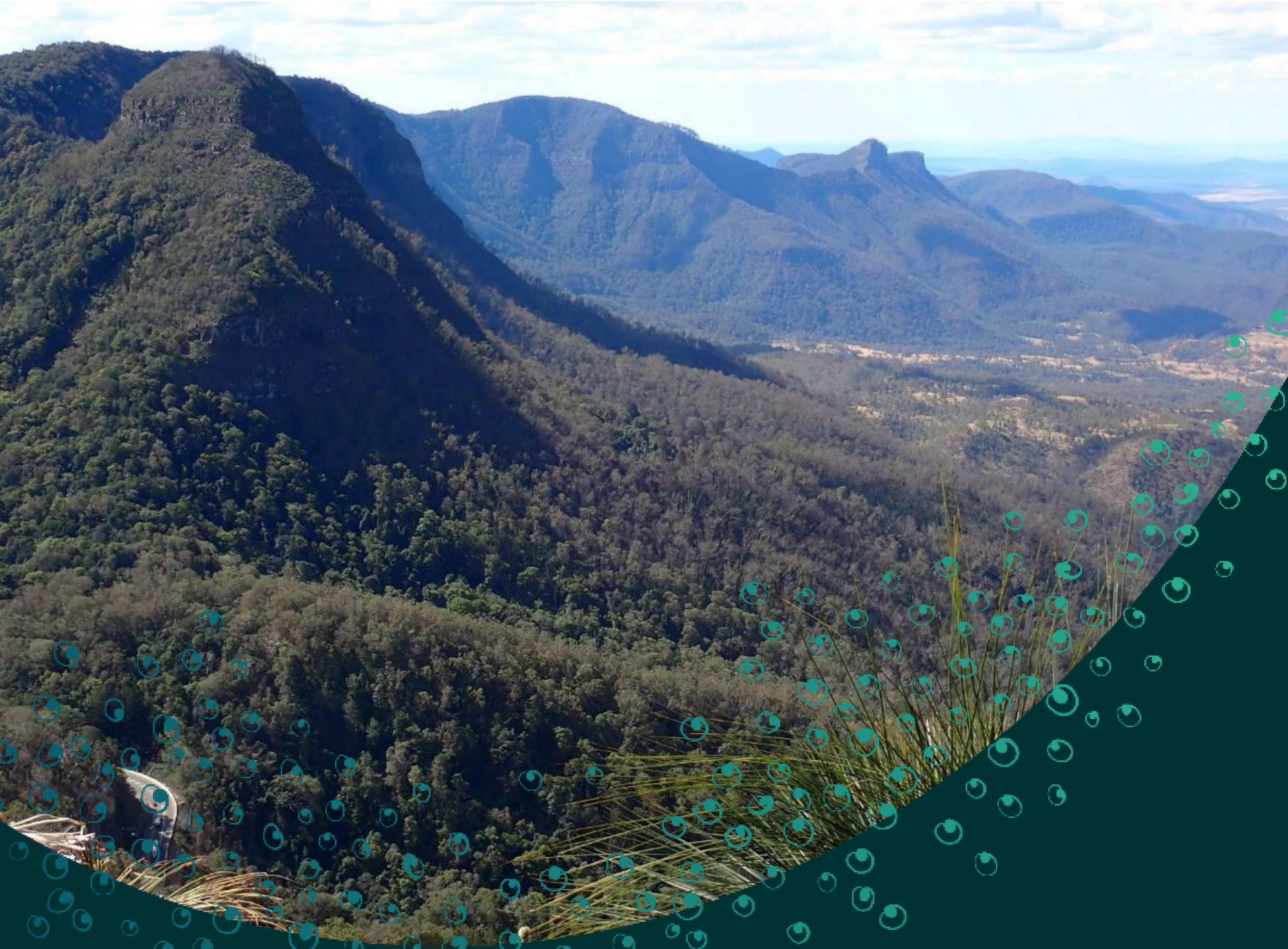

Bushfire Recovery Program 2020–2022:
Priority actions for threatened species in the Gondwana Rainforests of Australia World Heritage Area

South East Queensland

2023

Queensland Government

Prepared by: Threatened Species Operations, Queensland Parks and Wildlife Service and Partnerships Department of Environment and Science.

Citation

Churchill T.B., Laidlaw M.J., McCall A.H., Hines H.B., Gynther I.C., Molyneux J., Teixeira D., Stewart D., Rix M.G., Burwell C.J., Lambkin C.L., Venz M.F., Zadkovich J., Cooper S., Buch W., O'Connell J., Hughes D., Finlayson S., Gurra A., and Job C. (2023). Bushfire Recovery Program 2020–2022: Priority actions for threatened species in the Gondwana Rainforests of Australia World Heritage Area, South East Queensland. Brisbane: Department of Environment and Science, Queensland Government.

Acknowledgements.

Supported by the Australian Government's Bushfire recovery package for wildlife and their habitat program.

Twitter: @envirogov #BushfireRecoveryAU

Facebook: Australian Government Department of Agriculture, Water and the Environment #BushfireRecoveryAU

Front cover: Post-fire view towards Mt Cordeaux from Mt Mitchell, Main Range National Park. (Photo: T.B. Churchill).

Contents

Executive summary

The bushfires of late 2019 to early 2020 had extensive ecological impacts across 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 the Queensland section of the Gondwana Rainforests of Australia World Heritage Area (GWHA).

Across the fire-impacted sections of GWHA in Lamington, Mt Barney and Main Range National Parks, species prioritised for recovery efforts included 14 vertebrates, 24 plants and seven invertebrates. Recovery actions were undertaken between May 2020 and October 2022, including:

- **Post-fire assessment**—detailed spatial evaluation of fire extent and severity, and the associated potential ecological impact (PEI), to guide the survey of priority species and on-ground efforts to reduce threats to their recovery.
- **Monitor priority species**—field assessment of species' status 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**—implementation of 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 above actions to provide recommendations for reducing threats, ecological monitoring and research.

Post-fire assessment

The post-fire assessment documented identified that almost 30,000 hectares (ha) burned across Lamington National Park (NP) (Hines *et al.* 2020), Mt Barney NP (Hines *et al.* 2022) and Main Range NP and adjoining QPWS-managed areas (Hines *et al.* 2021). Fire severity was mapped by comparing satellite imagery before and after the 2019–2020 bushfires to create relative fire severity classes that reflected the level of impact to vegetative strata. For a given fire severity class, however, ecological impact varies across vegetation types based on their fire-tolerance. For fire-sensitive ecosystems, such as rainforests, a fire of even low fire severity can have significant ecological consequences. Fire severity was therefore integrated with the fire sensitivity of vegetation to spatially quantify the 'potential ecological impact' (PEI) (Laidlaw *et al*. 2022) and help direct recovery efforts to priority areas.

In Lamington NP, 1,574ha burnt, including 1,515ha within GWHA. Relative fire severity varied considerably across the fire ground and included small areas of full canopy consumption including within rainforest. Substantial areas of rainforest, wet eucalypt open forest and rainforest/eucalypt forest ecotones were burnt. The PEI was assessed as mostly moderate or high to catastrophic due to burning of fire-sensitive vegetation communities, particularly rainforests.

The total area burnt within Mt Barney NP was approximately 8,785ha, including 7,012ha within GWHA. Relative fire severity varied considerably across the fire ground and included considerable areas of full canopy consumption including within rainforest. Substantial areas of rainforest, wet eucalypt open forest and rainforest/eucalypt forest ecotones were burnt. About a fifth of the burnt area was assessed as having high to catastrophic PEI due to burning of fire-sensitive vegetation communities, particularly rainforests. About 41% of the rainforests within the park were burnt, including temperate rainforests and cloud forests above 1,000m altitude.

Main Range NP and adjoining QPWS-managed lands had the most extensive impacts, with approximately 19,592ha burnt including 11,723ha within GWHA. Fire severity varied across the burnt landscape. Substantial areas of rainforest, wet eucalypt open forest and rainforest/eucalypt forest ecotones were burnt. The potential ecological impact to burnt ecosystems was assessed as mostly moderate or high to catastrophic due to burning of fire-sensitive vegetation communities, particularly rainforests. This included temperate rainforests above 1,350m altitude on Mt Superbus, where recovery is likely to take decades or centuries and will be reliant upon ongoing fire exclusion.

The post-fire assessment reports identified a range of known or likely ecological impacts within each of the major vegetation groups for each of the three main impacted national parks. Key management recommendations included the prevention of establishment of high-biomass grasses, shrub and vine weeds immediately adjacent to and within burnt rainforest, wet eucalypt open forest and rainforest ecotone communities, reviews of fire and pest strategies, re-establishment of fences to prevent stock access to regenerating areas, and monitoring and assessment of the threatened species most likely impacted.

Priority vertebrate fauna

Five threatened mammal species were identified as the most fire-impacted for recovery efforts. Brush-tailed rock-wallabies *Petrogale penicillata* were detected at 16 of the 20 sites surveyed, which had a range of fire severity classes. Camera trapping at five sites confirmed successful breeding, as well as the presence of potential predators. The long-nosed potoroo *Potorous tridactylus tridactylus* was surveyed using 112 cameras deployed across 88 sites with various levels of fire severity; it was detected at five burnt sites in rainforest or open forest, as were potential predators. The maintenance of optimal habitat though planned burning, weed control and reducing the risk of predation from cats and foxes will support the recovery of both species. The southern subspecies of the spotted-tailed quoll *Dasyurus maculatus maculatus* was surveyed using the same camera array, but no quolls were detected. A quoll image was captured twice on two cameras deployed for pig control in unburnt rainforest of Main Range NP. Protecting preferred habitats from fire, reducing the risk of predation from cats and impacts from cane toads is recommended to support quoll populations. The Hastings River mouse *Pseudomys oralis* and the New Holland mouse *P. novaehollandiae* were surveyed at two locations in Main Range NP. At Cunninghams Gap, five Hastings River mice and five New Holland mice were captured in 2021, with a 100% increase in the number of Hastings River mice, alongside the capture of four New Holland mice, in 2022. Most captures of priority mouse species were in unburnt habitat, with the rest in areas of low fire severity. At Gambubal in 2021, 27 Hastings River mice were captured from both unburnt and burnt habitat across a range of fire severity classes. The 2022 survey was thwarted by ongoing extreme rain events. For all priority mammal species, a lack of pre-fire data hindered an ability to interpret fire impacts. The data derived during this project have established post-fire baselines, with ongoing monitoring for all species recommended, as well as priorities for ecological research identified.

Five threatened bird species were prioritised for recovery efforts. Albert's lyrebird *Menura alberti* was surveyed using the 112 cameras deployed across 88 sites described above. Albert's lyrebird was detected at 37 sites and seen or heard at another 62 burnt or unburnt sites in rainforest or open forest during other project activities. Feral cats and red foxes were also detected on camera, some within two hours of a lyrebird sighting. Reducing the risk from introduced predators and protecting suitable habitat from weed incursion and future unplanned fires was recommended. The Coxen's fig-parrot *Cyclopsitta diophthalma coxeni* was surveyed via analysis of acoustic recordings. No calls were detected using an improved call recogniser. Ongoing improvements in the acoustic analysis technique will support further assessment of call recordings. The glossy black-cockatoo *Calyptorhynchus lathami lathami* was surveyed using field calls, sightings or observation of evidence of feeding on she-oak cones, as well as acoustic recordings. In 2021, across 31 sites of different fire severity levels, this species was detected at three sites and feeding signs found at seven sites, with most unburnt. In 2022, 15 sites were re-surveyed with no detections. Acoustic recorders at 14 sites detected calls at six sites. The loss of feed trees in the bushfire and the limited availability of quality she-oak seeds is a significant concern. Protecting unburnt she-oak habitat and supporting recovery of fire-impacted habitat is a priority via fire exclusion and targeted weed control. The eastern bristlebird *Dasyornis brachypterus* was surveyed across two previously known localities but no calls were detected. Acoustic recorders were also deployed at these two sites. Analysis of the sound files from these acoustic recorders is progressing following the development of an eastern bristlebird call recogniser by the Queensland University of Technology. The rufous scrub-bird *Atrichornis rufescens* was surveyed by listening for calls and deploying acoustic recorders at two burnt locations and one unburnt location. No calls of the rufous scrub-bird were detected using standardised monitoring at two sites previously known to be occupied by the species. It was, however, detected opportunistically in burnt and unburnt forest elsewhere within GWHA during this project. Analysis of the acoustic recordings is pending development of a call recogniser. The loss of suitable understorey habitat and invertebrate food resources due to the bushfires makes the protection of unburnt refugia and recovery of burnt habitat a priority, along with the exclusion of fire and control of weeds. For all priority bird species, ongoing monitoring is critical to track post-fire change in their persistence or abundance, with cost-effective advances in monitoring techniques to be actively supported. Recommendations for ecological research are also outlined.

Three frog and one reptile species were prioritised for recovery actions. Fleay's barred frog *Mixophyes fleayi* and cascade treefrog *Litoria pearsoniana* were assessed using nocturnal stream surveys at 12 sites with a range of fire severity classes. Fleay's barred frog was detected at 11 sites and cascade treefrog at all 12 sites, with both species showing evidence of breeding. As fire impacts may be delayed, monitoring of future recruitment is recommended. The cryptic mountainfrogs (red-and-yellow mountainfrog *Philoria kundagungan* and Mt Ballow mountainfrog *P. knowlesi*) were surveyed using acoustic recorders and diurnal aural surveys. Both *Philoria* species had 27% of their modelled potential habitat burnt across the study area. Red-and-yellow mountainfrogs were detected at 11 of 20 surveyed sites, across a range of fire severity levels. Mt Ballow mountainfrogs were detected at 7 of 11 surveyed sites, including at two with moderate fire severity. For all four frogs, protecting unburnt habitat refugia from future fire and reducing impacts on populations and their habitats from weeds, pigs, cattle, deer, cats and foxes is essential.

The burrowing three-toed snake-tooth skink *Coeranoscincus reticulatus* had 12% of its modelled potential habitat burnt across GWHA. This cryptic species was surveyed by active searching, as well as by using an innovative camera trapping array with a drift fence. Active searching across 12 sites revealed two skinks, and another two individuals were detected elsewhere during the project. Protecting the rainforest habitat from even low severity fire and weed incursion, pigs and cattle is a priority. The risk of predation by cats and foxes needs to be reduced.

Priority invertebrate fauna

The conservation status of invertebrates is poorly known, yet many endemic species were likely impacted by the 2019–2020 fires. Taxa with high phylogenetic, taxonomic and conservation significance were therefore prioritised for this project. Pelican spiders were surveyed at 12 sites with different levels of fire severity. Pelican spiders were detected at five sites, with the discovery of a new species (Rix *et al*. 2022). Protecting rainforest from fire is critical, as even low severity fire can burn their microhabitat of suspended leaf litter near the rainforest floor. Moss bugs and wingless dung beetle were surveyed at the same 12 sites, but none was detected. Further surveys and research to understand their ecological requirements is advised, along with reducing the impacts of pigs and deer.

Priority flora

The 24 plant species prioritised for this project were associated with three types of ecosystems and were surveyed with traverses through known localities and similar habitats across all fire severity classes. A lack of data on the distribution and ecology of priority plant species limited the ability to assess bushfire impacts. Species in fire-sensitive ecosystems, such as rainforests, typically have limited or no capacity to persist after fire, and protecting these ecosystems from future fire is critical. In montane heath and open woodland/forest, protecting plants from fire frequencies less than recommended is important to support recovery. The additional risks to epiphytes and orchids from illegal collecting, and to herbs and shrubs from visitor trampling were highlighted. It is recommended that the impacts of pigs, deer and weeds are reduced to support the conservation of all priority species.

Priority ecosystems

An assessment of fire impacts was undertaken for regional ecosystem (RE) types across three categories: rainforests, wet eucalypt open forests and dry sclerophyll ecosystems. Of the 42 fire-impacted REs, nine were rainforests, with a range of notophyll and microphyll forests that had between <1 to 58% of their area burnt across GWHA. A total of 3,888ha of rainforest burned with significant ecological impacts. The most impacted rainforest RE was simple microphyll fern thicket, with 71% of the area burnt experiencing high to catastrophic PEI. The unprecedented fire impacts on rainforest REs were highlighted, as well as the critical need for continued monitoring and on-ground actions to reduce threats. Advancing the remote sensing methodology to quantify delayed fire impacts in rainforests is a priority for research. Threats to the recovery of all 42 fire-impacted REs include pigs, deer, cattle and ecosystem-transforming weeds. The risk from pathogens like myrtle rust is a major concern, and post-fire restoration plantings present a risk of introducing novel genetic material, invasive plants or pathogens, causing soil compaction and hindering natural regeneration through repeated visitation; therefore, they are not supported.

Reducing threats

Actions were undertaken to address key threats to the initial post-fire recovery of priority species and ecosystems. To reduce the risk of another fire in the short term and to support broader landscape-scale fire management, over 100km of firelines were upgraded or established, alongside maintenance works to other firelines. To support an emergency bushfire response in the remote sections of Mt Barney NP, two water tanks were installed. Planned burns were conducted across 6,585ha of GWHA in fire-adapted vegetation to maintain suitable habitat for recovering priority species and to mitigate the risk of future fires and high fire severity. All actions enhanced the capability to fight bushfires and limit fire progression into core habitats for priority threatened species and recovering ecosystems. Park-level fire strategies were revised to guide ongoing fire management actions to support ecological recovery.

Sixty-two pigs were removed during the project and 27 cattle were mustered in collaboration with adjoining landholders. To exclude cattle and feral horses, over 10km of fencing was installed in strategic locations. Cats were targeted for control to protect priority species, with 15 feral cats removed. Strategic control of weeds was undertaken with a total of 366ha treated, particularly targeting a wide range of ecosystem-transforming weeds. The pest strategy for each national park was revised to guide ongoing pest management across the extensive post-fire landscapes.

Lessons learnt

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 and 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 hectares (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* (EPBC) (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 one-third of species are considered described, yet an analysis of the fire impacts on known taxa found that they contributed 95% of the fauna species with a distributional overlap of at least 50% with the 2019–2020 bushfires (Marsh *et al.* 2021). Moreover, 382 invertebrate taxa had their entire known range burnt (Marsh *et al.* 2022). The bushfires are estimated to have caused the extinction of 700 invertebrate species (Lee 2020) with fire impacts on invertebrates found to persist for many decades (Henry *et al.* 2022).

In Queensland, more than 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 EPBC, of which 21 were Critically Endangered (Threatened Species Operations 2020). In southern Queensland, the preceding extensive drought (Bureau of Meteorology 2019) 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.* 2021), which would have significant consequences for wildlife during the fire and for post-fire recovery.

1.2 Queensland Bushfire Recovery Program

In January 2020, the Department of Environment and Science (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 study by the Australian Government's Wildlife and Threatened Species Bushfire Recovery Expert Panel for species listed as threatened under the EPBC. 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 (Queensland section); Coastal wallum-heath of the Cooloola area; Oakview and Nangur National Parks; and Bulburin National Park.

By March 2021, the Australian Government provided support to DES for Phase 2 Recovery and Resilience funding of $2.35 million to sustain efforts across Gondwana Rainforests of Australia World Heritage Area in Queensland (hereafter referred to as GWHA) and the Cooloola section of Great Sandy National Park through to October 2022. Three projects were established to continue reducing threats to the recovery of priority species: pest animal control; fire management; and strategic weed control. Ecological monitoring of a revised set of priority threatened species and priority ecosystems was incorporated into each project. This report documents the implementation of recovery actions for priority threatened species in GWHA between May 2020 and October 2022 for Phases 1 and 2.

1.3 Prioritisation of threatened species and ecological communities

The species classified as threatened under the NCA and/or EPBC were prioritised for recovery efforts based on the overlap of their modelled habitat with the fire extent, as well as expert evaluation of likely fire impacts and threats (Threatened Species Operations 2020). Across GWHA, the fires impacted Lamington, Mt Barney and Main Range NPs, with the prioritised species including 14 vertebrates (Table 1), seven invertebrates (Table 2) and 24 plants (Table 3). Habitat of the EPBC Critically Endangered crayfish *Euastacus jagara* (endemic to Main Range NP) was assessed as having only minor impacts, so was not considered further. In Phase 2, priority vertebrate and plant species were revised by the Australian Government (Tables 1 and 3) and ecosystems were included.

Table 1: Priority vertebrate species with the area of their statewide modelled habitat impacted by the 2019–2020 bushfires (Threatened Species Operations 2020), inclusion in Phase 1 and/or 2 of the program, conservation status under state (NCA) and/or Commonwealth (EPBC) legislation (NT – Near Threatened; V – Vulnerable; E – Endangered) and their known occurrence across Lamington, Mt Barney and Main Range NPs.

Species	Common name	Habitat Impacted		NCA	EPBC	Phase		Lamington	Mt Barney	Main Range
		(Ha)	%			1	2			
Class Mammalia										
Pseudomys oralis	Hastings River mouse	41,400	34	V	E	✓	✓	✓		✓
Pseudomys novaehollandiae	New Holland mouse	30,850	26	V	V	✓	✓			✓
Petrogale penicillata	Brush-tailed rock-wallaby	122,048	20	V	V	✓	✓		✓	✓
Potorous tridactylus tridactylus	Long-nosed potoroo	153,419	14	V	V	✓		✓	✓	✓
Dasyurus maculatus maculatus	Spotted-tailed quoll	119,480	13	V	E	✓		✓	✓	✓
Class Aves										
Menura alberti	Albert's lyrebird	13,406	32	NT	-	✓	✓	✓	✓	✓
Calyptorhynchus lathami	Glossy black-cockatoo	53,403	14	V	V	✓		✓	✓	✓
Cyclopsitta diophthalma coxeni	Coxen's fig-parrot	1,526	24	E	E	✓		✓		✓
Dasyornis brachypterus	Eastern bristlebird	3,217	35	E	E	✓	✓	✓	✓	✓
Atrichornis rufescens	Rufous scrub-bird	3,071	35	V	E	✓	✓	✓	✓	✓
Class Reptilia										
Coeranoscincus reticulatus	Three-toed snake-tooth skink	2,109	25	C	V		✓	✓		✓
Class Amphibia										
Mixophyes fleayi	Fleay's barred frog	52,451	30	E	E	✓	✓	✓	✓	✓
Litoria pearsoniana	Cascade treefrog	69,180	16	V	-	✓		✓	✓	✓
Philoria kundagungan	Red-and-yellow mountainfrog	34,151	52	V	E	✓	✓			✓

The Australian Government's Wildlife and Threatened Species Bushfire Recovery 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: Priority invertebrate species for Phase 1 and their occurrence across Lamington and Main Range NPs.

Order	Species	Common Name	Lamington	Main Range
Class Arachnida				
Araneae	*Austrarchaea cunninghami*	Main Range pelican spider		✓
	Austrarchaea dianneae	Gold Coast hinterland pelican spider	✓	
	Austrarchaea nodosa	McPherson Range pelican spider	✓	
Class Insecta				
Hemiptera	*Hackeriella echina*	Moss bug	✓	✓
	Hackeriella veitchi	Moss bug	✓	✓
Coleoptera	*Amphistomus macphersonensis*	Dung beetle	✓	✓
Class Malacostraca				
Decapoda	*Euastacus jagara*	Jagara hairy crayfish		✓

Table 3: Priority plant species with the area of their statewide modelled habitat impacted by the 2019–2020 bushfires (Threatened Species Operations 2020*), inclusion in Phase 1 and/or 2 of the program, their conservation status under state (NCA) and Commonwealth (EPBC) legislation (NT – Near Threatened; V – Vulnerable; E – Endangered) and their known occurrence across Lamington, Mt Barney and Main Range NPs.

Species	Habitat Impacted		NCA	EPBC	Phase		Lamington	Mt Barney	Main Range
	Ha	%			1	2			
Open Forest/ Woodland									
Brachyscome ascendens	450	40	V	-	✓	✓	✓	✓	✓
Coopernookia scabridiuscula	773	40	V	V	✓			✓	
Hibbertia monticola	1,134	43	NT	-	✓			✓	✓
Montane Heath									
Agiortia cicatricata	624	69	NT	-	✓			✓	
Bertya ernestiana	897	91	V	V	✓	✓		✓	
Comesperma breviflorum	957	29	NT	-	✓			✓	
Euphrasia bella	414	68	E	V	✓		✓	✓	
Gonocarpus hirtus	297	22	V	-	✓	✓			✓
Grevillea linsmithii	*not assessed		E	-		✓		✓	✓
Leionema elatius subsp*. beckleri*	473	61	E	-	✓			✓	
Leptospermum barneyense	806	50	V	-	✓	✓		✓	
Philotheca obovatifolia	*not assessed		LC	-	-	✓		✓	
Pimelea umbratica	1,220	68	NT	-	✓	✓	✓		✓
Pseudanthus pauciflorus subsp*. pauciflorus*	692	58	NT	-	✓	✓		✓	
Pultenaea whiteana	619	61	V	-	✓	✓	✓	✓	
Tetramolopium vagans	1,155	74	V	-	✓	✓		✓	
Zieria montana	524	100	CE	-	✓	✓	✓	✓	
Rainforest/Dry Vine Forest									
Bulbophyllum weinthalii subsp. *weinthalii*	592	57	V	-	✓	✓	✓		✓
Clematis fawcettii	65,548	21	V	V	✓		✓	✓	✓
Dendrobium schneiderae var. *schneiderae*	892	62	NT	-	✓		✓	✓	✓
Muellerina myrtifolia	922	27	NT	-	✓				✓
Phlegmariurus varius	314	23	V	-	✓		✓	✓	
Sarcochilus hartmannii	476	44	V	V	✓	✓	✓	✓	✓
Sarcochilus weinthalii	338	26	E	V	✓		✓	✓	✓

1.4 Priority recovery actions

This project aimed to deliver a range of actions that aligned to expert advice to protect and support the ongoing recovery of priority threatened species:

- **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.
- **Monitor priority threatened species**—field assessment of species' status by expert ecologists using best-practice techniques to set a baseline to track recovery and to compare to pre-fire data, where available.
- **Reduce threats to recover**—implementation of actions to reduce the risk to priority species and their habitats from future fires, invasive weeds and pest animals.
- **Recommendations and guidance**—assessment of the information and insights gained from the previous actions to provide recommendations for ecological monitoring and research and for reducing threats.

A summary of the implementation of these recovery actions across Lamington, Mt Barney and Main Range NPs between May 2020 and October 2022 for Phases 1 and 2 is captured in this report.

2 Post-fire ecological impact assessment

A post-fire assessment documented the fire extent, patterns of fire severity and ecological impacts across Lamington (Hines *et al.* 2020), Mt Barney (Hines *et al.* 2022) and Main Range protected areas (Hines *et al.* 2021). Summary results from the post-fire assessment reports are reproduced here for context (refer to Hines *et al.* 2020, 2021 & 2022 for the full analysis, and the details and caveats of the remote sensing methodology).

2.1 Fire extent and severity

Almost 30,000ha burned across GWHA (Figure 1), which represented an increasing proportion of the QPWS-managed estate across Lamington NP (7%), Mt Barney NP (48%) and Main Range NP (56%), respectively. Fire severity was analysed by comparing remote imagery before and after the 2019–2020 bushfires to create fire severity classes (Table 4). These classes reflect the variable levels of impact to vegetation strata which were quantified across Lamington NP, Mt Barney NP and Main Range NP (Hines *et al.* 2020, 2022 & 2021, respectively).

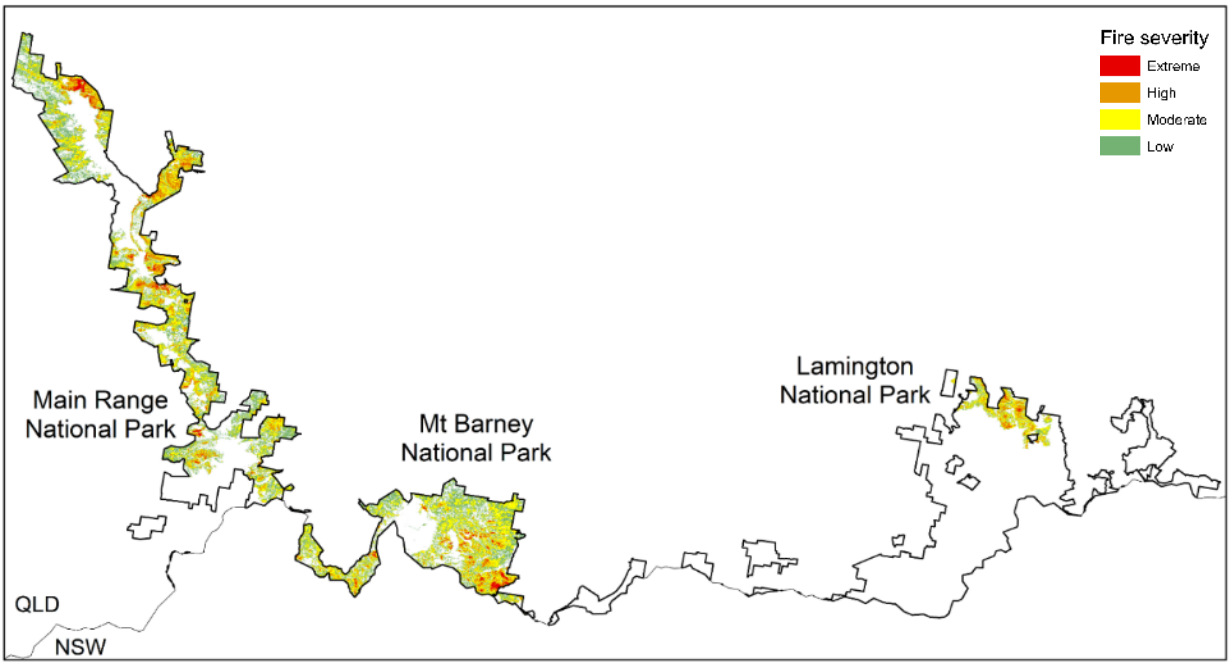

Figure 1: Extent of the 2019–2020 fires at Lamington, Mt Barney and Main Range NPs and levels of fire severity.

At Lamington NP, 1,532ha burned, with half of this area burnt at a moderate level of fire severity with the tree canopy affected and the understorey mostly lost (Table 4). Approximately one-quarter of the fire extent was at low fire severity with the canopy unscorched and another quarter at high severity with significant impacts to the vegetation canopy and the understorey consumed by the fire. Over 30ha experienced the extreme level of fire severity with the vegetation completely consumed (Table 4). Across Mt Barney NP, 8,729ha burnt, with most at a low (42%) or moderate (46%) level of fire severity and the remainder having greater impacts to the vegetation at a high (9%) or extreme (3%) level of fire severity (Table 4). Main Range NP had the most extensive impacts, with almost 20,000ha burnt. A similar area was burnt at a low (44%) and moderate (39%) level of fire severity with the understorey vegetation affected. The remaining area experienced considerable canopy damage or loss at high (15%) and extreme (2%) levels of fire severity (Table 4, Figure 2).

Table 4: The area (ha) burnt at Lamington, Mt Barney and Main Range NPs across different fire severity classes (data from Hines *et al.* 2020, 2022 & 2021, respectively).

Fire severity class	Description of effect on vegetation	Lamington	Mt Barney	Main Range
Low	Canopy and subcanopy unscorched, shrubs may be scorched, fire-sensitive low shrubs may be killed.	358	3,645	8,447
Moderate	Partial canopy scorch, subcanopy partially or completely scorched, and/or fire-sensitive tall shrub or small tree layer mostly killed.	765	4,016	7,490
High	Full canopy scorch to partial canopy consumption, subcanopy fully scorched or consumed.	378	801	2,910
Extreme	Full canopy, subcanopy and understorey consumption	31	267	346
		1,532	**8,729**	**19,193**

2.2 Potential ecological impacts

The ecological consequences of a fire at a given level of fire 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 endemic to fire-sensitive ecosystems, such as rainforests and vine forests, 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 (Laidlaw *et al.* 2022). As a result, surveys of fire-impacted wildlife and recovery actions can be better directed to where they are most needed.

In Lamington NP, a similar area of fire-tolerant and fire-sensitive vegetation burned, with the latter including lowland subtropical rainforest and dry vine forest that experienced moderate (30%), high (50%) and catastrophic (20%) PEI levels across 658ha (Figures 3 & 5; Hines *et al.* 2020). Vegetation with a fire-tolerant canopy and a fire-sensitive understorey included wet eucalypt forest and the eucalypt-rainforest ecotone that had 24% of their burnt area with limited or no PEI and the rest with moderate to high PEI levels. The burning of fire-tolerant communities resulted in 65% of the area with limited to no PEI, and the rest mostly with moderate PEI (Figures 3 & 5; Hines *et al.* 2020).

At Mt Barney NP, almost half of the burnt area was in fire-tolerant plant communities with 91% having limited or no PEI. For the more fire-sensitive vegetation types, the PEI levels were much greater (Figures 3 & 5; Hines *et al.* 2022). Ecosystems such as rainforest, with a fire-sensitive canopy and understorey, had moderate (39%), high (45%) and catastrophic (15%) PEI across more than 2,100ha. Vegetation with a fire tolerant canopy but a fire-sensitive understorey had PEI at all four levels, dominated by moderate (49%) and limited or no impacts (36%) (Figures 3 & 5; Hines *et al.* 2022).

At Main Range NP, the fire-tolerant ecosystems represented 70% of the area burnt in the 2019–2020 bushfires, which mostly had limited or no PEI (83%). For communities with fire-tolerant canopies and a fire-sensitive understorey, the majority of the PEI was of a moderate level (40%) or limited/none (43%). The remainder was at a high to catastrophic level, which represented over 700ha. Fire-sensitive vegetation that burned represented 1,695ha, with moderate (49%), high (33%) and catastrophic (18%) PEI outcomes (Figure 4 & 5; Hines *et al.* 2021).

Figure 2: High to extreme PEI in burnt rainforest at Cunninghams Gap, Main Range NP. (Photo: T. Churchill)

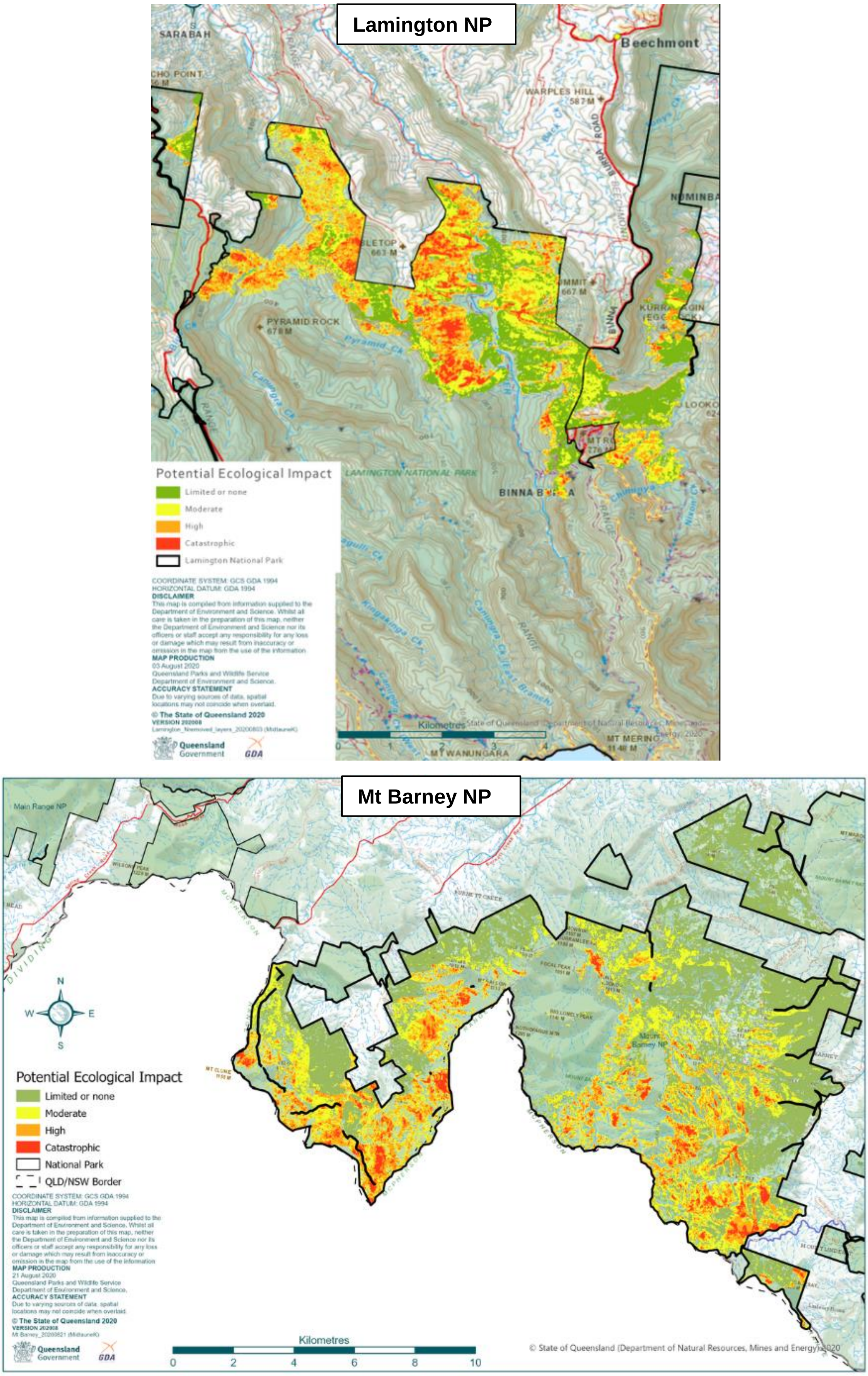

Figure 3: PEI map of the 2019–2020 bushfires at Lamington NP (above) and Mt Barney NP (below). Reproduced from Hines *et al.* (2020 & 2022)

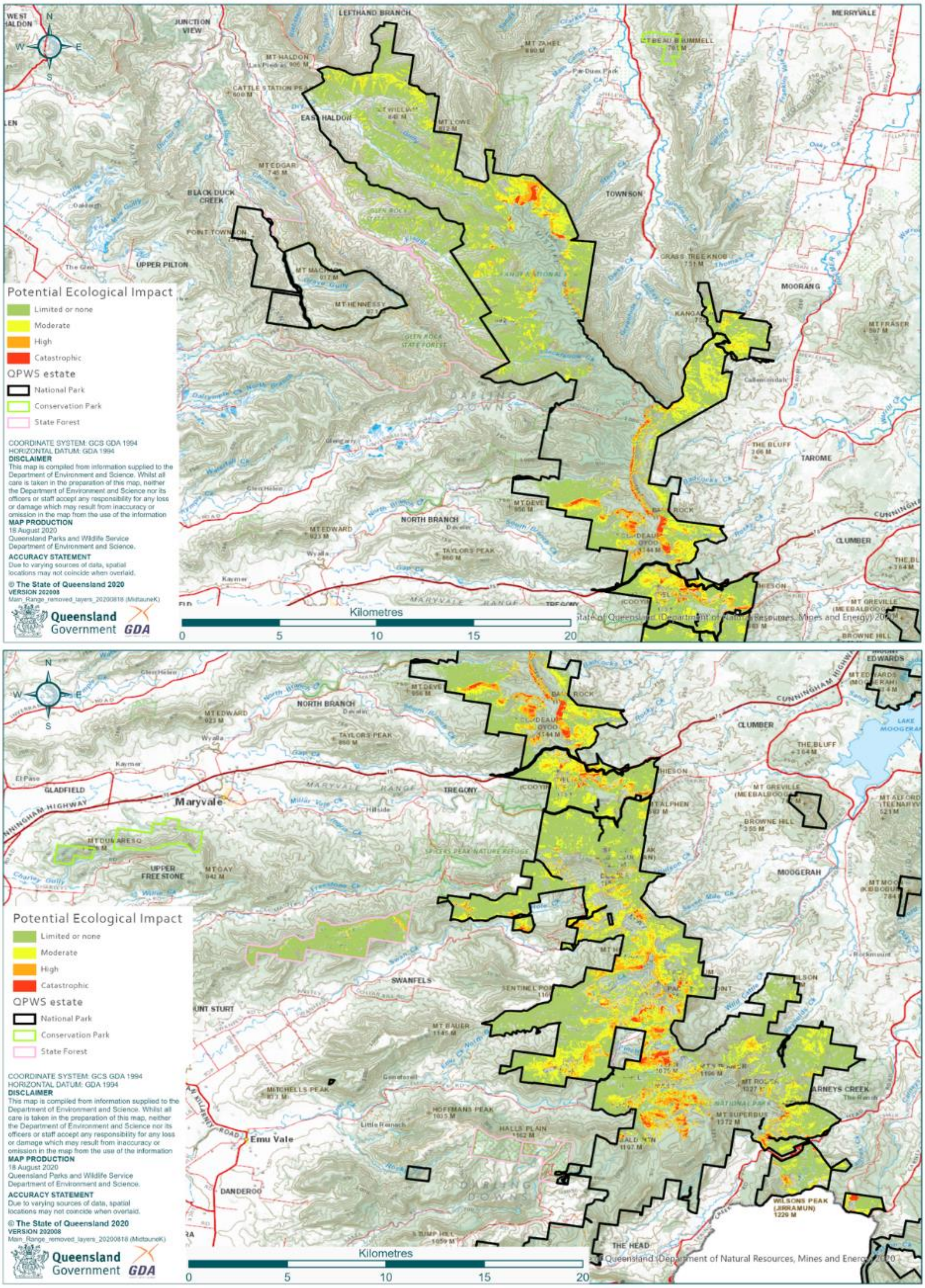

Figure 4: PEI map of the 2019–2020 bushfires at Main Range NP (northern section – above; southern section – below). Reproduced from Hines *et al.* (2021)

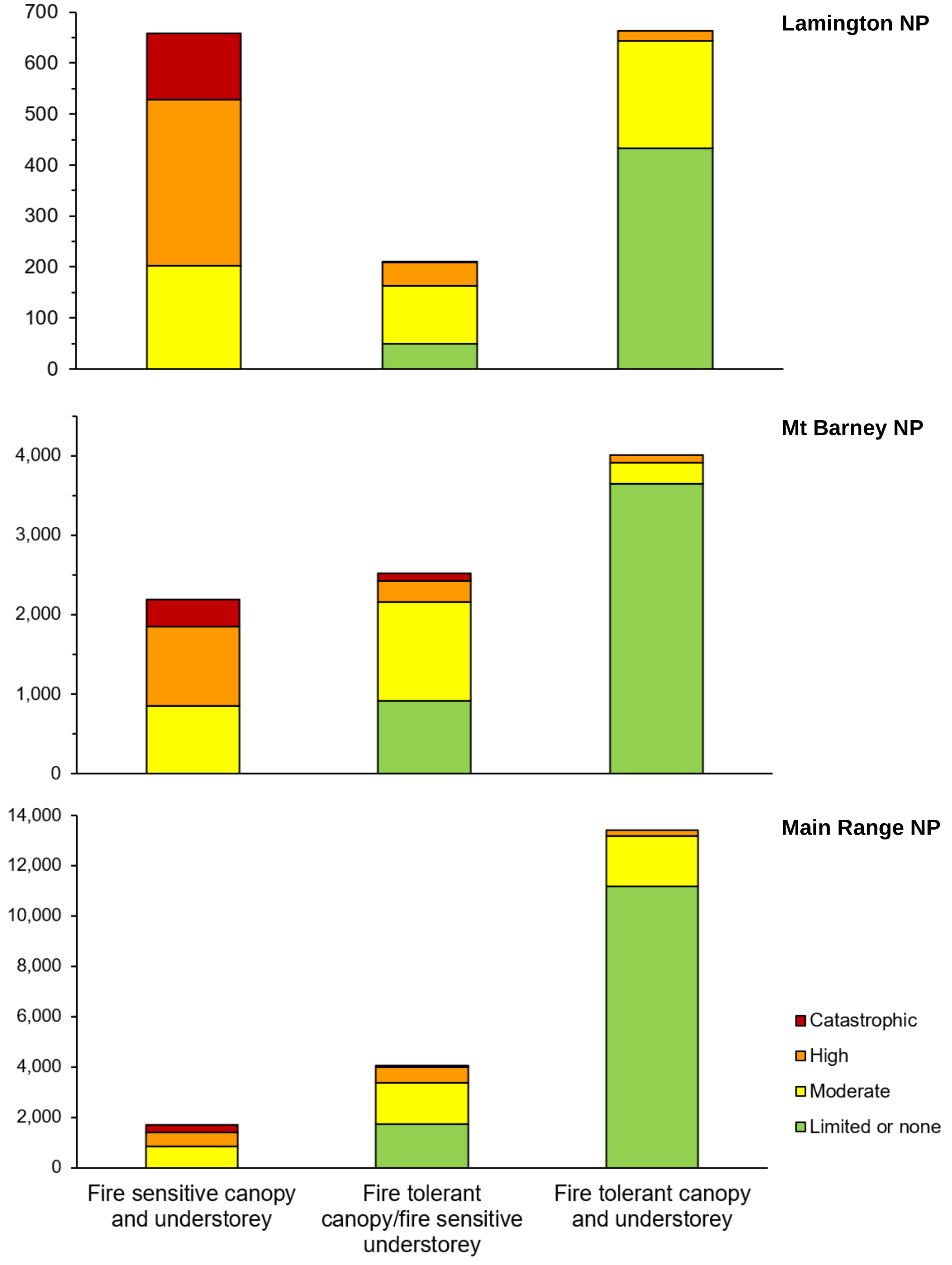

Figure 5: The area (ha) that burned with a limited/none (green shading), moderate (yellow shading), high (orange shading) or catastrophic (red shading) level of PEI across three vegetation types, based on their fire sensitivity or tolerance at Lamington, Mt Barney and Main Range NPs (data from Hines *et al.* 2020, 2022 & 2021, respectively).

3 Priority mammals

3.1 Brush-tailed rock-wallaby

3.1.1 Conservation context

The brush-tailed rock-wallaby *Petrogale penicillata* is listed as Vulnerable under both the NCA and EPBC. The brush-tailed rock-wallaby has experienced substantial population declines, particularly in Victoria and New South Wales (NSW) due to habitat loss, disturbance or modification, invasive species impacts, disease and potentially climate change (Department of Agriculture, Water and the Environment 2020). The habitat, distribution and diet of the brush-tailed rock-wallaby in Queensland are described in Krieger (2010).

3.1.2 Survey sites and methods

Multiple surveys methods were utilised to monitor brush-tailed rock-wallabies between 15 March and 30 December 2021. In March and July 2021, monitoring focused on visual surveys at preselected sites detected through sightings of individuals or the presence of fresh/recent scats. At each site, search surveys were conducted by two personnel for a minimum of 30 minutes or until individuals or scats were detected.

A total of 16 sites was surveyed across Mt Barney NP, Main Range NP and Glen Rock State Forest. In addition, four sites located in properties adjacent to QPWS estate boundaries were surveyed. Sites were selected to represent a range of fire severity classes in areas with known sighting records, suitable habitat and good accessibility.

From July to December 2021, in addition to visual surveys, camera trapping was also conducted on a subset of sites (n = 5). Sites were selected based on accessibility and representation of varying fire severity classes and with sampling conducted across non-connected areas of refuge habitat (rocky escarpments) in Mt Barney NP, Main Range NP and Glen Rock State Forest (SF). Camera monitoring aimed to detect breeding since the fire event through the presence of subadults (born 2020) and pouch young (born 2021). Two unbaited cameras, 200–300m apart, were deployed at each site. Cameras were placed at varying heights (50–150cm) due to the different locations and availability of mounting structures and angled to face target areas likely to detect rock-wallabies, e.g. runways or sunning spots. Where necessary, vegetation directly in front of the camera was removed by hand-pulling to minimise false triggers and obstructions. Two camera models were used: Swift Enduro and Reconyx HC600. All cameras were constantly active and set to take two still photos per trigger with a 1 second trigger delay and 30 second quiet period between activations. All cameras were set to the highest sensitivity and resolution possible for each model. Cameras were deployed for a minimum of 3 months.

Data from paired cameras at each site were combined because although considered independent at an individual scale, the distance between cameras was within known colony extent (Laws & Goldizen 2003). Images were analysed using Camelot, an open-source camera trapping software (Hendry and Mann 2018). Variables recorded were sex (if possible), age (adult, juvenile/subadult, young at foot), presence of pouch young and visual health/condition concerns.

3.1.3 Survey results

Visual surveys

Brush-tailed rock-wallabies were detected (Figure 7) at 12 of the 16 sites within QPWS estate and all four sites in adjacent private land (Figure 6, Table 5). The sites where rock-wallabies were not detected included three sites surrounding Mt Maroon and the Lower Portals site in Mt Barney NP. Although not unique to these sites, all sites were unburnt or had 'low fire severity' with relatively low grass and sedge/herb cover. During broader bushfire surveys, there were incidental sightings of five individuals at Black Duck Creek in Glen Rock SF, two individuals at the Gambubal escarpment in Main Range NP and three individuals at Mt Ballow/Mt Barney in Mt Barney NP.

Camera surveys

Cameras were retrieved from all sites in November and December 2021, except the Upper Portals, which was unable to be accessed due to high rainfall. Male and female brush-tailed rock-wallabies and evidence of successful breeding during 2020 and 2021 were detected at all sites (Table 6). Although individual identification was not possible due to the species' uniform colouring, at least three individuals were detected at each site. No visible evidence was found of loss of condition or health concerns in any of the rock-wallabies seen on cameras.

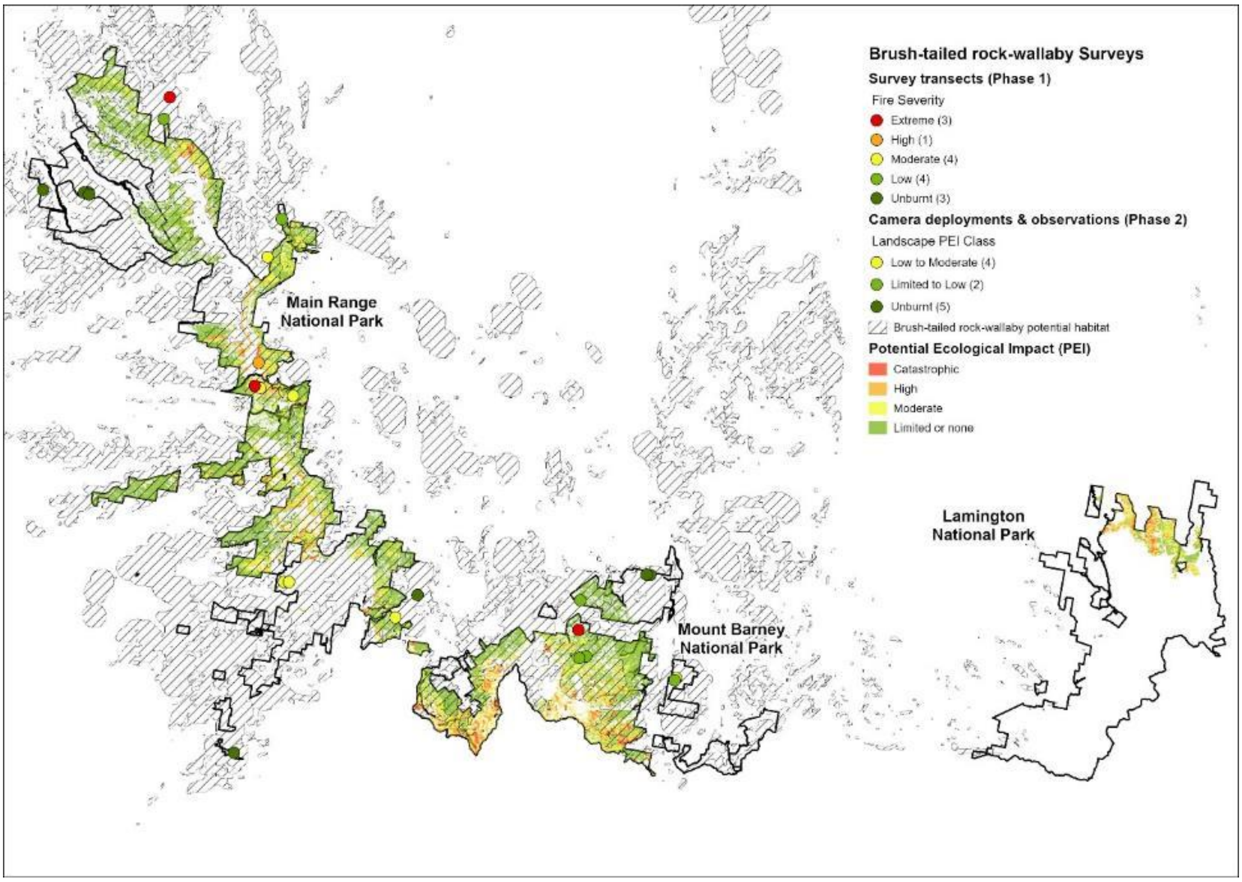

Figure 6: The potential habitat (DES 2021) of brush-tailed rock-wallaby across GWHA with the location of camera trap detections and the PEI of the 2019–2020 bushfires.

Table 5: Visual survey results for the brush-tailed rock-wallaby across sites with a range of fire severity classes.

	Main Range NP	Mount Barney NP	Glen Rock SF	Outside QPWS estate
Number of sites surveyed	6	9	1	4
Fire severity class (number of sites)	Extreme (1) High (1) Moderate (2) Low (2)	Extreme (1) Moderate (1) Low (3) Unburnt (4)	Unburnt (1)	Extreme (1) Moderate (1) Low (1) Unburnt (1)
Number of sites with fresh/ recent scat	6	5	1	4
Number of sites with sightings (total number seen)	2 (3)	1 (1)	2 (8)	1 (1)

Table 6: Camera survey results for the brush-tailed rock-wallaby across sites with a range of PEI levels.

	Main Range NP		Mount Barney NP		Glen Rock SF	
	Mount Mitchell	Mount Maroon	The Steamers	Lower Portals	Mount Machar	Total
Potential ecological impact category	Low to Moderate	Unburnt	Low to Moderate	Limited to Low	Unburnt	
Camera trap-days	278	180	276	*	224	**958**
Total images (non-target images; % blank images)	4,666 (3,744; 80%)	10,904 (10,586; 97%)	6,035 (5,918; 98%)	*	2,7248 (2,6825; 98%)	**48,853** (4,7073; 96%)
Number of target images	922	318	117	*	423	**958**
Days to detection	0.56 - 0.73	2.1 - 4.4	1.15 - 22.55	*	0.72 - 0.73	**0.56 - 22.55**

*Camera not retrieved at time of reporting

3.1.4 Discussion

Survey results indicated that brush-tailed rock-wallabies continue to persist across the fire-impacted areas of Mt Barney NP, Main Range NP and Glen Rock SF, as well as adjacent private land, following the 2019–2020 bushfires. Typically, bushfires are not considered to be a direct threat to brush-tailed rock-wallabies due to their ability to find refuge from fire in the rocky escarpments. However, indirect threats following bushfires include greater exposure to predators (particularly impacting smaller, younger rock-wallabies) and/or limited food supply. Detection of both pouch young and subadults through camera surveys provided evidence of breeding and survivorship of young brush-tailed rock-wallabies following the 2019–2020 bushfires into the second year.

Assessing the apparent condition of all individuals that were detected on camera showed no visible health concerns. This suggests sufficient access to food resources, likely due to the high rainfall that followed the bushfires and which stimulated grass growth in these regions. Notably, the four areas where brush-tailed rock-wallabies were not detected during visual surveys were unburnt or had low fire severity. The lack of detections is assumed to be due to detectability issues rather than reflecting population declines. This was supported by the detection of brush-tailed rock-wallabies through incidental observations and camera surveys in adjacent escarpments.

Although predation was not directly observed, feral predators, both dingoes and red foxes, were observed on the same camera traps that detected brush-tailed rock-wallabies at three of the five camera sites. No cats were detected at any sites. Foxes and cats are considered a key threat to rock-wallabies due to their ability to navigate rocky escarpments, whilst dingoes are likely limited to preying on brush-tailed rock-wallabies only when they move away from the escarpment to feed.

3.1.5 Recommendations

Reducing ongoing threats

- Maintain optimal habitat

  The use of strategic planned burns is advised to promote the growth of suitable grass food resources in areas surrounding suitable brush-tailed rock-wallaby habitat.

- Reduce impacts of cats and foxes

  Monitoring of feral predators in suitable habitat areas with appropriate controls will support population recovery.

- Reduce impacts of weeds in core habitat areas

  The incursion of weeds reduces protective understorey cover and foraging resources in suitable habitat areas.

Ecological monitoring

- Continue monitoring brush-tailed rock-wallabies

  Ongoing monitoring will track post-fire recovery and improve knowledge of the species' distribution and abundance to guide conservation actions. The use and efficacy of alternative survey methods should be investigated (e.g. thermal scope and helicopter surveys), especially for less accessible areas.

- The current habitat mapping should be updated following this project to capture the known extent of brush-tailed rock-wallaby colonies across QPWS estate and to inform further monitoring efforts.

Ecological research

- More detailed surveys to improve knowledge of the species' ecology and abundance in known locations.

Figure 7: Brush-tailed rock-wallaby observed at Main Range NP. (Photo: B. Kulp)

3.2 Long-nosed potoroo

3.2.1 Conservation context

The long-nosed potoroo *Potorous tridactylus tridactylus* is found in subtropical and warm-temperate rainforest (including *Nothofagus* and notophyll vine forest), wet sclerophyll forest (with *Lophostemon*, *Eucalyptus saligna*, *E. microcorys*) and tall open forest (Amos 1982; Jarman *et al.* 1987; Seebeck *et al.* 1989; Bennett 1993; Johnston 2008) where it requires access to dense lower-storey vegetation for shelter (Bennett 1987) and an abundant supply of fungi for food (Claridge *et al.* 1992). Its known Queensland distribution is Bulburin NP (north-west of Bundaberg) south to the Queensland–NSW border (Lindenmayer & Viggers 1994). The subspecies is listed as Vulnerable under the NCA and EPBC. There is currently no recovery plan, but the subspecies does have an approved Conservation Advice (Threatened Species Scientific Committee 2019). Threats to this subspecies include feral predators (Maxwell *et al.* 1996; Norton *et al.* 2015), destruction and fragmentation of habitat (Johnston 2008; Maxwell *et al.* 1996), weed invasion, climate change and inappropriate fire regimes (Maxwell *et al.* 1996).

3.2.2 Survey sites and methods

Camera trapping was used to survey long-nosed potoroos, with 112 cameras deployed between 8 September 2020 and 18 February 2022 across 88 sites (Figure 8) with a range of PEI classes.

Cameras targeting potoroos were set horizontally (lens roughly horizontal to ground), 30–50cm from the ground, angled slightly downward, facing southwest when possible, and spaced approximately 500m apart (Appendix 1, Table A1.1). Baited cameras (Figure 9) were set approximately 1.5–2m from the bait, aimed directly at the bait, while unbaited cameras were often set along an established track or game trail, aimed at an approximately 45° angle to the trail. Where necessary, vegetation directly in front of the camera was thinned by hand-pulling to minimise false triggers and obstructions. Only still photos were taken at a rate of three photos per trigger with a 5-second trigger delay. The sensor sensitivity of each camera was set to High, except for the BolyGuard SG2060-Ds, which were set to Normal after the first round of deployments due to a high instance of false triggers.

Swift Enduro cameras were baited with a) mammal bait (a mixture of rolled oats, peanut butter, golden syrup, peanut oil and pistachio essence) (n=8 sites); b) mammal bait and raw chicken (necks and/or wings) (n=2 sites); c) peanut butter and raw chicken (n=19 sites); or d) peanut butter only (n=2 sites). All other camera models were unbaited. The same cameras deployed to survey long-nosed potoroos were also used to detect spotted-tailed quolls (section 3.3) and Albert's lyrebirds (section 4.1). A summary the overall camera trapping effort is provided in Appendix 1 (Table A1.1), as are the technical specifications of the cameras used (Table A1.2). Images were analysed using Camelot, an open-source camera trapping software (Hendry & Mann 2018).

Camera trap results were analysed with respect to Landscape PEI which provides a measure of PEI in the landscape surrounding a camera deployment site (Laidlaw *et al*. 2022; Appendix 2).

3.2.3 Survey results

Long-nosed potoroos were detected on camera at Mt Barney NP (Figure 10) – at one site on Mt Ballow and one site near Stags Head – and at three sites in the Gambubal section of Main Range NP (Table 7). Two individuals were detected in September on Mt Ballow, one individual in October, and at least two individuals were photographed at the same site in November 2020 (Figure 11). It was not possible to determine if these were unique individuals or repeated detections of the same individuals.

In May 2021, at least three long-nosed potoroos were detected by three camera traps in the Gambubal section of Main Range NP. At least one individual was detected in September, October and December 2021 and in February 2022 at the site near Stags Head in Mt Barney NP. All detections of long-nosed potoroos were at burnt sites in areas of limited–low or low–moderate Landscape PEI (Figure 11).

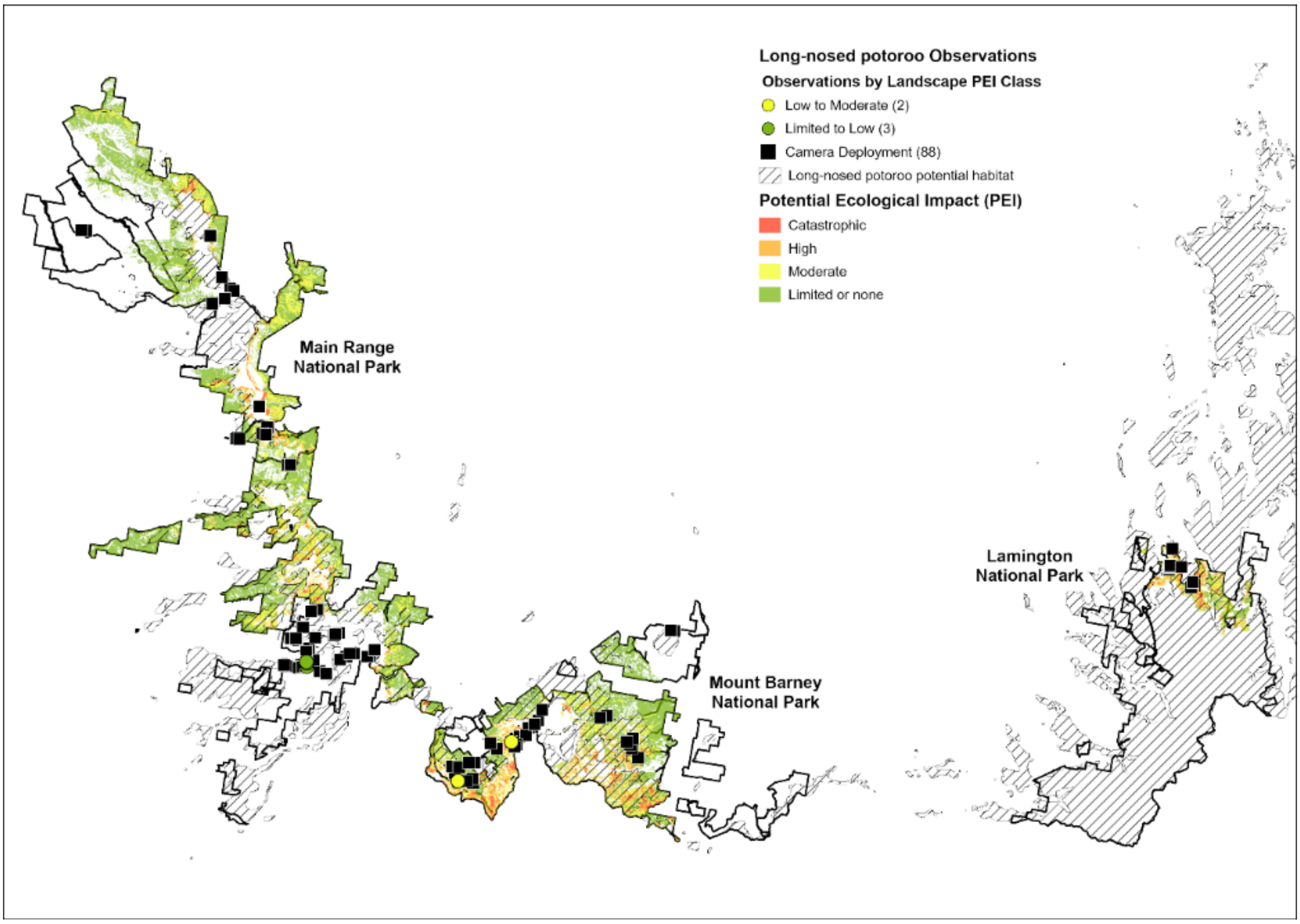

Figure 8: The potential habitat (DES 2021) of long-nosed potoroo across GWHA with the location of camera trap detections and the PEI of the 2019–2020 bushfires.

Figure 9: Setting bait canister with peanut butter and pistachio essence (left) to lure long-nosed potoroos to the camera trap (right). (Photo: A.H. McCall)

Figure 10: Long-nosed potoroos detected by camera trap in September 2020 at Mt Barney NP. (QPWS)

Table 7: Summary of trapping effort and long-nosed potoroo detections on camera traps.

	Mt Barney NP		Main Range NP		Lamington NP		Total
	Baited	Unbaited	Baited	Unbaited	Baited	Unbaited	
Number of sites detected (sites surveyed)	0 (10)	2 (23)	3 (23)	0 (23)	0 (2)	0 (7)	**5 (88)**
Camera trap-days detected (total trap-days)	0 (1551)	25 (3396)	3 (1080)	0 (1667)	0 (182)	0 (388)	**28 (8264)**
Days detected per 100 trap-days	0	0.73	0.28	0	0	0	**0.34**
Total images	0	49	34	0	0	0	**83**

[1]One site at Main Range NP had both a baited and an unbaited camera

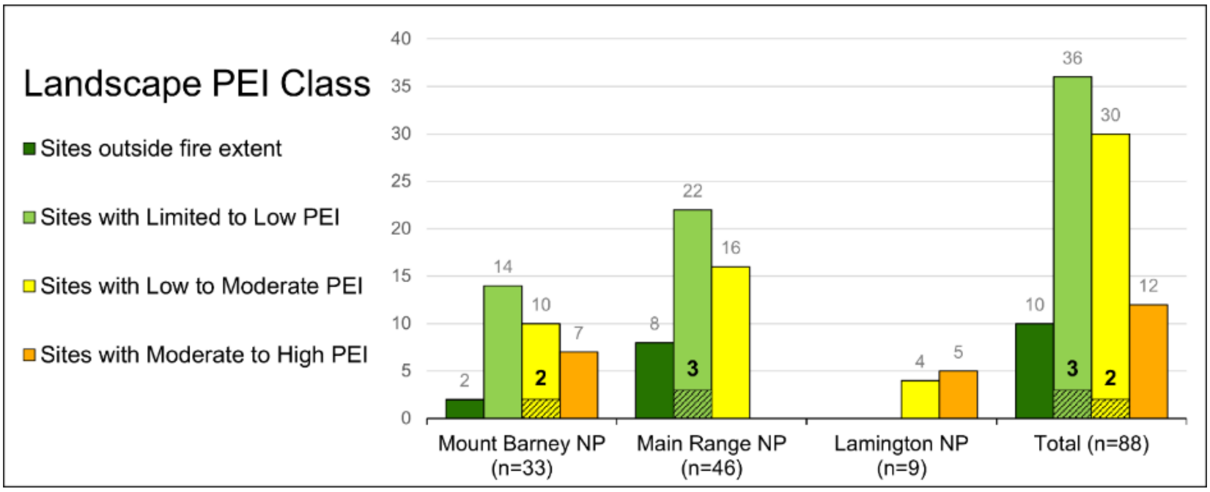

Figure 11: The number of sites surveyed for the long-nosed potoroo with specific Landscape PEI classes. Hatched areas and bold numbers indicate sites where long-nosed potoroos were detected on cameras.

The potential habitat modelling (Laidlaw & Butler 2021) undertaken for the study area revealed that 29% of likely habitat was impacted by the 2019–2020 bushfires across GWHA (Table 8).

Table 8: Area of modelled potential habitat (PH) for the long-nosed potoroo and the estimated proportion burnt across the study area in the 2019–2020 fires.

PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
35,347	19	10,227	29

3.2.4 Discussion

Though long-nosed potoroos were seldom detected on camera traps, it was demonstrated that the subspecies persists in burnt habitat post-fire. The low number of detections is suspected to be due to detectability issues rather than actual population declines resulting from impacts of the 2019–2020 bushfires. Assessment of the impacts of the fire on the subspecies was hindered by limited or no pre-fire baseline.

The potoroos detected were found to be using both burnt rainforest and burnt open forest habitat.

Although predation was not directly observed, feral predators, both cats and red foxes, were observed on the same camera traps that detected potoroos at two of five sites. The camera that detected potoroos at Mt Ballow detected a red fox only five hours after detecting a potoroo. A cat was detected on the same camera three days after detecting a potoroo. At Main Range NP, a fox was detected on a camera only 80m from a camera that detected a potoroo on the same day.

Long-nosed potoroos may play an important role in the reestablishment of forests following fire. Fungi make up 90% or more of a long-nosed potoroo's diet (Claridge *et al.* 1993, Norton 2012). The subspecies is known to consume over 50 fungal species, mostly hypogeal (underground fruiting) species, which are thought to form mycorrhizae on the roots of a variety of plants (Claridge *et al.* 1992, Claridge *et al.* 1993, Claridge 2002). Mycorrhizae are believed to facilitate nutrient and water uptake of the host plant, as well as possibly protecting the host from root pathogens (Claridge 2002). Long-nosed potoroos may enhance the establishment of these mycorrhizal colonies in disturbed forest by dispersing fungal spores from nearby undisturbed habitat in their faeces, promoting the recovery of the disturbed forest (Claridge *et al.* 1992).

3.2.5 Recommendations

Reducing ongoing threats

- Maintain optimal habitat

  The maintenance of the preferred habitat with patches of dense understorey can be achieved through strategic planned burn programs where required. Restoring habitat connectivity will facilitate post-disturbance recolonisation from refugia.

- Reduce impacts of cats and foxes

  Monitoring of feral predators is advised with appropriate control measures to support population recovery.

- Reduce impacts of weeds in core habitat areas

  The significant incursion of weeds threatens the integrity of preferred habitat, such as through dominance of invasive grasses. Weeds can also elevate the risk of bushfire and fires of high severity.

Ecological monitoring

- Continue monitoring for long-nosed potoroos

  Ongoing monitoring is critical to track post-fire recovery at the fire-impacted sites to improve the currently limited understanding of the distribution and abundance of long-nosed potoroos to guide conservation actions. The cost-effective use of cameras in this project can be replicated every two years for at least 8–10 years and serves to concurrently monitor other threatened species and threats from invasive animals.

Ecological research

- Broader surveys to improve knowledge of the distribution and abundance of long-nosed potoroos
- Investigate the impacts of fire, weeds and feral herbivores on key food resources
- Research the distribution and abundance of key food resources, such as fungi, roots, tubers and soil-dwelling invertebrates that are critical to post-fire natural regeneration.

3.3 Spotted-tailed quoll

3.3.1 Conservation context

The southern subspecies of the spotted-tailed quoll *Dasyurus maculatus maculatus* occurs across a range of habitats including rainforest, wet and dry sclerophyll forest (e.g. with *Eucalyptus andrewsii*, *E. saligna*, *E. tereticornis* and *Corymbia intermedia*), woodland, coastal heathland and riparian forest (Watt 1993; Edgar & Belcher 1995; Catling & Burt 1997). In Queensland, it occurs coastally from Gladstone to the NSW border and inland to Monto and Stanthorpe (Department of the Environment 2021; Department of Environment, Land, Water and Planning 2016). The subspecies is listed as Endangered under the NCA and EPBC. The National Recovery Plan (Department of Environment, Land, Water and Planning 2016) includes this subspecies and there is also a subspecies-specific Conservation Advice (Threatened Species Scientific Committee 2020). Threats to this subspecies include destruction, modification and fragmentation of habitat (Woinarski *et al.* 2014), competition and predation from feral predators (Edgar & Belcher 1995), poisoning by cane toads (Covacevich & Archer 1975), loss of den sites due to fire (Borsboom 1996), poisoning associated with control of feral predators (Körtner *et al.* 2003; Claridge & Mills 2007), weed invasion, road mortality and climate change (Department of Environment, Land, Water and Planning 2016).

3.3.2 Survey sites and methods

Camera traps were used to survey spotted-tailed quolls with 112 cameras deployed across 88 sites that represented a range of fire severity impacts (Figure 13), between 8 September 2020 and 18 February 2022. These were the same cameras as those used to detect long-nosed potoroos (section 3.2) and Albert's lyrebirds (section 4.1): refer to section 3.2.2 for details of methodology.

3.3.3 Survey results

Despite the total survey effort, no quolls were detected on the baited camera traps targeting this species. Two images of quolls were captured (e.g. Figure 12) in August and September 2020 on two cameras deployed by QPWS Rangers monitoring feral pig traps in unburnt rainforest of the Goomburra section of Main Range NP (Figure 14).

Figure 12: Spotted-tailed quoll captured on camera at a pig trap in August 2020 at Main Range NP.

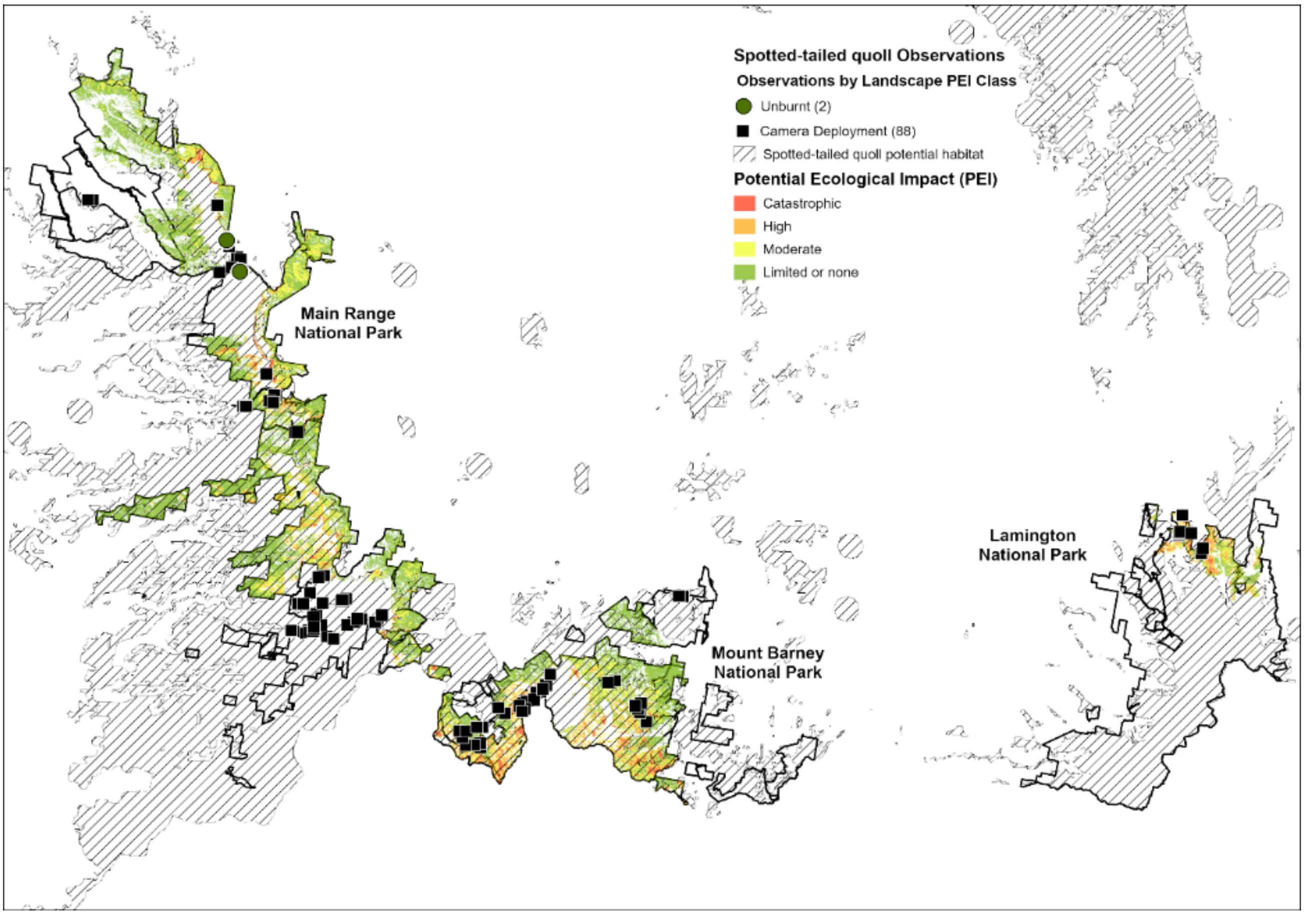

Figure 13: The potential habitat (DES 2021) of the spotted-tailed quoll across GWHA with the location of camera trap detections and the PEI of the 2019–2020 bushfires.

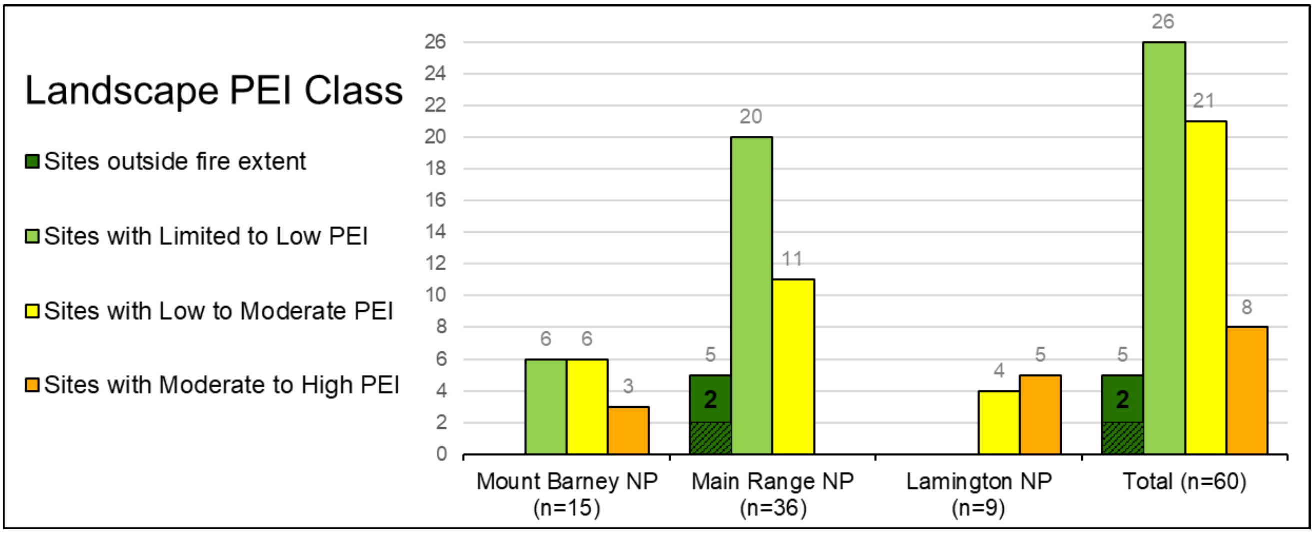

Figure 14: The number of sites surveyed for spotted-tailed quolls in each of the Landscape PEI classes. Sites at which two opportunistic quoll detections on pig trap cameras were made are included. Hatched areas and bold numbers indicate sites where spotted-tailed quolls were detected on camera.

The potential habitat modelling (Laidlaw & Butler 2021) undertaken for the study area revealed that 35% of likely habitat was impacted by the 2019–2020 bushfires across GWHA (Table 9).

Table 9: Area of modelled potential habitat (PH) for the spotted-tailed quoll and the estimated proportion burnt across the study area in the 2019–2020 fires.

PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
54,373	14	19,085	35

3.3.4 Discussion

It is not possible to fully assess the impacts of the 2019–2020 bushfires on the spotted-tailed quoll without pre-fire baseline data concerning the population size and distribution of the subspecies across GWHA. Adults are typically solitary and occupy large home ranges. This low population density makes them difficult to detect (Department of Environment, Land, Water and Planning 2016).

Spotted-tailed quoll populations were in decline prior to the 2019–2020 bushfires and the small number of remaining individuals may have retreated to refugia outside of the fire extent, which was not well surveyed during this project. The detection of quolls twice on camera during the project period using cameras deployed for pig trapping in unburnt rainforest in the Goomburra section of Main Range NP, suggests that this subspecies may have contracted to unburnt refugia following the bushfires.

The southern end of Main Range NP, in the vicinity of Queen Mary Falls, appears to be a refuge for spotted-tailed quolls, with regular detections made on cameras in this area, which was not impacted by the 2019–2020 bushfires. The lack of cane toads at this high-elevation site, which experiences low winter temperatures, may be an important factor in the apparent higher abundance of spotted-tailed quolls at Queen Mary Falls, compared to other sites across Main Range NP.

3.3.5 Recommendations

Reducing ongoing threats

- Protect habitat from future fires

  The protection of suitable habitat from future bushfires, particularly where spotted-tailed quolls have been detected, and ensuring habitat connectivity will support remnant populations.

- Reduce impacts of cats and foxes

  Monitoring of feral predators is advised with appropriate control measures to support population growth.

- Reduce impacts of cane toads

  Monitoring of cane toads and appropriate control measures at localities with known spotted-tailed quoll populations (e.g. Queen Mary Falls) will reduce the risk of fatal ingestion of toads by quolls in the broader Main Range landscape.

Ecological monitoring

- Continue monitoring spotted-tailed quolls

  Expanded monitoring across a wide range of unburnt and fire-impacted sites is critical to improve the currently limited understanding of their distribution and abundance and to guide conservation actions. The cost-effective use of cameras in this project can be replicated every two years for at least 8–10 years and serves to concurrently monitor other threatened species and threats from invasive animals.

Ecological research

- Broader surveys to improve knowledge of the distribution and abundance across South East Queensland.
- Investigate the impacts of fire on key food resources and den sites.
- Research into the interactions with cane toads and the level of threat posed.

3.4 Hastings River mouse and New Holland mouse

3.4.1 Conservation context

The Hastings River mouse *Pseudomys oralis* is listed as Endangered under both the NCA and EPBC. The first records of this species in Queensland were from 1969–1970, when it was trapped at four separate localities on the western side of the Great Dividing Range, between Warwick and Main Range NP, South East Queensland (Kirkpatrick & Martin 1971, King 1984). The species was not seen again until 1993, when it was 'rediscovered' near the original capture locations but at higher elevation, in what is now the Gambubal section of Main Range NP (Poole 1994). This location was intensively studied from 1994–1995 by Townley (2000), who identified the Gambubal population of Hastings River mouse as the most abundant of any she surveyed in Queensland and New South Wales, making it significant on a national scale. Despite this, no further trapping work was conducted there for another decade. However, prompted by an August 2004 bushfire that burnt the entire study site and removed all ground storey vegetation, an annual Hastings River mouse monitoring program at Gambubal was instigated in 2005. Standardised monitoring was undertaken each year until 2016 (I. Gynther unpubl. data), except for 2011, when prolonged wet weather prevented vehicle access.

Approximately 19km further north, the Hastings River mouse was first recorded from the Cunninghams Gap section of Main Range NP in July 2010, when a female was captured at the QPWS base at Tregony (A. Lowe pers. comm., I. Gynther unpubl. data). In early 2013, this location and the surrounding habitat were the focus of a University of Queensland Honours student project investigating the ecology of the Hastings River mouse and its response to habitat disturbance (Dixon 2014). The intensive trapping program yielded a total of 49 individuals across an area that included Main Range NP and parts of adjoining freehold properties (including one that later became Spicers Peak Nature Refuge). In addition, the study established the presence of the New Holland mouse *P. novaehollandiae*, listed as Vulnerable under both state and Commonwealth legislation, with the capture of 11 individuals. No subsequent monitoring for either *Pseudomys* species has been conducted at Cunninghams Gap, despite the monitoring of subpopulations being identified as a required management action (Woinarski *et al.* 2014).

During the 2019–2020 bushfires, almost all the Hastings River mouse monitoring site at Gambubal was burnt, as was most of the forested habitat of the Cunninghams Gap section of Main Range NP in the vicinity of the QPWS base, south of the Cunningham Highway (Hines *et al.* 2021), and the adjacent portion of Spicers Peak Nature Refuge (NR). Most of the understorey and midstorey vegetation layers were removed during these fires, resulting in major impacts to the small mammal habitats at both locations. The Hastings River mouse and New Holland mouse (Figure 15) were identified as priority species for this project, with post-fire surveys essential to confirm whether these threatened rodents continued to persist at both Cunninghams Gap and Gambubal.

Figure 15: Hastings River mouse (left) and New Holland mouse (right) caught in the Cunninghams Gap section of Main Range NP. (Photos, left to right: A.H. McCall; I. Gynther)

3.4.2 Survey sites and methods

Cunninghams Gap was surveyed twice following the 2019–2020 bushfires, in successive years. The first survey was conducted from 12–16 January 2021 in the part of Main Range NP immediately to the east of the QPWS base at Tregony, as well as in the adjacent north-western corner of Spicers Peak NR. Two separate trap grids consisting of both Elliott and cage traps were established (Table 10, Figure 16A)—one within the boundaries of Main Range NP (centred on 28°03’42.6” S, 152°22’13.7” E ± 350m; GDA94) and the other within Spicers Peak NR (centred on 28°03’47.6” S, 152°22’09.3” E ± 150m; GDA94). The total trapping effort for the four-night survey was 1600 Elliott trap-nights and 45 cage trap-nights (Table 10). This mostly targeted grassy open eucalypt forest and woodland on the flats and slopes, although human-modified areas within and surrounding the QPWS base were also included.

A second survey at Cunninghams Gap from 4–8 April 2022 employed an identical Elliott trap effort (1600 trap-nights) and similar trap-grid layouts, but on this occasion no cage trapping was undertaken (Table 10, Figure 16B).

The survey of the standard Hastings River mouse monitoring site within the Gambubal section of Main Range NP was undertaken from 10–14 May 2021. It employed a grid of 250 Elliott traps set over four nights (centred on 28°13’33.0” S, 152°25’36.5” E ± 350m; GDA94), giving a total effort of 1000 trap-nights (Table 10, Figure 17).

All traps were baited with a mixture of rolled oats, peanut butter, golden syrup and peanut oil. For the cage traps employed at Cunninghams Gap, pistachio essence was also added to the mixture to improve the bait’s attractiveness to long-nosed potoroos to enable a survey for this subspecies to be undertaken concurrently.

Table 10: Hastings River mouse and New Holland mouse survey efforts and timing in two separate sections of Main Range NP and in Spicers Peak NR adjacent to the Cunninghams Gap section of Main Range NP.

Survey period	Site location	Trap type	Survey night no.				Trap-nights
			1	2	3	4	
Jan 2021	Main Range NP (Cunninghams Gap)	Cage traps	10	10	10	–	**30**
		Elliott traps	250	250	250	250	**1000**
	Spicers Peak NR	Cage traps	5	5	5	–	**15**
		Elliott traps	150	150	150	150	**600**
May 2021	Main Range NP (Gambubal)	Elliott traps	250	250	250	250	**1000**
Apr 2022	Main Range NP (Cunninghams Gap)	Elliott traps	250	250	250	250	**1000**
	Spicers Peak NR	Elliott traps	150	150	150	150	**600**

3.4.3 Survey results

Cunninghams Gap

The January 2021 trapping program at Cunninghams Gap yielded a total of seven native species of mammal (Table 11). One introduced mammal, the house mouse *Mus musculus*, was also recorded; in fact, this species was extremely abundant during the period of the survey. From the total of 400 Elliott traps that were set, more than 220 house mouse individuals (range 222–290) were captured nightly across both trapping grids, sometimes with two or three house mice present per trap. In total, 1028 individuals were captured over the four-night survey (Table 11).

Despite these unfavourable circumstances, five Hastings River mouse individuals were caught on the Main Range NP grid (Table 11). Three of these (an adult female and two adult males) were captured beneath the main office building at the QPWS base, around which a relatively small area of habitat had been protected from fire in November 2019. The other two individuals (an adult female and an unsexed animal) were caught 175–260m to the north-east, in open forest that had been burnt in November 2019 (Figure 16A). Of the two adult females that were captured, one appeared to be pregnant, while the other had teats in a regressed state, indicating previous breeding. No Hastings River mice were captured on Spicers Peak NR.

Five New Holland mice were recorded during the January 2021 survey, four of which were from the trap grid located in Spicers Peak NR, where they occupied habitat that was regenerating after the bushfire (Figure 16A, Table 11). The remaining individual was caught close to one of the QPWS buildings at the Main Range NP base. Three of the New Holland mice were adult males with testes that had begun to regress, one was a subadult male and the remaining individual was a subadult female (i.e. yet to breed). The single recapture was an adult male animal that had moved downslope approximately 37m the following night.

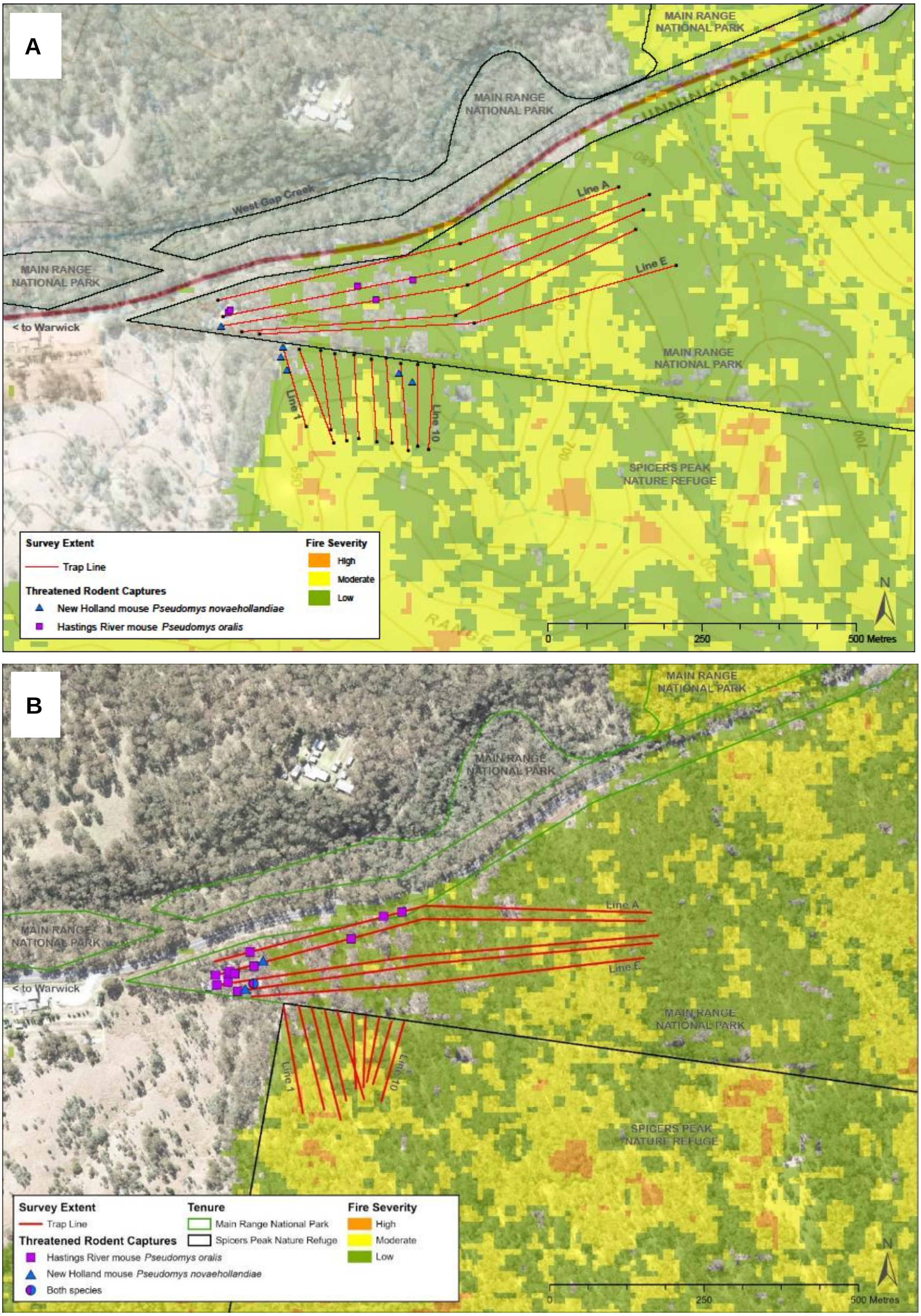

Figure 16: Trapping grids at Cunninghams Gap with the extent and severity of the November 2019 fire in Main Range NP and Spicers Peak NR (Hines *et al.* 2021). Capture locations of Hastings River mice and New Holland mice are indicated. Grid layouts are shown for 12–16 January 2021 (A) and 4–8 April 2022 (B).

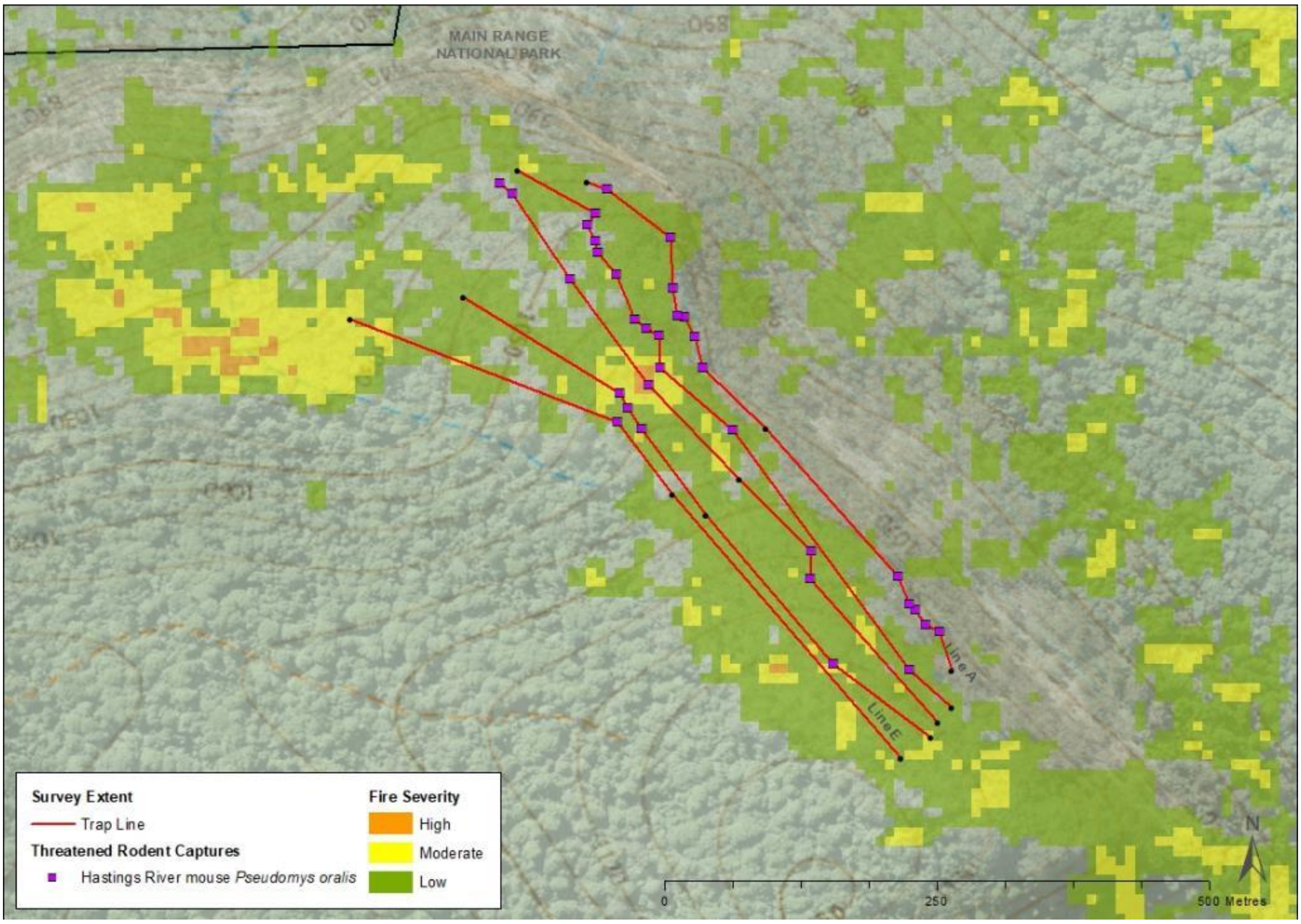

Figure 17: Trapping grid in the Gambubal section of Main Range NP in relation to the extent and severity of the November 2019 fire (Hines *et al.* 2021). Survey conducted 10–14 May 2021 with capture locations of Hastings River mice indicated.

Of the additional native rodents discovered during the first survey at Cunninghams Gap, the bush rat *Rattus fuscipes* was most prolific, particularly on the Main Range NP trap grid (Table 11). In decreasing order of abundance, the other species captured were the pale field-rat *R. tunneyi*, swamp rat *R. lutreola* and eastern chestnut mouse *Pseudomys gracilicaudatus*.

Cage-trapping success in January 2021 was relatively poor, due in part to frequent disturbance that these traps experienced from non-target fauna species, very likely bandicoots, brush-tailed possums *Trichosurus* spp. or lace monitors *Varanus varius*. Many cages were discovered with their doors closed, sometimes also with bait missing.

In April 2022, the repeat survey at Cunninghams Gap revealed a higher diversity of native mammals overall, with a total of 10 species captured across both trapping grids (Table 11). Species not captured the previous year were the yellow-footed antechinus *Antechinus flavipes* (three individuals), along with single representatives of the common dunnart *Sminthopsis murina* and fawn-footed melomys *Melomys cervinipes*. Compared to the survey results from January 2021, notable increases in abundance were recorded for some native rodent species—numbers of eastern chestnut mice and bush rats had more than doubled, while the swamp rat was approximately 72% more abundant (Table 11). No such trend was apparent for the pale field-rat; numbers of individuals of this native rodent species were similar in both survey periods. Although house mice were still present in April 2022, their numbers had plummeted compared to January of the previous year, with only 11 individuals being caught over the four-night duration of the survey (Table 11). This represented an almost 99% decrease in abundance over the interval of 15 months.

Compared to the first survey period, twice as many Hastings River mouse individuals (10) were captured on the Main Range NP grid in April 2022, and the recapture frequency was also higher (Table 11). The ratio of males to females was equal, as was the ratio of adults to subadults. No juveniles were trapped. Two of the three adult females that were caught had teats in a regressed state, and the remaining female had developed teats but was not lactating; this indicated that all three had bred previously. As in January 2021, no Hastings River mice were recorded on the trapping grid within Spicers Peak NR.

Four New Holland mouse individuals were captured in April 2022, suggesting that the abundance of this species had not changed markedly between the two survey periods (Table 11). However, unlike the situation in January 2021, the species was not recorded in Spicers Peak NR, with all New Holland mouse captures being made on the trapping grid in Main Range NP. Of the three individuals examined, two were subadult females and one a subadult male, so none had yet bred.

During the April 2022 survey, 13 out of the 16 Hastings River mouse captures were either from beneath the QPWS base's main building or its environs, including open forest habitat that was not burnt by the bushfire in November 2019. The remaining three captures were made up to 290m to the north-east, in open forest that experienced low severity fire (Figure 16B). All New Holland mouse captures were recorded from the unburnt open forest within approximately 60m of the QPWS base (Figure 16B).

Table 11: Mammal captures in Elliott and cage traps in the Cunninghams Gap Section of Main Range NP and adjacent part of Spicers Peak NR, January 2021 and April 2022. Figures are numbers of individuals, with values in brackets representing the number of recaptures.

Species	Main Range NP (Cunninghams Gap)		Spicers Peak NR		Total	
	2021[1,4]	2022[1]	2021[2,5]	2022[2]	2021[3,6]	2022[3]
Elliott traps						
Antechinus flavipes	-	2 (2)	-	1 (0)	**-**	**3 (2)**
Isoodon macrourus	-	2 (1)	1 (0)	2 (2)	**1 (0)**	**4 (3)**
Melomys cervinipes	-	-	-	1 (0)	**-**	**1 (0)**
Mus musculus	630 (N/A)	9 (N/A)	398 (N/A)	2 (N/A)	**1028 (N/A)**	**11 (N/A)**
Pseudomys gracilicaudatus	4 (1)	20 (0)	11 (0)	16 (6)	**15 (1)**	**36 (6)**
Pseudomys novaehollandiae	1 (0)	4 (2)	4 (1)	-	**5 (1)**	**4 (2)**
Pseudomys oralis	5 (1)	10 (6)	-	-	**5 (1)**	**10 (6)**
Rattus fuscipes	63 (35)	113 (94)	6 (6)	32 (28)	**69 (41)**	**145 (122)**
Rattus lutreola	20 (5)	52 (29)	26 (2)	27 (20)	**46 (7)**	**79 (49)**
Rattus tunneyi	32 (33)	30 (12)	21 (10)	27 (20)	**53 (43)**	**57 (32)**
Sminthopsis murina	-	1 (0)	-	-	**-**	**1 (0)**
Cage traps						
Rattus fuscipes	-	(N/A)	1 (0)	(N/A)	1 (0)	**(N/A)**

Figures based on: [1]1000 Elliott trap-nights; [2]600 Elliott trap-nights; [3]1600 Elliott trap-nights; [4]30 cage trap-nights; [5]15 cage trap-nights; [6]45 cage trap-nights

Table 12: Mammal captures in Elliott traps in the Gambubal section of Main Range NP, 10–14 May 2021. Figures are numbers of individuals, with values in brackets representing the number of recaptures.

Species	Total[1]
Antechinus stuartii	**2 (0)**
Mus musculus	**183 (N/A)**
Pseudomys oralis	**27 (19)**
Rattus fuscipes	**36 (16)**
Rattus lutreola	**29 (9)**

[1]Figures based on 1000 Elliott trap-nights

Gambubal

The May 2021 survey within the Gambubal section of Main Range NP recorded four native mammal species, three of which were rodents (Table 12). Bush rats were most abundant, followed by swamp rats and Hastings River mice. The only other native mammal caught during the post-fire survey was the brown antechinus *Antechinus stuartii*, which was only trapped twice. Large numbers of house mice were also captured.

In total, 27 Hastings River mouse individuals were captured, comprising 12 adults, 13 subadults and two juveniles.

The sex ratio of adults was heavily biased towards females whereas for subadults, males greatly outnumbered females. Both juvenile individuals were females. Of the 10 adult females caught over the four nights of trapping, eight (80%) possessed regressed teats and had bred previously. The remaining two were first-year individuals that had not yet reproduced. Although Hastings River mice were caught on each of the five trap transects, most captures were from areas of the trapping grid that were closer to the eastern escarpment than the rainforest/open forest ecotone (Figure 17). Captures were made in both unburnt and burnt habitat, the latter comprising low, moderate and high classes of fire severity (Figure 17).

3.4.4 Discussion

Following a severe, prolonged drought, the unprecedented 2019–2020 megafires that impacted vast swathes of vegetation and habitat for threatened species across eastern and southern Australia (Ward *et al.* 2020, Wintle *et al.* 2020) also resulted in forested areas at Cunninghams Gap and in the Gambubal section of Main Range NP being burnt, with potentially serious ramifications for the populations of Hastings River mouse and/or New Holland mouse. The results from this project, however, confirmed that both species survived the bushfires at Cunninghams Gap, and the Hastings River mouse also continued to persist at Gambubal. Moreover, Hastings River mouse abundance (27 individuals) at Gambubal in May 2021 was the greatest ever recorded at this standard monitoring site (Table 12), the previous highest tally being 16 in 2008 (I. Gynther unpubl. data).

While these findings were welcome, caution should be exercised in drawing conclusions about the impacts of the drought and fire events on population sizes of both *Pseudomys* species. For example, although at Cunninghams Gap the overall mammal diversity and abundances of the Hastings River mouse and some other native rodent species appeared to increase between January 2021 and April 2022, only two post-fire surveys were conducted, and the validity of the results from the first survey event were doubtful due to the concurrent house mouse 'plague' (Table 11). The extremely high capture rates of this introduced rodent must have significantly reduced the number of traps available to catch other species, and consequently, the trap success for native mammals was very likely not an accurate reflection of their true population sizes. Also, at Gambubal, only a single Hastings River mouse survey was conducted (in 2021), and house mouse abundance on this occasion far exceeded what had been recorded from the trapping grid since annual monitoring commenced in 2005 (I. Gynther unpubl. data).

Dixon (2014) documented 49 Hastings River mouse and 11 New Holland mouse individuals from a combined grid and transect trapping program conducted at Cunninghams Gap during January–February 2013. Although these data potentially represent a pre-2019 (i.e. pre-bushfire) baseline, it is difficult to make meaningful comparisons between them and the results of the present work. Trapping effort in 2013 (4,235 trap-nights) was more than 2.5 times greater than employed in either January 2021 or April 2022, the total area surveyed was larger and encompassed different areas, and most of the habitats surveyed at that time were classed as unburnt (i.e. had not experienced fire in at least five years).

To obtain more representative and useful data about the relative abundances and population trends of the two threatened rodents and other small native mammals at Cunninghams Gap and Gambubal, trapping surveys should be repeated at regular intervals, with the monitoring conducted during periods when house mice are absent or their numbers are low. In conjunction with such surveys, detailed information about fire history and other disturbance factors should be collected and a vegetation monitoring program instigated, particularly focused on ground and midstorey layers. This may enable key environmental variables responsible for determining the spatial distribution of Hastings River mice and New Holland mice in these forested habitats to be identified.

3.4.5 Recommendations

Reducing ongoing threats

- Maintain suitable habitat

  The maintenance of the preferred habitat for *Pseudomys* species, namely a grassy woodland or open forest with a low density of understorey and midstorey shrubs, can be achieved through strategic planned burn programs.

- Reduce impacts of weeds in core habitat areas

  The incursion of significant weed populations threatens the integrity of preferred habitat for *Pseudomys* species, such as through dominance of invasive grasses and midstorey thickening by shrubs and low trees. Weeds can also elevate the risk of bushfire and fires of high severity.

Ecological monitoring

- Continue monitoring the populations of Hastings River mouse and New Holland mouse

  The minimal requirements to track post-fire recovery at the fire-impacted sites is to replicate the survey methodology used in this project every two years for at least 8–10 years. Understanding longer-term population trends is critical to support the ongoing conservation of these species. Avoiding periods with plagues of the introduced house mouse is advised.

- Continue assessment of post-fire habitat regeneration

  Quantifying the post-fire changes in vegetation and key habitat attributes is required to complement the monitoring data for Hastings River mouse and New Holland mouse and improve understanding of the ecological requirements of these species to guide ongoing park management and conservation actions.

Ecological research

- Instigate a New Holland mouse research program at Cunninghams Gap

  Instigation of a research program for the New Holland mouse within Main Range NP and Spicers Peak NR would provide critical knowledge of this species' basic ecology, key threats and responses to fire and other disturbance. To date, all research for the New Holland mouse has been conducted in southern states, and the species remains poorly known at the northern limit of its national distribution in South East Queensland.

4 Priority birds

4.1 Albert's lyrebird

4.1.1 Conservation context

Albert's lyrebird *Menura alberti* is found in rainforest, including cool temperate rainforest with beech *Nothofagus*, subtropical vine forest with tree ferns and *Archontophoenix cunninghamiana*, and adjacent mixed eucalypt-rainforest with dense vines (Beruldsen 1973; Blakers *et al.* 1984; Gilmore & Parnaby 1994; Shields & Rowland 1994; Pizzey & Knight 1997). Its known Queensland distribution is the ranges and plateaux in the vicinity of the Queensland/NSW border, including the Mistake, Great Dividing, McPherson and Tweed Ranges, with an isolated population on Mt Tamborine. The species is not listed under the EPBC and is listed as Near Threatened under the NCA. Consequently, there is no conservation advice or recovery plan for Albert's lyrebird. Identified threats to this species include the destruction and fragmentation of habitat (Garnett & Crowley 2000), predation by feral cats and red foxes (Gilmore & Parnaby 1994) and the impacts of fire (Rounsevell *et al.* 1998; Nugent *et al.* 2014).

4.1.2 Survey sites and methods

Camera trapping was used to survey for Albert's lyrebirds, with 112 cameras deployed across 88 sites that represented a range of PEI classes (Figure 19), between 8 September 2020 and 18 February 2022.

The cameras deployed to survey Albert's lyrebirds were the same as those used to detect long-nosed potoroos (section 3.2) and spotted-tailed quolls (section 3.3): refer to section 3.2.2 for details of methodology.

Additional records involving both sightings and calls were captured by ecologists whilst surveying for other priority taxa.

4.1.3 Survey results

Albert's lyrebirds were detected at 99 sites (e.g. Figure 18), including 37 of 88 (42%) camera sites (Figure 19), both baited and unbaited (Table 13), across a range of Landscape PEI classes including moderate to high (Figure 20).

Figure 18: Albert's lyrebird captured by camera trap at Main Range NP. (QPWS)

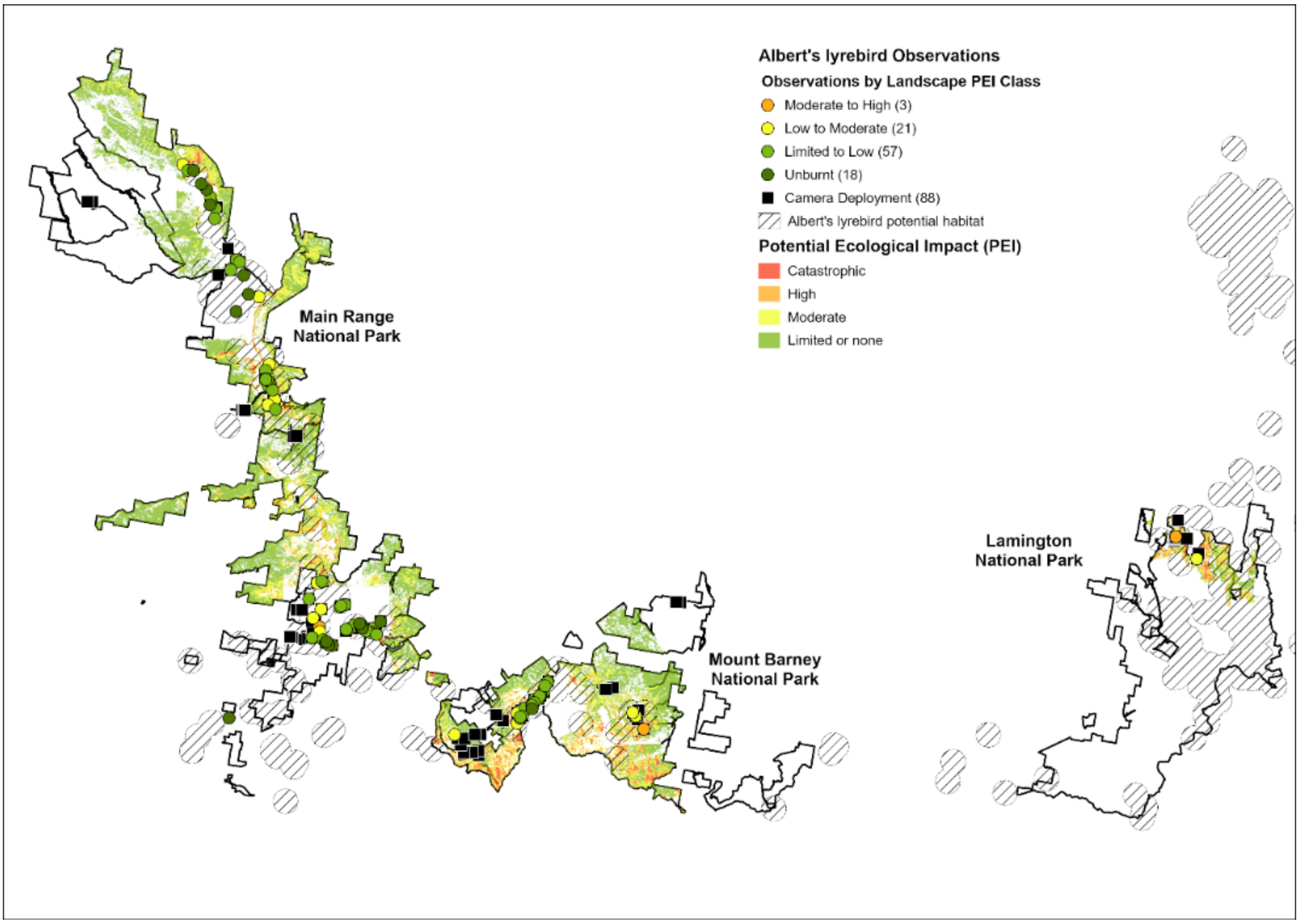

Figure 19: The potential habitat (DES 2021) of Albert's lyrebird across GWHA with the location of camera trap detections and the PEI of the 2019–2020 bushfires.

Table 13: Summary of trapping effort and Albert's lyrebird detections on camera traps.

	Mt Barney NP		Main Range NP		Lamington NP		Total
	Baited	Unbaited	Baited	Unbaited	Baited	Unbaited	
Number of sites detected (sites surveyed)	7 (10)	7 (23)	14 (23)	7 (23)	2 (2)	0 (7)	**37 (88)**
Camera trap-days detected (total trap-days)	162 (1551)	204 (3396)	154 (1080)	151 (1667)	4 (182)	0 (388)	**675 (8264)**
Days detected per 100 trap-days	10.44	6.00	14.26	9.06	2.20	0	**8.17**
Total images	**1059**	**817**	**1461**	**856**	**21**	**0**	**4214**

[1]One site at Main Range NP had both a baited and an unbaited camera

The potential habitat modelling (Laidlaw & Butler 2021) undertaken for the study area revealed that 31% of likely habitat for Albert's lyrebird was impacted by the 2019–2020 bushfires across GWHA (Table 14).

Table 14: Area of modelled potential habitat (PH) for Albert's lyrebird and the estimated proportion burnt across the study area in the 2019–2020 fires.

PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
23,355	42	7,300	31

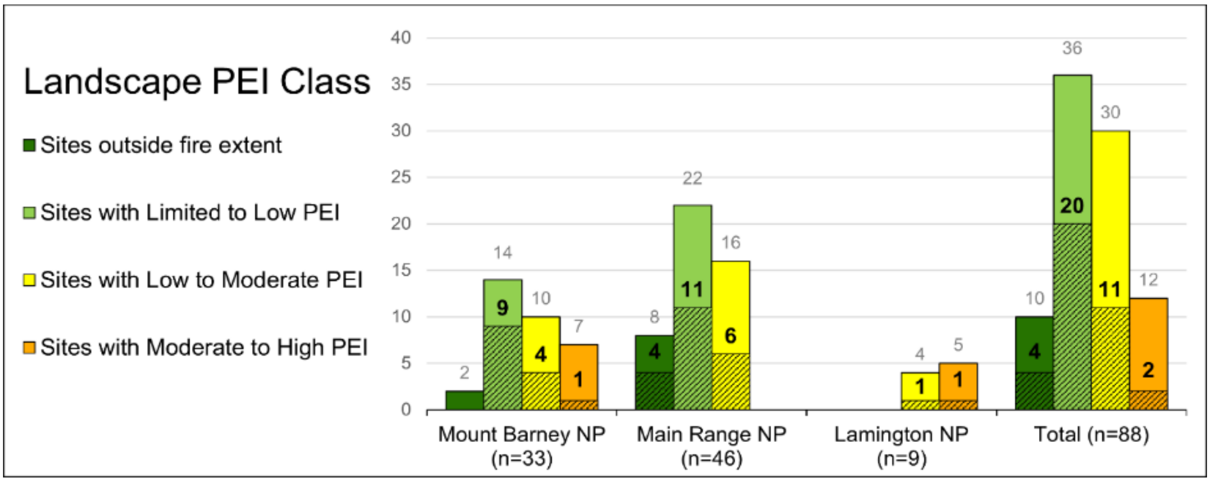

Figure 20: The number of sites surveyed for Albert's lyrebird in each of the Landscape PEI classes across the three NPs and in total. Hatched areas and bold numbers indicate sites where Albert's lyrebirds were detected.

4.1.4 Discussion

Albert's lyrebirds were not only found to have persisted post-fire but to be widespread within the project area, where they were recorded relatively frequently by both camera trapping and incidental observations. Albert's lyrebird was found to use burnt habitat in both rainforest and open forest. Although there was no direct evidence of predation, feral predators, both cats and red foxes, were detected on the same camera traps that detected lyrebirds at 22 of 37 sites. The time between detections of lyrebirds and feral predators varied greatly, but at three sites in Main Range NP the camera detected a cat within two hours of a lyrebird.

4.1.5 Recommendations

Reducing ongoing threats

- Protect suitable habitat from fire

  The preferred ecotonal habitat between rainforest and open forest needs to be protected from fire through strategic planned burn programs. Regenerating habitat and restored habitat connectivity will facilitate recolonisation of fire-impacted habitats.

- Reduce impacts of cats and foxes

  Monitoring of feral predators with appropriate control measures will reduce this threat to the species.

- Reduce impacts of weeds in core habitat areas

  The incursion of significant weed populations can alter the open understorey habitat required for foraging and the availability of food resources. Weeds can also elevate the risk of bushfire and fires of high severity.

Ecological monitoring

- Continue monitoring of Albert's lyrebird as part of a broader camera-based program for multiple species to improve the understanding of population dynamics and threats from feral predators, as well as support future interpretations of fire impacts.

Ecological research

- Broader surveys to improve knowledge of the species' distribution, abundance and habitat use and to consider the future impacts of climate change.
- Investigate the impacts of fire and weeds on key food resources and suitable habitat.

4.2 Coxen's fig-parrot

4.2.1 Conservation context

Coxen's fig-parrot *Cyclopsitta diophthalma coxeni* is distributed sparsely from Mid East Queensland, south to North East NSW. It is the southernmost of Australia's three subspecies of double-eyed fig-parrot and is very rarely reported. There are no known authentic photographs of live birds and no known recordings of their calls (Pedersen 2021). In South East Queensland, it occurs in rainforest, open forest, woodlands and riparian corridors, at all elevations. The subspecies is listed as Critically Endangered under the NCA and EPBC. In 'The Action Plan for Australian Birds 2020', Coxen's fig-parrot (as *Cyclopsitta coxeni*) is listed as Critically Endangered (Gynther *et al.* 2021). A national recovery plan has been prepared for the bird (Coxen's Fig-Parrot Recovery Team 2001). The key fire impacts of concern for the Coxen's fig-parrot include habitat loss and fragmentation, destruction of key food resources and habitat degradation from weed incursions.

4.2.2 Survey sites and methods

Passive acoustic monitoring using solar-powered Bioacoustic Audio Recorders (BARs) was utilised to survey for Coxen's fig-parrot. This method offers a relatively low cost, landscape-scale approach for a species that occurs in very low densities and provides infrequent calls (Pedersen 2021).

One BAR was deployed at Cunninghams Gap in Main Range NP and a second BAR was deployed adjacent to Canungra Creek at the northern end of Lamington NP (Figure 21). Sites were chosen based on likely flyways, historical records and the presence of mature food trees (Figure 22). The BARs were deployed in September 2020 and set to record from one hour pre-sunrise to one hour post-sunset, seven days a week. An automated acoustic recogniser was developed for this project to support an initial analysis of the recordings (Pedersen 2021).

Figure 21: Solar-powered Bioacoustic Audio Recorder (BAR) set to survey for Coxen's fig-parrot at Lamington NP (left) and Main Range NP (right). (Photos: I. Gynther)

4.2.3 Survey results

The initial development of an acoustic recogniser in September 2021 enabled a preliminary analysis of the acoustic recordings captured from the two BARs set at Main Range and Lamington NPs (Pedersen 2021). Given the extensive volume of recordings, a sub-sampling procedure was adopted that selected optimal time periods for analysis. From a 294-day survey period, the sub-samples represented 25% and 26% of field data recordings (i.e. 74 and 76 recorder-days) from the Canungra Creek site at Lamington NP and Cunninghams Gap site at Main Range NP, respectively (Pedersen 2021).

No Coxen's fig-parrot flight calls were detected, but the findings were considered indeterminate with respect to the presence of the bird at either monitoring site (Pedersen 2021). Based on a tentative power analysis of survey design, the probability of capturing a detectable call with the single BARs set at Main Range and Lamington NPs is 0.26% and 0.20%, respectively. This apparent low detection probability was not due to recogniser performance but rather highlights the effort and power that would be required to achieve the survey objective of detecting an extremely rare bird in such an extensive landscape. Increasing the number of acoustic recorders and deployment localities would improve the probability of detection (Pedersen 2021).

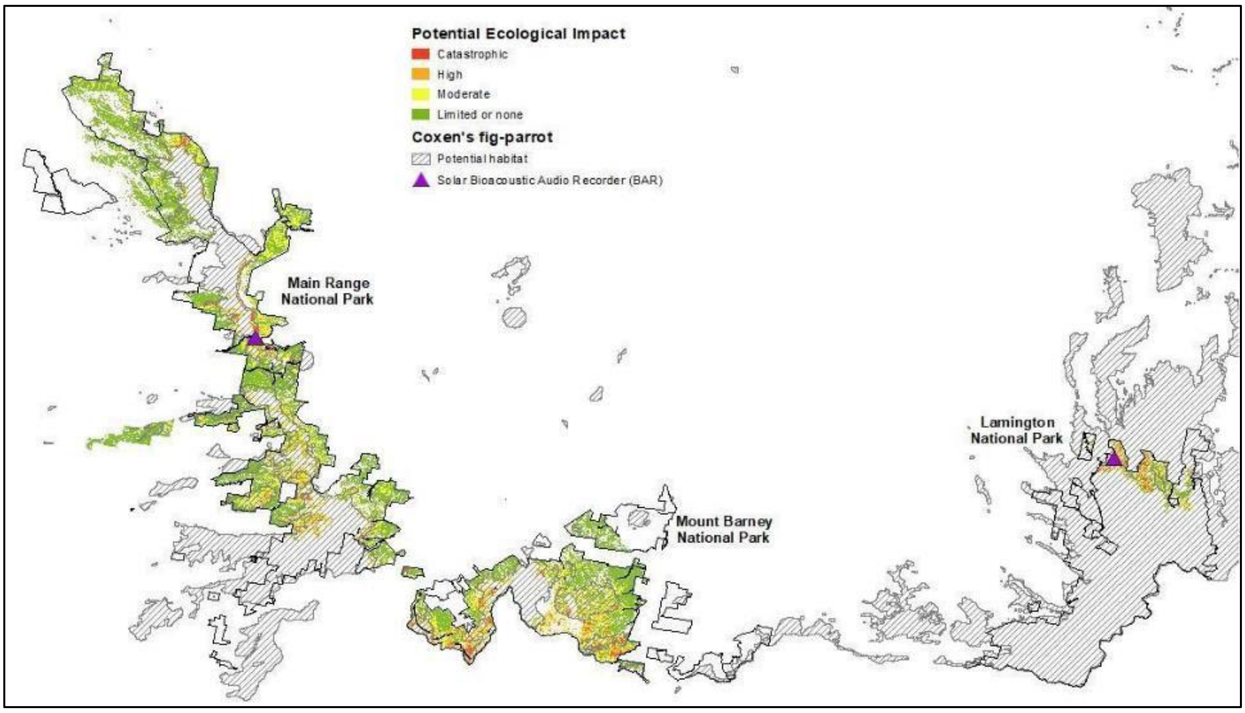

Figure 22: The potential habitat (DES 2021) of Coxen's fig-parrot across GWHA with the location of solar-powered Bioacoustic Audio Recorders and the PEI of the 2019–2020 bushfires.

4.2.4 Discussion

The Coxen's fig-parrot population is critically low, and the potential impacts of the 2019–2020 bushfires on its required habitat and primary food resource of figs is of concern. The bushfires had considerable impacts on rainforest habitats in Lamington NP (Hines *et al.* 2020) and Main Range NP (Hines *et al.* 2021), with mature trees such as fig trees displaying delayed mortality. This could lead to important spatial and temporal gaps in the availability of crucial fig supplies across the extensively fire-impacted landscapes within the bird's range.

Acoustic recorders are an invaluable method to detect calls of this rare and possibly nomadic species, especially in providing a greater temporal survey effort (Pedersen 2021). The recordings are complex, with multiple sounds from wildlife and human-induced activities. The development of a recogniser is a critical step in supporting the ongoing monitoring of this Critically Endangered bird. An analysis of the remaining recordings and further refinements to the acoustic recogniser are planned as part of ongoing efforts to detect the Coxen's fig-parrot across GWHA.

4.2.5 Recommendations

Reducing ongoing threats

- Protect rainforest habitats and food resources from fire

  The rainforest habitat needs to be protected from fire through strategic planned burn programs in surrounding fire-adapted ecosystems. Ensuring the survival of mature fig trees and supporting the recruitment of new fig trees is essential to sustain the availability of critical food resources for Coxen's fig-parrot.

- Restore rainforest habitats and plant fig trees

  Habitat restoration and planting of fig trees and other food species across the landscape needs to be promoted.

- Reduce impacts of weeds in core habitat areas

  The post-fire regeneration of rainforest and riparian corridors needs to be actively supported to ensure ongoing availability of suitable habitat and fig resources. Weeds also elevate the risk of future bushfires.

Ecological monitoring

- Continue acoustic monitoring to confirm the presence of Coxen's fig-parrots and identify key locations for targeted observational monitoring and conservation action.

4.3 Glossy black-cockatoo

4.3.1 Conservation context

The glossy black-cockatoo *Calyptorhynchus lathami* is a rare and threatened species whose habitat was severely impacted in the 2019–2020 Black Summer bushfires. As a result, the south-eastern subspecies *C. lathami lathami,* whose distribution extends from southern Queensland to the Mornington Peninsula[1] in Victoria, is listed as Vulnerable under the EPBC and NCA.

The glossy black-cockatoo is a dietary specialist. It feeds exclusively on seeds of *Allocasuarina* and *Casuarina* trees (collectively termed 'she-oaks'), which makes it highly vulnerable to any loss or degradation of feeding habitat (Glossy Black Conservancy 2022). Generally, she-oaks are short-lived and relatively fire-tolerant (but this varies by species), and at least some species show high cone productivity in early life stages or before 20–40 years post-fire (Delzoppo *et al.* 2021). Additionally, some she-oaks can tolerate relatively poor-quality soil and will resprout readily after disturbance. However, severe fire can cause tree mortality and consequently alter glossy black-cockatoos' distribution (Pepper 1997). Reductions in food, in addition to losses of nesting hollows, may limit reproductive output (Cameron 2009).

An estimated 4% (by area) of feeding habitat for *C. lathami lathami* was burned in the South East Queensland NRM region during the 2019–2020 bushfires. The areas most affected contained high-value habitat and, as such, impacts on local populations may be serious. This is of particular concern because the preceding drought is likely to have already limited food supply (Cameron 2006). However, the impacts of the fires on the species' distribution, and how this varies by fire impact severity, is not known. To plan management actions, a better understanding of glossy black-cockatoos' distribution in post-fire landscapes is urgently required.

The primary objective of this survey was to determine the presence or absence of glossy black-cockatoos at two time points (2021 and 2022) in three important habitat areas: Lamington NP, Main Range NP and Mt Barney NP. These areas contain known high-value feeding habitat (Glossy Black Conservancy) and were partly burned in the bushfires.

Although glossy black-cockatoos are rare and relatively inconspicuous, surveys are greatly aided by the birds' obvious feeding sign, the remains of chewed she-oak cones. Feeding sign is colloquially referred to as "chewings" or 'orts. Feeding sign persists for several months and gradually changes colour over time. As such, where feeding sign is observed, presence over several months can easily be determined during field surveys.

In 2021, 31 sites were surveyed in Lamington, Main Range and Mt Barney NPs to confirm the post-fire presence of glossy black-cockatoos. The presence of birds and feeding signs were surveyed for, and basic habitat quality data were collected, to provide a baseline assessment of glossy black-cockatoos in these NPs. In 2022, 15 sites were re-surveyed to determine the presence-absence of glossy black-cockatoos 24-plus months post-fire. Although fewer sites were surveyed in 2022, transects were standardised in area (not just search time as in 2021) and habitat quality measurements were more comprehensive. Additionally, in 2022 the survey effort was increased by deploying sound recorders at survey sites, to improve detectability of the birds. These changes will allow for data to be directly comparable to surveys being undertaken as part of a larger study in South East Queensland[2]. Together, these results should improve the understanding of the post-fire occupancy habitat use of glossy black-cockatoos in the region.

4.3.2 Survey sites and methods

Survey sites

Surveys were undertaken at Lamington NP, Main Range NP and Mt Barney NP. In 2021, a minimum of ten sites that experienced various fire severities (Hines *et al.* 2020, 2021 & 2022, respectively) was selected in each national park (Figure 23). An additional survey in unburnt habitat was carried out at Lamington NP because another unburnt site (LAM_10) may have been impacted by bushfire in nearby areas. To select survey sites, the fire severity mapping (Hines *et al.* 2020, 2021 & 2022) was intersected with glossy black-cockatoo essential feeding habitat mapping (Glossy Black Conservancy) using ESRI ArcMap version 10.8.1. Survey sites (points) were randomly generated to capture all fire severities in each park. Site selection was also adapted for logistical or safety reasons based on park management advice. Some sites were relocated after field visits clarified that the habitat was unsuitable (likely an artefact of the resolution of habitat mapping). At Mt Barney NP, some sites were positioned based on local knowledge (Mt Barney Lodge, Glossy Black Conservancy) as accessibility was more limited than in other parks and accessing high impact sites required expert field guidance. Sites were limited to areas accessible via established tracks, due to time constraints and safety concerns. Surveys were undertaken between 1 April 2021–27 May 2021.

[1] Before the 2019–2020 bushfires, the southernmost extent of the range of subspecies *C. lathami lathami* was considered North East Victoria, near Mallacoota. The fires appeared to have initiated a range extension which has been maintained as of the time of writing (June 2022).

[2] Project: *Post-fire dispersal and habitat use by South-eastern Glossy Black-Cockatoos*. Regional Bushfire Recovery for Multiregional Species and Strategic Projects Program, Department of Industry, Science, Energy and Resources. Principal Investigators: D. Teixeira (Queensland University of Technology), G. Castley (Griffith University) and G. Conroy (University of the Sunshine Coast).

In 2022, 15 sites were re-surveyed across all three parks between 17 May 2022 and 27 May 2022. These surveys were impacted by high rainfall and park closures, precluding access to some sites. In each park, attempts were made to survey sites that varied in fire severity impacts (Hines *et al.* 2020, 2021 & 2022) but this was not possible for Mt Barney, where only low–moderate fire severity sites could be accessed. Sites were a subset (roughly 50%) of 31 sites that were surveyed in 2021. All sites surveyed in 2022 were in the same locations as those surveyed in 2021.

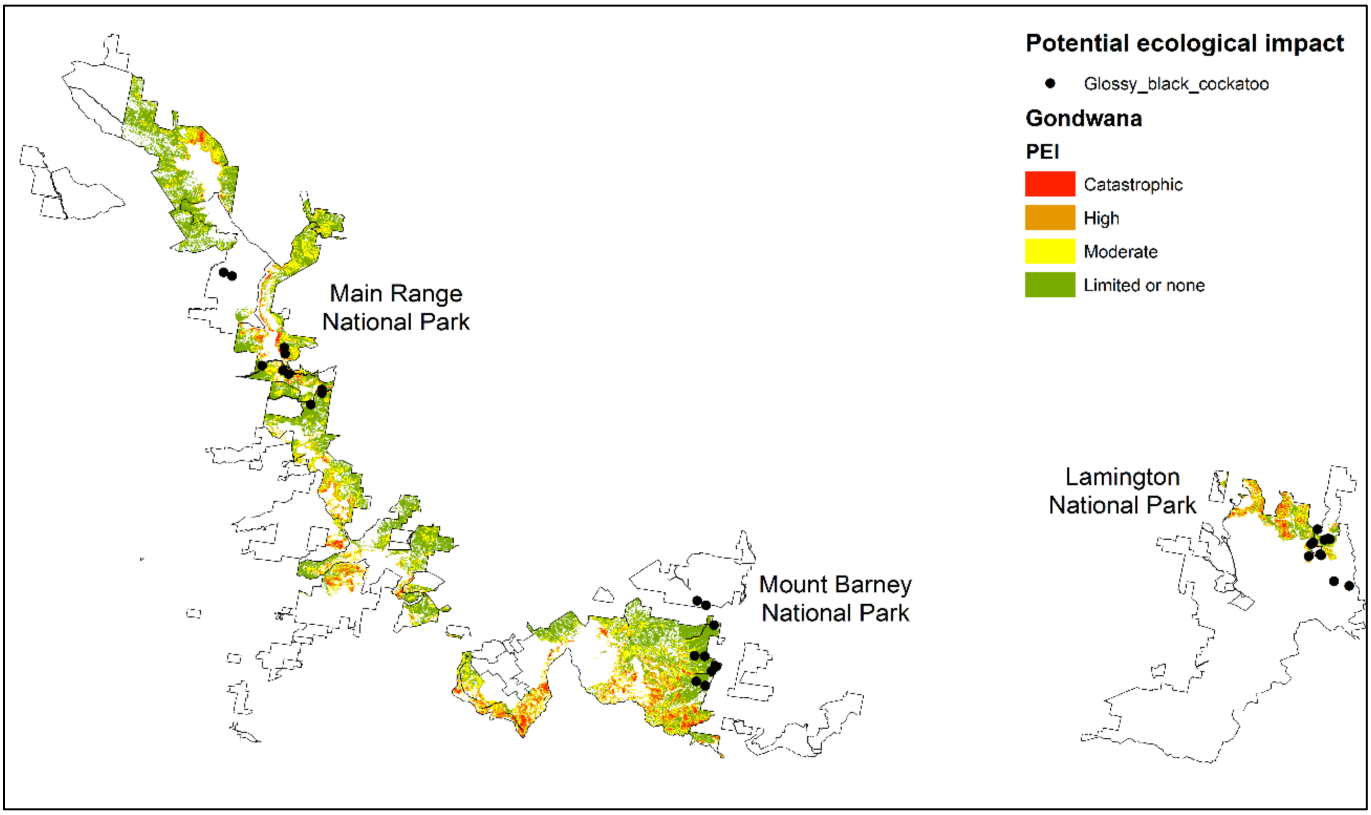

Figure 23: The location of 2021 survey records for the glossy black-cockatoo across GWHA with PEI of the 2019–2020 bushfires.

2021 Survey

Each site was surveyed by one 20-minute search by two people (40 minutes survey effort). Due to differences in terrain and understorey among sites, survey area was not standardised. Where terrain was particularly steep or unstable, searches were conducted along tracks or close to their edge. During each search, the presence-absence of glossy black-cockatoos was recorded (seen or heard), as were trees with feeding signs (chewings). If glossy black-cockatoos were seen, their behaviour was recorded as feeding, allofeeding, perched/roosting, flying overheard, drinking, displaying or begging. The number of birds was also recorded. If feeding signs were found, the colour of the chewed cones was recorded as dark brown/grey, dark orange, light orange or green/cream (or mixed, where multiple colours were present), which approximates chewing age from oldest to youngest. The species of feed tree at the site was also recorded, the presence of immature cones (buds) on female trees and, at burnt sites, any evidence of tree resprouting.

At each site, apparent fire severity was noted, based on the height of fire scars, the number of burnt and dead she-oak trees, and the density of understorey weeds. From this, fire severity was categorised as low-moderate, high-extreme or unburnt. Apparent fire severity at some sites differed from the fire severity mapping, particularly because survey areas often covered multiple mapped fire severities.

As a rapid measure of feeding habitat quality, the first ten live female trees encountered were visually scored for their canopy size and cone density. Scores ranged from 1 to 5 (lowest to highest). Overall tree score was the product of canopy and cones scores. This method is similar to that used annually for monitoring stringybark, *Eucalyptus baxteri* and *E. arenacea,* and buloke, *Allocasuarina leuhmannii,* in the recovery program for the south-eastern red-tailed black-cockatoo and has been used in one study on Kangaroo Island's drooping she-oak *A. verticillata* (D. Teixeira, pers. obs.). At six sites (LAM_0, LAM_1, LAM_4, MAIN_3, BARN_5, BARN_7), ten live female trees were unable to be found during the 20-minute survey period. Incidental observations of glossy black-cockatoos and feeding sign outside of survey periods (e.g. when walking to a site) were also recorded.

2022 Survey

Survey methods were modified slightly in 2022 to align with a larger study being undertaken in South East Queensland. Specifically, sites were surveyed by one 100m x 4m strip transect. Within each strip transect, the following were recorded.

- Number, age and sex of glossy black-cockatoos seen or heard
- Species of feed tree
- Number of dead trees by sex and age (adult female, adult male/unknown, juvenile)
- Number of live juvenile trees (<5cm DBH and no cones or flowers)
- Number of live adult trees >5cm DBH or any tree with cones or flowers present.

For each live tree (adult >5cm DBH or with cones/flowers)

- Sex (male, female, unknown)
- DBH.

Additionally, for each live female tree (adult >5cm or with cones/flowers), the following were recorded:

- Presence of chewings
- Density of chewings
- Density of cones
- Presence of flowers
- Presence of immature cones (buds).

Cone density was visually estimated for all live female trees (adult >5cm DBH or with cones/flowers). Scores ranged from 1 to 5 (lowest to highest) based on the area (%) of suitable tree limb space that had cones present. Unlike the 2021 survey, canopy size was not visually estimated. Instead, the DBH of all live trees was measured. To allow for comparison to the 2021 data, an overall tree score for adult female trees was calculated by first categorising tree size by DBH on a scale of 1–5: 1 (<10cm DBH), 2 (10–29cm DBH), 3 (30–59cm DBH), 4 (60–89cm DBH), 5 (>= 90cm DBH). Overall tree score was calculated as cone density score multiplied by DBH score.

To improve the detectability of glossy black-cockatoos, a remote autonomous sound recorder (Frontier Labs Bioacoustic Audio Recorder) was deployed at every site, except for MAIN_14. Recorders were programmed to record daily for seven days, from 30mins before sunrise to 30mins after sunset. Recordings were made in uncompressed wave format at a sample rate of 44.1 kHz. Sound files were processed using a custom call recogniser to aid detection of glossy black-cockatoo vocalisations. All detections were manually verified as true positive or false positive.

Although attempts were made to run strip transects at every site, this was not possible at four sites due to safety concerns (difficult/steep terrain). However, all but one of these (MAIN_14) were surveyed with sound recorders.

4.3.3 Survey results

Survey sites

In Lamington, Main Range and Mt Barney NPs, 31 sites were surveyed in 2021, of which 15 sites were re-surveyed in 2022 (Table 15). Of these, six were categorised as having experienced high-extreme fire severities during the 2019–2020 bushfires. Eighteen experienced low-moderate fire severities, and seven were unburnt. However, one site (LAM_12) that did not burn in the 2019–2020 fires was subsequently burnt in 2021 after surveys were conducted. In 2022, sound recorders were installed at 14 sites.

Presence of glossy black-cockatoos

In 2021, glossy black-cockatoos were seen or heard at three sites, two of which were unburnt (MAIN_15 and LAM_12) and one was impacted by low-moderate fire (MAIN_1) (Table 15). At one unburnt site (MAIN_15), on the Cascade Circuit at Main Range NP, a single bird was heard giving perch calls (a type of contact call). This suggests that at least one other unobserved bird was present. At the other unburnt site (LAM_12), on the Daves Creek Circuit at Lamington NP, a small group of birds was heard feeding in mountain she-oak *A. rigida.* They called frequently throughout the 20-minute survey. At one fire-impacted site (MAIN_1), a pair was observed feeding in *A. torulosa.*

Feeding sign (chewings; Figure 25) was observed at seven survey sites, including all unburnt sites in Main Range NP and Lamington NP (Table 16). Feeding sign was present at two sites with low-moderate fire impacts, both at Main Range NP. One burnt site (MAIN_2) had a high number of trees with feeding sign (n = 13) and these showed a mix of cone colours, suggesting feeding over several months (Table 17). At the other burnt site (MAIN_1), feeding sign was only observed in a tree where a pair was feeding. The unburnt sites at Main Range NP (MAIN_17 and MAIN_15) also showed a mix of feeding sign age. At Lamington NP, two sites (LAM_12 and LAM_13) had a high number of trees with feeding sign (n = 14 and n = 26, respectively) and these were mixed in colour. At another unburnt site (LAM_10), one tree had old, chewed cones.

In 2022, glossy black-cockatoos were not seen or heard at any site during field surveys (Table 16). However, glossy black-cockatoo vocalisations were detected in sound recordings from six sites, three of which were in Main Range NP, two were in Mt Barney NP and one was in Lamington NP (Table 16). Only two sites had detections on more than one survey day: site BARN_16 had detections on two consecutive days and site MAIN_2 had detections on six consecutive survey days.

Table 15: Summary of survey sites by fire severity (as recorded following the 2019–2020 bushfires), feed tree species, and the installation of a sound recorder during data collection (2022 only).

Site ID	Park area	Fire severity	Feed tree species	Re-survey 2022	Sound recorder
Lamington NP					
LAM_0	Lower Bellbird Track	HIGH-EXT	*A. torulosa* (2021) None observed▲ (2022)	✓	✓
LAM_1			*A. torulosa*	X	na
LAM_10	Binna Burra Road	UNBURNT			
LAM_11					
LAM_12	Daves Creek Circuit	UNBURNT (2021) BURNT (2022)★	*A. torulosa, A.rigida*	✓	✓
LAM_13		UNBURNT	*A. torulosa*		
LAM_4	Caves Circuit	LOW-MOD		X	na
LAM_5	Egg Rock Fire Break			✓	✓
LAM_7					✓
LAM_8				X	na
LAM_9					
Main Range					
MAIN_1	Spicers Gap Road	LOW-MOD	*A. torulosa*	✓	✓
MAIN_12	Palm Grove Circuit	HIGH-EXT			
MAIN_14		LOW-MOD			na
MAIN_15	Cascades Circuit	UNBURNT			✓
MAIN_17				X	na
MAIN_2	Spicers Gap - Pioneers Track	LOW-MOD		✓	✓
MAIN_3	Mt Matherson Trail			X	na
MAIN_4	Mt Mitchell Track	HIGH-EXT			
MAIN_6				✓	✓
MAIN_9	Box Forest Track	LOW-MOD		X	na
Mt Barney					
BARN_1	Upper Logan Rd (west)	LOW-MOD	*A. torulosa*	✓	✓
BARN_4	Yellow Pinch		*A. torulosa, A. littoralis*	X	na
BARN_9	Lower Portals				
BARN_10	Golden Stairs	UNBURNT			
BARN_15					
BARN_16	Yellow Pinch	LOW-MOD	*A. torulosa*	✓	✓
BARN_2	Upper Logan Rd (east)		*A. torulosa*	✓	✓
BARN_8	SE Ridge Summit Route		*A. torulosa,A. littoralis*	✓	✓
BARN_7	Logan's Gate	LOW-MOD	*A. torulosa*	X	na
BARN_5	Logan's Ridge	HIGH-EXT	*A. torulosa,A. littoralis*	X	na

★ Presumably dead trees collapsed between the 2021 and 2022 surveys.

▲ Burnt in 2021 after surveys were conducted.

Figure 24: A resprouting of *Allocasuarina torulosa* with a dead female tree to its right (burned cones present) (left) and epicormic resprouting at Daves Creek Circuit in Lamington NP in 2022. (Photos: D. Teixeira)

Figure 25: Lamington NP: a site (LAM_12) burnt between the 2021 and 2022 surveys (left); feeding sign of *Allocasuarina torulosa* with the light orange colour of the cones indicating recent feeding (right). (Photos: D. Teixeira)

Table 16: Summary of survey sites where glossy black-cockatoos and/or their feeding sign (chewings) were observed during field surveys in 2021 and 2022 surveys, and in sound recordings in 2022 surveys. Blue cells highlight differences between 2021 and 2022 for the presence of glossy black-cockatoos as determined through in-field observations of birds or chewings and/or detections in sound recordings (2022 only). Pink cells highlight sites where glossy black-cockatoos were detected in both survey years. "na" represents sites not re-surveyed in 2022.

		2021		2022		
Site ID	**Fire severity**	**GBC present**	**Chewings**	**GBC present**	**Chewings**	**GBC in sound recordings**
BARN_1	LOW-MOD	N	N	N	N	**Y**
BARN_2		N	N	N	N	N
BARN_8		N	N	N	N	N
BARN_16		N	N	N	N	**Y**
LAM_0	HIGH-EXT	N	N	N	N	N
LAM_5	LOW-MOD	N	N	N	N	**Y**
LAM_7		N	N	N	N	N
LAM_12	UNBURNT	**Y**	**Y**	N	N	N
LAM_13		N	**Y**	N	N	N
LAM_10		N	**Y**	na	na	na
MAIN_1	LOW-MOD	**Y**	**Y**	N	N	**Y**
MAIN_2		N	**Y**	N	N	**Y**
MAIN_6	HIGH-EXT	N	N	N	N	N
MAIN_12		N	N	N	N	**Y**
MAIN_14	LOW-MOD	N	N	N	N	N
MAIN_15	UNBURNT	**Y**	**Y**	N	N	N
MAIN_17		N	**Y**	na	na	na

Table 17: Summary of sites where feeding sign (chewings) was observed in 2021. Feeding sign colour represents the age of the chewed cones, from dark orange (old) to green/cream (new). Mixed represents a mixture of colours, indicative of feeding over several months.

Park	Site ID	Chewings colour	Trees with chewings (n)
Main Range NP	MAIN_17	Mixed	2
	MAIN_15	Mixed	4
	MAIN_2	Mixed	13
	MAIN_1	Green/cream	1
Lamington NP	LAM_12	Mixed	14
	LAM_13	Mixed	26
	LAM_10	Dark orange	1

Table 18: Tree mortality in 2022: mean number of live and dead trees by sex and age (live adult female: Live F; live adult male: Live M; live juvenile: Live J; live unknown: Live Unk; dead adult female: Dead F; dead adult male or unknown sex: Dead M/Unk; dead juvenile: Dead J) and fire severity at habitat survey sites.

Fire severity	Surveys (n)	Live F	Live M	Live J	Live Unk	Dead F	Dead M/Unk	Dead J
HIGH-EXT	1	1	2	50	11	0	11	23
LOW-MOD	7	2.6	3.7	20.9	2.7	0.1	4.3	2.4
UNBURNT	3	6.0	9.7	5.3	5.0	0.0	2.3	0.0

Feeding habitat quality

Of the sites where habitat surveys were undertaken in 2022 (n = 11), those that had experienced fire had, on average, more live juvenile trees (<5cm DBH) and more live trees of unknown sex (adult or juvenile with cones/flowers) (Table 18). Unburnt sites had more live adult male and female trees compared to burnt sites. Sites that experienced high-extreme fire severities had more dead trees (e.g. Figure 24). These measures were not quantified in 2021.

In 2021, immature cones (buds) were present at unburnt and low-moderate impact sites in all parks, and at one high impact site at Mt Barney NP (Table 19, Figure 26). In Lamington and Main Range NPs, low-moderate impact sites had a greater proportion of trees with immature cones than unburnt sites. At Mt Barney NP, proportions were similar at unburnt and low-moderate impact sites, and these proportions were, on average, greater than those of the other parks. Although the high impact site at Mt Barney had a greater proportion of live female trees with immature cones, the total number of live female trees was low (only 5 trees found in 20 minutes). In 2022, flowers and immature cones (buds) were not observed on female trees at any site (Table 19). Epicormic resprouting (Figure 24) was observed at two sites, BARN_1 (low-moderate fire) and MAIN_6 (high-extreme fire).

Table 19: Summary of survey sites where immature cones (buds), flowers or resprouting (epicormically or basally), were observed in 2021 and 2022 surveys. Flowers and buds were recorded from female trees only. Resprouting was recorded from trees of any sex. Green cells highlight differences between 2021 and 2022 results. “na” represents sites not re-surveyed in 2022.

		2021		2022		
Site ID	Fire severity	Imm. cones	Resprouting	Imm. cones	Resprouting	Flowers
BARN_1	LOW-MOD	**Y**	**Y**	N	Y	N
BARN_2	LOW-MOD	**Y**	**Y**	N	N	N
BARN_8	LOW-MOD	**Y**	**Y**	N	N	N
BARN_16	LOW-MOD	**Y**	**Y**	N	N	N
LAM_0	HIGH-EXT	**Y**	N	N	N	N
LAM_5	LOW-MOD	**Y**	**Y**	N	N	N
LAM_7	LOW-MOD	**Y**	**Y**	N	N	N
LAM_12	UNBURNT	N	na	N	N	N
LAM_13	UNBURNT	**Y**	na	N	na	N
MAIN_1	LOW-MOD	N	**Y**	N	N	N
MAIN_2	LOW-MOD	**Y**	N	N	N	N
MAIN_6	HIGH-EXT	N	**Y**	N	Y	N
MAIN_12	HIGH-EXT	**Y**	**Y**	N	N	N
MAIN_14	LOW-MOD	**Y**	**Y**	N	N	N
MAIN_15	UNBURNT	**Y**	na	N	na	N

In 2022, DBH was measured for every adult tree within the strip transects. The size of *A. torulosa*, by far the most encountered feed tree species, was highest at unburnt sites, especially at Lamington NP (Figure 27). Tree size at low-moderate fire impact sites were similar between the three parks. Overall tree scores of live female trees (all species) varied among sites and fire severity classes (Figure 28) but were similar between the 2021 and 2022 surveys. This suggests that food availability has not changed substantially in the past 12 months. Like 2021, tree scores were highest at unburnt sites in Lamington NP.

Incidental observations

In 2021, feeding sign was recorded incidentally at Lamington NP, in unburnt areas on the Daves Creek Circuit, and Main Range NP, in unburnt areas on the Cascades Circuit. Additionally, a pair of glossy black-cockatoos was incidentally observed at Main Range NP, near the Spicer’s Gap campground. The birds’ behaviours indicated possible nesting. At Mt Barney, four birds (two pairs) and feeding sign were observed in unburnt areas on private property adjacent to the NP. There were no incidental observations of birds or feeding sign in 2022.

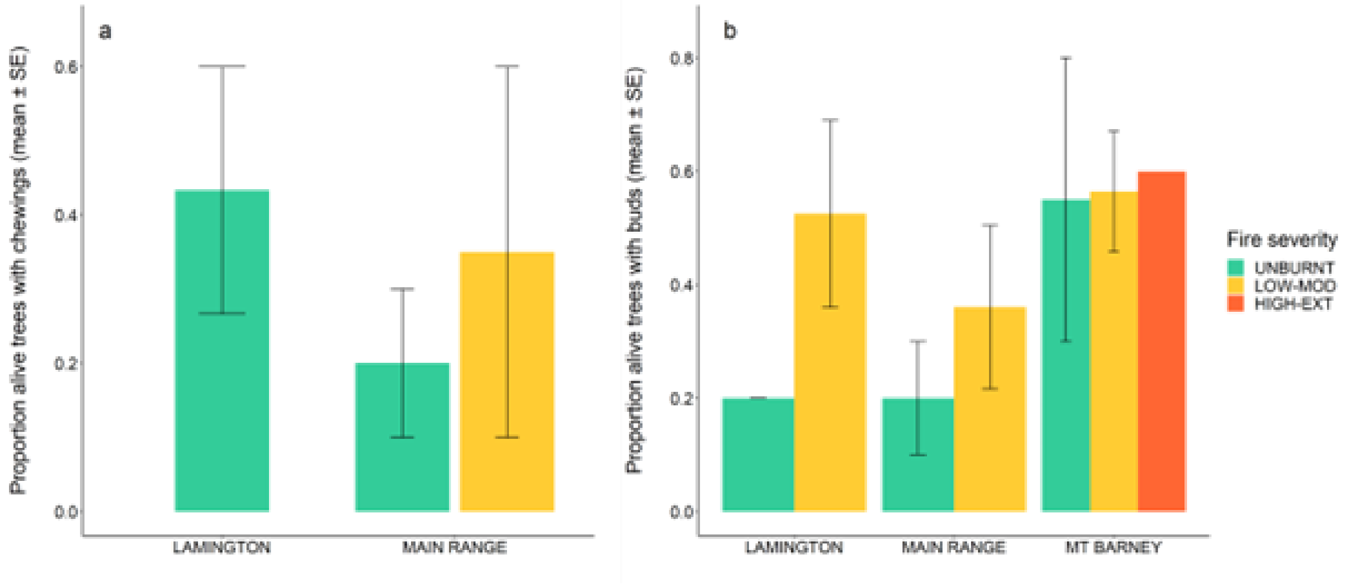

Figure 26: Mean (± SE) proportion of female trees within survey sites at Lamington, Main Range and Mt Barney NPs where feeding sign (chewings) and immature cones (buds) were observed across fire severity classes in 2021. Only one high-extreme site was surveyed at Mt Barney, therefore errors bars are not shown. Feeding sign was not present at any high-extreme site in 2021, or any site in 2022.

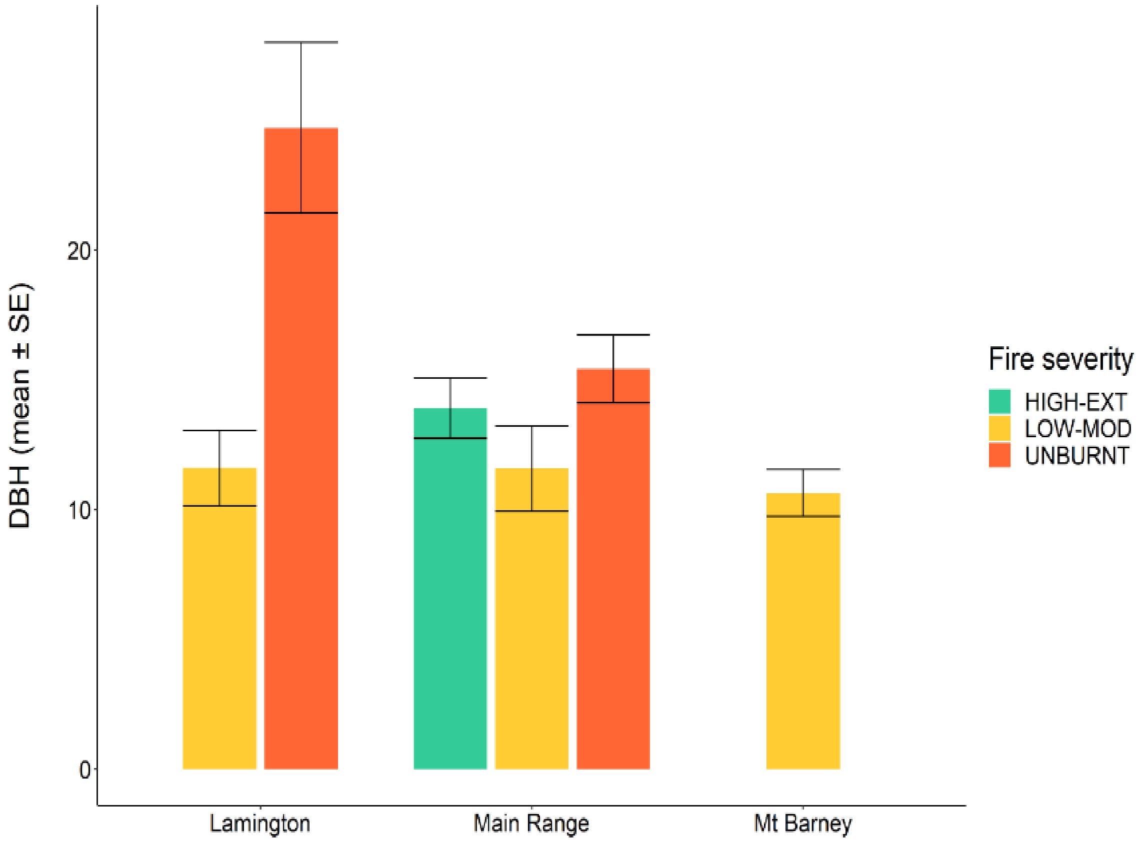

Figure 27: DBH (mean ± SE) of *Allocasuarina torulosa* at Lamington, Main Range and Mt Barney NPs by fire severity class in 2022 surveys. DBH was not measured in 2021.

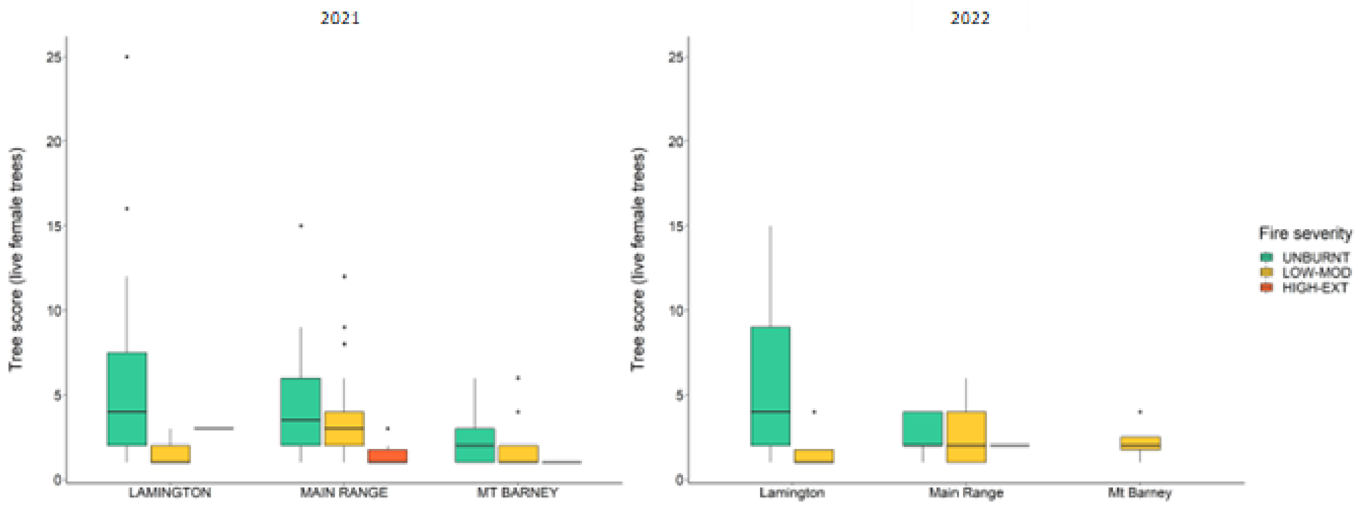

Figure 28: Tree score across fire severity classes at Lamington, Main Range and Mt Barney NPs in 2021 and 2022. Note that in 2022 only Main Range was surveyed for all five severity classes, which is why data are missing from other areas.

4.3.4 Discussion

Presence of glossy black-cockatoos and habitat quality

This survey confirms that in 2021 and 2022 glossy black-cockatoos were present in Lamington, Main Range and Mt Barney NPs, mostly in areas that were unburnt or experienced only low to moderate fire impacts during the 2019–2020 bushfires. In 2022, the birds' vocalisations were detected in sound recordings from one site that had experienced high-extreme fire impacts (MAIN_12), but there was no other indication that the birds were using such areas. At only two sites (MAIN_1 and MAIN_2) was the birds' presence recorded in both survey years. At four sites (BARN_1, BARN_16, LAM_5 and MAIN_12) the birds' presence was recorded only in sound recordings from 2022. At two sites (LAM_12 and MAIN_15) the birds' presence was recorded only in 2021, from in-field observations of birds and chewings. Although feeding sign is a conspicuous indicator of the birds' presence, it is clear from the 2022 surveys that the greater temporal survey effort afforded by acoustic monitoring is hugely beneficial. Despite no birds or feeding sign being observed in-field in 2022, their vocalisations were recorded from six of the 15 sites surveyed. This suggests that the birds' presence may have been underestimated in 2021.

Both in 2021 and 2022, feeding habitat quality was generally poor in all parks. In 2021, sites that had experienced high to extreme fire impacts appeared to have many dead she-oak trees, but this was not quantified. In the 2022 survey, all live and dead trees were counted within standardised strip transects. Although only one high-extreme site was surveyed for habitat quality, this site did have more dead trees than other sites, on average. This accords with surveys on Kangaroo Island in South Australia which reported that, on average, 74% of drooping she-oak trees died in a severe bushfire in the 1990s (Pepper 1997); this event contributed to a permanent shift in glossy black-cockatoos' distribution on the island.

Food availability was measured by multiplying a visual cone density score by a visual canopy size score in 2021 or a tree size (DBH) score in 2022. This allowed for scores to be compared between the two surveys. Overall, tree scores in 2022 were similar to those recorded in 2021. This suggests that, at the surveyed sites, food availability was similar, despite no birds being detected at any site in 2022. This may reflect variations in food availability at larger spatial scales, not within survey sites *per se.* The factors of feeding habitat that influence glossy black-cockatoo presence are not well understood and may vary by location and feed tree species (North *et al.* 2020). Indeed, preliminary results from the other larger project in South East Queensland show that cone production and abundance is highly spatially variable. This variability may be driven by local differences in rainfall, soil type and fire history, among other variables, but this remains to be tested.

In 2021, immature cones were observed in all fire severity classes but were more prevalent at unburnt and low-moderate impact sites. Although a high impact site at Mt Barney had a large proportion of live female trees with immature cones (60%), the overall number of live trees was very low (only five trees found in 20 minutes) and all were *A. torulosa* (i.e. all *A. littoralis* were dead). Thus, this site is unlikely to provide high quality habitat for many years. Unlike in the 2021 survey, very little evidence was found of immature cones or resprouting in the 2022 surveys.

Again, this may relate to differences in rainfall; summer-autumn of 2022 experienced exceptionally high rainfalls. Follow-up surveys in 2023 would provide more insight into these patterns. In both 2021 and 2022, the highest quality feeding habitat was recorded at sites along the Daves Creek Circuit in Lamington NP. In this area, *A. torulosa* are exceptionally large and it is likely that this area is very important to the persistence of glossy black-cockatoos in this park. Protecting this area from disturbance, including fire, is a priority.

Interestingly, in 2021 at one site on the Daves Creek Circuit, glossy black-cockatoos were recorded at a site dominated by *A. rigida*, which is not generally known to be a common feed tree species. This may indicate a shift in feeding habits during periods of food limitation, since neither glossy black-cockatoos nor recent feeding sign were observed at any other site in Lamington NP. As such, these lesser-known feed trees should also be protected. Unfortunately, this site was burnt in between the 2021 and 2022 surveys, which would have impacted food availability. No birds were observed at this site in 2022.

In both survey years, glossy black-cockatoos were detected at sites around the Spicer’s Gap area in Main Range NP. This area had experienced low to moderate fire impacts in the 2019–20 bushfires. Food quality was low to moderate, which suggests the birds may be feeding in suboptimal habitat. This may be out of necessity; for example, if the birds are nesting in the area. Indeed, in 2021, a pair incidentally observed near the Spicer’s Gap campground exhibited behaviours indicative of nesting (e.g., female begging and being allofed at sunset; Teixeira *et al.* 2020). However, food limitation may reduce the chance of successful nesting (Cameron 2009). Nonetheless, that birds were present in both years, and recorded over six consecutive survey days in 2022, suggests that this area is critical habitat for glossy black-cockatoos.

Although resprouting was observed in all fire severity classes, the small number of living trees in high-extreme impact sites will limit recovery for glossy black-cockatoos. In 2022, sites that experienced high-extreme or low-moderate fire had a greater number of live juvenile trees compared to unburnt sites, which suggests that some habitat recovery is underway. Whether or not recovery is sufficient to support glossy black-cockatoos in the future is as yet unknown.

Future improvements

The primary objective of this survey was to confirm the presence or absence of glossy black-cockatoos in three fire-impacted NPs. To achieve this, a range of fire severity classes was surveyed for evidence of the birds in the field and through acoustic recordings. In addition, to examine potential drivers of presence-absence, habitat data were collected consistent with a larger project underway examining glossy black-cockatoo habitat use in South East Queensland. Results from the current survey will be integrated into the larger project to form a more complete picture of glossy black-cockatoo occupancy across fire-impacted areas of South East Queensland. Conservation planning would benefit from long-term standardised data on glossy black-cockatoo presence-absence and habitat quality, especially given the subspecies’ recent listing under the EPBC Act.

Figure 29: Male glossy black-cockatoo observed feeding on *Allocasuarina torulosa* at Main Range NP. (Photo: D. Teixeira)

Figure 30: Example of a site with high to extreme fire impacts at Main Range NP in 2021. (Photo: D. Teixeira)

4.3.5 Recommendations

Reducing ongoing threats

- Protect feeding habitat from fire

  The recovery of she-oak feeding habitat in fire-impacted areas and the protection of unburnt areas of feeding habitat (e.g. Springbrook NP, Nerang NP) is critical, with protection from future fires a priority.

- Reduce impacts of weeds in feeding habitat

  Weeds can impede the post-fire regeneration of she-oaks and the quality of unburnt feeding habitats. Weeds can also elevate the risk of future bushfires and fires of high severity.

- Restore and expand feeding habitats

  Restoration and planting programs that can expand the availability of she-oak feed trees across diverse land tenures needs to be promoted.

Ecological monitoring

- Ongoing acoustic monitoring and assessment of feeding habitat is required to track the presence of glossy black cockatoos across GWHA and the post-fire recovery of feeding habitat to guide park management actions. As a minimum:
  - undertake acoustic monitoring at 15 sites for at least one week in autumn, using a recording schedule of sunrise -30 mins to sunset +30 mins. For further details see Teixeira *et al.* (2022). Ideally, increase the number of sites acoustically surveyed (min. 30 sites) and preferably, repeat acoustic surveys in the non-breeding season (spring-summer)
  - collect basic habitat quality data from 15 sites every other year and preferably, collect habitat quality data from 30+ sites every year

Ecological research

- Examine sightings data for trends in pre- and post-fire occupancy.
- Determine the predictors of feeding habitat quality and glossy black-cockatoo occupancy.
- Determine priority locations for revegetation and weed control works.

4.4 Eastern bristlebird

4.4.1 Conservation context

The eastern bristlebird *Dasyornis brachypterus* (Figure 31) occurs in fragmented populations from the montane open woodlands of South East Queensland south to coastal heathlands of South East Victoria. Two taxa have been described (Schodde & Mason 1999), which are considered subspecies (e.g. Office of Environment and Heritage 2012): the northern eastern bristlebird *Dasyornis brachypterus monoides*, and the southern eastern bristlebird *Dasyornis brachypterus brachypterus*. Northern eastern bristlebirds occur in the coastal hinterland of South East Queensland and North East NSW. In Queensland, they are currently known from a site near Mt Gipps on the Queensland/NSW border and possibly Mt Barney NP and Spicers Gap in Main Range NP (Charley *et al.* 2021). In NSW, they occur at several sites near Kyogle in the Border Ranges (Charley *et al.* 2021). Local extinction of northern eastern bristlebird populations is assumed in Queensland in the Conondale Ranges and areas on the Lamington Plateau (including the Stretcher Track and Duck Creek Road), and in NSW at Razorback Mountains, Mt Burrell, Big Scrub, Mt Richmond and the Dorrigo Plateau (Charley *et al.* 2021). Southern eastern bristlebirds can be found from the Red Rock Nature Reserve in central NSW south through to Howe Flat in Croajingolong NP in Victoria, with populations around Jervis Bay and in Budderoo NP, Beecroft Peninsula, Barren Grounds Nature Reserve and Nadgee Nature Reserve (Bain *et al.* 2021).

The eastern bristlebird is listed as Endangered under the NCA, EPBC and the NSW *Biodiversity Conservation Act 2016* and as Threatened in Victoria under the *Flora and Fauna Guarantee Act 1988* (January 2021 list). Recent population analysis indicates that the northern eastern bristlebird now only persists at scattered sites, each with few birds and may qualify for listing as Critically Endangered (IUCN Red List criteria: A3ce, D).

Threatening processes

A range of processes threatening the survival of the northern eastern bristlebird (hereafter referred to as the eastern bristlebird) has been identified (summarised from Office of Environment and Heritage 2012), including:

- inappropriate fire regimes—too frequent fires cause a loss of suitable grass cover and too infrequent fires result in the replacement of suitable grass habitat with an unsuitable dense shrub layer.
- habitat loss—historical clearing of coastal heath and the escarpments is a major reason for population declines. Preventing any additional loss of eastern bristlebird habitat from clearing or degradation is a priority. ‘Land clearance’ is listed as a Key Threatening Process under the EPBC, including the clearance of native vegetation for crops, improved pasture, plantations, gardens, houses, mines, buildings and roads (Threatened Species Scientific Committee 2001).
- climate change—the eastern bristlebird is one of the 100 terrestrial Australian bird taxa that have been identified as being the most sensitive to climate change impacts and likely to be affected by changes in fire frequency (Garnett & Franklin 2014). Modelling has predicted that at the current rate of global warming, there will be a moderate decline of suitable habitat for eastern bristlebirds by 2085. Range contraction is likely to occur from the north; however, the montane areas in northern NSW are expected to be suitable for bristlebirds into the future (Garnett & Franklin 2014).

Other threatening processes that may affect eastern bristlebird populations include:

- predation, particularly by pest animals such as cats and foxes, especially after fire
- impacts to habitats, feeding and breeding from exotic species, such as pigs and wandering stock
- impacts to habitats, feeding and breeding from human visitors and recreational activities
- habitat degradation through weed invasion and a changing climate (e.g. more frequent droughts)
- genetic bottlenecks and inbreeding depression.

Conservation actions

Eastern bristlebirds are currently being monitored at sites with known populations and surveyed across areas where they historically occurred, as well as across potential habitat in Queensland and northern NSW. This work is being undertaken as a collaboration between DES Threatened Species Operations, NSW Office of Environment and Heritage, Birdlife Australia and specialist consultants.

A goal of re-establishing wild populations is being supported through a captive breeding program for eastern bristlebirds at Currumbin Wildlife Sanctuary, Queensland, with individual birds mostly sourced from northern NSW. A small number of southern eastern bristlebirds from the central region of NSW has been introduced to the colony to reduce the risk of inbreeding depression, under the advice of Dr. Andrew Weeks from the University of Melbourne.

To create suitable habitat for eastern bristlebirds with grassy undergrowth and an open tree canopy, fire management efforts have recently been undertaken on private properties where the bird is known to occur. In some of these managed areas, bristlebirds have responded positively to the change in fire regime and improved habitat with additional eastern bristlebird calls being recorded (Stewart 2021).

Figure 31: Eastern bristlebird. (Photo: G. Fraser)

4.4.2 Survey sites and methods

Large sections of Main Range and Mt Barney NP where eastern bristlebirds were known or potentially occurred were burnt during the 2019–2020 bushfires. Modelling of the eastern bristlebird habitat and fire mapping indicates that approximately 3,217ha (35%) of this bristlebird habitat in Queensland was burnt in 2019 (Threatened Species Operations 2020).

To investigate the effects of the bushfires on the eastern bristlebird and determine if these birds have the capacity to recolonise fire-affected areas, Spicers Gap and Mt Barney have been monitored for the presence of bristlebirds using acoustic recorders. These two locations were chosen to assess the eastern bristlebird's response to the 2019–2020 bushfires because both are known bristlebird sites and potential records of the bird were made in both areas prior to them being burnt. A bristlebird detector dog gave a strong indication of bristlebirds in the Spicers Gap area (Charley *et al.* 2021). Although this area was surveyed using call playback, no bristlebirds could be found. Additional surveys of Spicers Gap were planned for 2020; however, much of the Spicers Gap region was burnt before any follow-up surveys could be completed. In July 2019, a local birdwatcher recorded eastern bristlebirds on Mt Barney but unfortunately did not communicate his find with either the Mt Barney QPWS office or the Eastern Bristlebird Northern Working Group until early December of that year. Because of this delay, it was not possible to confirm the presence of eastern bristlebirds on Mt Barney before extreme high temperatures limited field work in South East Queensland Five AudioMoths were deployed at both Spicers Gap and Mt Barney close to where the eastern bristlebirds were last recorded at each site. The AudioMoths were attached to trees at approximately 1.5m above the ground. The AudioMoths at each site were approximately 100m apart. These recorders were set to record for two hours between 7:00 and 9:00 am every day. This period was chosen because it was thought to be the peak calling period for eastern bristlebirds in northern NSW territories (D. Charley pers. comm.). Approximately every two months, the AudioMoths were collected and replaced with recalibrated AudioMoths with recharged batteries and empty SD cards. Sound files recorded by the AudioMoths were saved and backed up. Some of these acoustic files have been analysed using an eastern bristlebird call recogniser developed by the Queensland University of Technology, and it is hoped that the remainder of the files will be analysed soon.

Eastern bristlebirds are known to occur on private property adjacent to Lamington NP, which was not burned during the 2019–2020 bushfires. This property is only infrequently visited to minimise disturbance to the remaining known eastern bristlebird population in Queensland. AudioMoths have not yet been used at this site; however, there are plans to expand the acoustic recording program to include this area and other areas where eastern bristlebirds previously occurred on the Lamington Plateau from 2022. Surveys for eastern bristlebirds were also undertaken during servicing of the AudioMoths. Call play back has not been used in these areas because this sound would be recorded by the AudioMoths.

4.4.3 Survey results

No eastern bristlebirds were heard calling at either Spicers Gap or on Mt Barney during surveys for this project, and to date, no eastern bristlebird calls have been detected in the acoustic files recorded from either Spicers Gap or Mt Barney that have been analysed using the call recogniser. However, recently recorded acoustic files have yet to be analysed using this eastern bristlebird call recogniser.

The acoustic recordings collected during these surveys will be analysed once the development of an eastern bristlebird call recogniser is finalised in collaboration with the Queensland University of Technology.

The area of burnt forest at Spicers Gap where the eastern bristlebirds were previously known to occur does not appear very suitable for these birds at present, with the large tussock grass *Sarga leiocladum* being replaced by small *Poa* tussocks. There are numerous saplings growing through the forest, and on the edges of the bristlebird area is a dense growth of rough-barked apple *Angophora floribunda*.

Much of Mt Barney was burnt during the 2019–2020 bushfires, including the montane heath understorey and midstorey where eastern bristlebirds had been reported previously. At present it is difficult to identify areas of potential eastern bristlebird habitat on Mt Barney, which has made the task of deploying audio monitors in the best locations to survey for these bristlebirds challenging. Weeds were not noted as an issue on Mt Barney (Ian Gynther pers comm.).

4.4.4 Discussion

To date, no eastern bristlebirds have been recorded at Spicers Gap or on Mt Barney where the AudioMoths continue to operate. Sound files from both locations have been used in the development of the eastern bristlebird call recogniser.

The habitat at Spicers Gap is not considered to be the optimal eastern bristlebird habitat for Main Range NP. In the past, this species was found in open forest in Main Range NP where the undergrowth included dense tussock-grasses, such as *Sarga leiocladum*, approximately 1.0–1.5m tall that provided between 65–90% ground cover (Holmes 1989, 1998; Lamb *et al.* 1993; Hartley and Kikkawa 1994). This dense grass layer provided the eastern bristlebirds with protection from predators and nesting locations. At Mt Barney, the suitable habitat of montane heath that was impacted by the 2019–2020 bushfires will be slow to recover.

To assist the long-term persistence of eastern bristlebirds in Queensland and northern NSW, captive breeding will provide birds suitable for release. In preparation for this, the identification and management of areas suitable for the release of captive bred eastern bristlebirds is in progress. To increase the success of the wild release program, birds will be released where they can be protected and their habitat suitably managed with appropriate fire regimes and control of weeds and pest animals. In Queensland, thresholds for ecological condition and threats have been developed for core habitat areas in Lamington and Main Range NPs. These areas are monitored through the QPWS Health Check program in accordance with the national park monitoring and research strategy, with thresholds triggering planned burning and other management actions to establish suitable habitat conditions.

4.4.5 Recommendations

Reducing ongoing threats

- Reduce impacts of cats and foxes
- Monitoring of feral predators with appropriate control measures will reduce the predation risk for the pending release of captive-bred eastern bristlebirds. Assess the need for predator control in areas where eastern bristlebirds may still occur.

Ecological monitoring

- Continue acoustic monitoring at Spicers Gap to confirm the presence of the eastern bristlebird

  Acoustic monitoring locations should be expanded to areas where eastern bristlebirds previously occurred

  It is also recommended that call playback be used when the AudioMoths are serviced to check for the presence of eastern bristlebirds. Any acoustic data file containing call play back audio should be removed prior to analysis.

Ecological research

- Identify additional occupied sites and potential habitat within Queensland.
- Develop a post-fire recovery strategy.

4.5 Rufous scrub-bird

4.5.1 Conservation context

The rufous scrub-bird *Atrichornis rufescens* occurs in high rainfall areas of the Main Range and Lamington Plateau region of South East Queensland and northern NSW (Stewart *et al.* 2021), south along the Great Diving Range to Barrington Tops in north central NSW (Stuart *et al.* 2021). Two subspecies are recognised: the northern rufous scrub-bird *A. r. rufescens* and southern rufous scrub-bird *A. r. ferrieri*. The northern rufous scrub-bird occurs from Main Range NP in Queensland south to the Gibraltar Range in NSW. There are four known subpopulations of the northern rufous scrub-bird: Main Range (upper reaches of Dalrymple Creek, Mt Cordeaux, Mt Mitchell and Cunninghams Gap); McPherson Range (Lamington NP west to Mt Barney NP); Border Ranges; and Gibraltar Range and Barool NPs (Stewart *et al.* 2021). The southern rufous scrub-bird population is centred at: Dorrigo and Ebor Plateaux in New England NP; Hastings Range including Werrikimbie NP; and Barrington Tops, including Gloucester Tops (Stuart *et al.* 2021).

The rufous scrub-bird is listed as Endangered under the EPBC and Vulnerable under the NCA and the NSW *Biodiversity Conservation Act 2016*. Recent population analysis suggested that both the northern (Stewart 2021) and southern rufous scrub-bird (Stuart *et al.* 2021) subspecies have declined by between 50–80% of mature individuals in the last ten years (one generation is 3.2 years) and may now qualify for listing as an Endangered conservation status (IUCN Red List criteria: A2bc+4bc).

There are three categories of threatening processes that are thought to influence the survival of northern rufous scrub-bird (hereafter referred to as the rufous scrub-bird), summarised in Stewart *et al.* (2021):

Fire and logging—Most of the known populations of rufous scrub-birds are now within areas managed by QPWS. Some of the remaining habitat which supports these birds is now threatened by inappropriate burning and logging regimes (Garnett *et al.* 2011; Garnett & Crowley 2000).

Climate change—The rufous scrub-bird is one of the 100 terrestrial Australian bird taxa that have been identified as being most sensitive to climate change (Garnett & Franklin 2014). Climate change modelling indicates that the distribution of these scrub-birds will be affected by both the contraction of suitable habitat southward with increased global warming and loss of available habitat from increased fire frequency (Appendix 1) The sensitivity to climate change is primarily a consequence of the scrub-bird's reliance on ground-dwelling invertebrates.

Predation—Other possible threats to the viability of rufous scrub-bird populations include predation by dingoes or wild dogs, feral cats and red foxes (Ekert 2002).

With most of the lowland rainforest in Queensland being cleared by the mid-19th century, rufous scrub-birds are now confined to closed forests or wet open forests above 600m (Ferrier 1984). Most areas where the remaining rufous scrub-birds occur are within the protected area estate. Threatened Species Operations (DES) has monitored the rufous scrub-bird population in the Lamington and Main Range NPs since 2006. Several recommendations were made to the QPWS for the management of the rufous scrub-birds on park estate. (Stewart 2017).

4.5.2 Survey sites and methods

Large sections of Main Range and Mt Barney NP where rufous scrub-birds were known to occur were burnt during the 2019–2020 bushfires. Modelling of the rufous scrub-bird habitat and fire mapping indicates that approximately 3071ha (35%) of this habitat in Queensland was burnt in 2019 (Threatened Species Operations 2020). To investigate the effects of the bushfires on the rufous scrub-birds and their recovery, monitoring was undertaken at Cunninghams Gap where surveys have been conducted by DES since 2006 (Stewart 2017) and the area was impacted by the 2019–2020 bushfires in December 2019 (Hines *et al.* 2021).

Surveys were conducted at three listening points along the Palm Grove Circuit and seven points along the Mt Cordeaux Track, each 400m apart. The locations are confidential to protect the species. The methods used to survey rufous scrub-birds replicated those used previously in both Main Range and Lamington NPs since 2006. Surveys were conducted within three hours of sunrise or one hour before sunset. Surveys were postponed if strong wind or rain was due on the day planned for surveys. At each fixed survey point, observers listened for calls of male rufous scrub-birds for a period of 7.5 minutes. If no rufous scrub-birds were heard, a 'nil response' was recorded. If a rufous scrub-bird was heard, both the distance (in metres) was estimated and the compass bearing recorded. If rufous scrub-birds were recorded while travelling between points, these incidental observations were captured alongside the same information for surveys (e.g. location, compass bearing and distance) (Stewart 2006, 2007, 2017).

At each site, characteristics important for rufous scrub-birds, such as attributes relating to the ground layer or lower stratum vegetation cover and levels of disturbance, were recorded on specific data proforma, as well as fire related parameters.

In 2020, three AudioMoths were deployed at Cunninghams Gap for rufous scrub-birds – two along the Palm Grove Circuit and one along the Mt Cordeaux Track (Table 20), where scrub-birds had been heard calling in past surveys. In 2021, two additional AudioMoths were deployed in the Goomburra Section of Main Range NP, which was not burnt during the 2019–2020 bushfires, as there had been reports of rufous scrub-birds in this area.

A call recogniser for the rufous scrub-bird is under development by Queensland University of Technology.

4.5.3 Survey results

Since 2019, no rufous scrub-birds have been recorded during the surveys of Palm Grove Circuit or Mt Cordeaux Track at Cunninghams Gap or at Goomburra. All survey data, including nil results for rufous scrub-bird and records of other species recorded, were provided to the Queensland Government wildlife database, WildNet.

During the project, rufous scrub-birds were recorded opportunistically during other surveys. A rufous scrub-bird was seen and heard on Mt Barney in an area that was burnt during the 2019–2020 bushfires and subsequently regenerating with dense native vegetation (I. Gynther pers. comm.). Several different individuals were heard calling from unburnt cool temperate and upland subtropical rainforest in the Mt Ballow area of Mt Barney NP and the adjoining Mt Nothofagus NP (NSW) (H. Hines, A.H. McCall and I. Gynther pers. comm.). One individual was captured on a camera trap in unburnt forest in this area. Another individual was calling from dense native regeneration in a patch of *Nothofagus moorei* forest that had been severely damaged by fire south of Mt Ballow. Call recordings of this species from acoustic recorders deployed at Mt Barney and Mt Ballow, together with additional recordings from Cunninghams Gap, were provided to Queensland University of Technology to support development of a rufous scrub-bird sound recogniser. Analysis of the Mt Barney and Mt Ballow recordings using the rufous scrub-bird call recognisers developed by the Queensland University of Technology and NSW Department of Planning and Environment revealed positive detections of this species. No rufous scrub-birds were detected in the sound files from the Palm Grove Circuit, Mt Cordeaux Track and Goomburra section of Main Range NP. A summary of scrub-bird censuses at Main Range NP is presented in Table 20.

Table 20: Number of rufous scrub-birds seen or heard during each survey undertaken at Main Range NP (data retrieved from WildNet).

Month and year of survey	Palm Grove transect Main Range NP	Mt Cordeaux transect Main Range NP
October 2006	3	1
November 2007	2	0
December 2010	0	Incomplete
December 2013	0	2
January 2015	0	0
December 2016	0	2
December 2021	0	0

4.5.4 Discussion

The lack of records for rufous scrub-birds during the surveys at Main Range NP is of significant concern. Although sections of the Mt Cordeaux transect had been burnt, large sections of the habitat along both Palm Grove and Mt Cordeaux transects appeared suitable for rufous scrub-birds. One other survey event, in December 2015, failed to record a rufous scrub-bird in these same locations. In other surveys along these transects, between one and three rufous scrub-birds were recorded (Table 20). In 2015, it is thought that the breeding activity of the scrub-birds was reduced, as the habitat was recovering from damage related to rain and strong wind associated with ex-Tropical Cyclone Oswald. This weather event caused considerable damage to Main Range NP with numerous treefalls and sections eroded (D. Stewart pers. obs).

Some localities with known rufous scrub-bird populations in Queensland, such as the Border Track in Lamington NP, are in the protected area estate and surrounded by expanses of dense rainforest (D. Stewart pers. obs). Other localities, such as on Mt Cordeaux and in other areas of Main Range NP are adjacent to open forest and have the potential to burn under very hot and dry conditions when fires occur (Herold *et al.* 2018).

In December 2019 the vegetation, including the upper canopy, was burnt in some sections of Mt Cordeaux (Hines *et al.* 2021). Although vegetation is now naturally regenerating in this area, there are extensive populations of weeds. Although rufous scrub-birds should be able to survive in these fire-affected areas, there is likely to be a reduction in the birds' invertebrate food resources, as the ground litter layer and shrub layer have been depleted (Sands 2018). It is unlikely that rufous scrub-birds would breed until conditions became more favourable.

4.5.5 Recommendations

Reducing ongoing threats

- Protect suitable habitat and food resources from fire

  The suitable habitats need to be protected from fire through strategic planned burn programs in surrounding fire-adapted ecosystems.

- Reduce impacts of weeds

  The post-fire recovery of suitable habitat in Main Range NP needs to be supported through the ongoing control of weeds to facilitate regeneration of the shrub layer and ground leaf litter,

Ecological monitoring

- Continue monitoring at established sites in Main Range NP.
- The following modifications to the survey techniques are recommended:
  - With the recent success of acoustic monitoring of rufous scrub-birds (Stuart and O'Leary 2019) and the development of a rufous scrub-bird call recogniser by the NSW Department of Planning and Environment, it is recommended that a monitoring program be developed around the use of acoustic recorders recording for several hours per day at each monitoring point. This should be conducted during the peak calling period between October and December. This program would:
    - have a greater potential to record a calling rufous scrub-bird than someone listening at the designated point for 7½ minutes
    - eliminate variables such as:
      - Differences in observer abilities,
      - Differences in the time of day between sites, and
      - Differences in climate conditions between sites and survey periods.
- Implement monitoring at additional sites within Main Range NP where positive records were made prior to the 2019–2020 bushfires. Data relevant to habitat condition should be collected concurrently.

  Partnerships with Birdlife Australia Southern Queensland should be considered to continue surveys of rufous scrub-birds and monitor disturbance.

Ecological research

- Assess the threat of climate change

  The threat of climate change may require consideration of assisted translocation and/or captive breeding to supplement small and/or isolated scrub-bird populations and minimise the risk of localised extinctions. Impacts from climatic stressors such as drought, heat and fire need to be assessed.

- Identify fire refugia at local and landscape levels.
- Develop a post-fire recovery strategy.
- Obtain demographic and other population data.
- Assess impacts of human disturbance during the breeding season.

5 Priority frogs and reptiles

5.1 Stream frogs

5.1.1 Conservation context

In Queensland, the obligate stream-breeding frogs Fleay's barred frog *Mixophyes fleayi* (Figure 32) and cascade treefrog *Litoria pearsoniana* (Figure 33) occur in wet forest streams south from the Conondale Range, including Lamington, Main Range and Mt Barney NPs affected by the 2019–2020 bushfires. Fleay's barred frog is listed as Endangered under the NCA and EPBC and *L. pearsoniana* is listed as Vulnerable under the NCA. Both species are included in the *Recovery plan for stream frogs of South East Queensland 2001–2005* (Hines & SEQTFRT 2002) and there is a Conservation Advice for Fleay's barred frog (Threatened Species Scientific Committee 2017). Each species likely experienced disease-driven declines during the 1970–1990s (McDonald & Davies 1990, Ingram & McDonald 1993, Laurance *et al.* 1996, Hines *et al.* 1999, Hines & SEQTFRT 2002, Hero & Morrison 2004, Newell *et al.* 2013, Quick *et al.* 2015, Berger *et al.* 2016). Declines seem to have stabilised and there is some evidence of recovery of both species in most areas they historically occurred in Queensland (Hines & South-east Queensland Threatened Frogs Recovery Team 2002). Current known or potential threats to these species include habitat degradation and erosion facilitated by non-native ungulates (pigs, cattle, deer), predation by feral predators (cats, pigs, red foxes), weeds limiting regeneration of native vegetation impacting cover, bank stability and future fire risk, drought (Hines *et al.* 1999, Hines & SEQTFRT 2002), climate change and disease. Fire-related threats to the species may include direct mortality, loss of shelter sites and food resources, post-fire runoff leading to altered hydrology and water chemistry, increased sediment and charcoal load, and bank destabilisation (Lyon & O'Connor 2008, Alexandra & Finlayson 2020), and the opening of habitat allowing increased incursion of pest animals and weeds.

Figure 32: Fleay's barred frog (left) and *M. fleayi* nest and eggs (right) at Main Range NP. (Photos, left to right: A.H. McCall; H.B. Hines)

Figure 33: Cascade treefrog, Main Range NP. (Photo: A.H. McCall)

5.1.2 Survey sites and methods

Under suitable conditions both frog species are conspicuous along streams, with males calling strongly, often from exposed positions. Detection of adult female and juvenile *M. fleayi* is not reliable as they live in surrounding forests, at times hundreds of metres from breeding sites. Adult female and juvenile *L. pearsoniana* are more reliably detected along streams as they sit on top of fringing vegetation and tend not to disperse far into the surrounding forest.

Nocturnal visual encounter survey along streams was the primary survey method for the two stream frog species, though several incidental observations were also made whilst undertaking other project surveys. Sites were selected to target known populations, primarily within the extent of the 2019–2020 bushfires and preferably with historical quantitative data (H.B. Hines unpubl. data), although half of the sites had not been surveyed for at least ten years and three sites had not previous been surveyed by QPWS (Table 22). The typical breeding season for both species is spring to summer and is strongly influenced by stream flow (and hence rainfall) in *M. fleayi* (Knowles *et al.* 2015), so surveys took place from September-November with replication in January-March. Where possible, surveys for *M. fleayi* were conducted following rain and subsequent return of streams to near basal flow. Forty-nine surveys were conducted at 12 sites between 30 April 2020 and 17 March 2022 (Table 21). Each transect (lengths varied from 100–500m, with results recorded for each 100m section) was surveyed at night by two or three observers, including at least one observer highly experienced in stream frog surveys. Transects were slowly walked along the stream bed. Head torches were used to scan exposed rock, low vegetation, and the forest floor for frogs. Any frogs heard but not seen were also recorded. Observations of other vertebrate fauna were also noted. The following information was recorded during nocturnal censuses: date, start and finish times, observers, dry and wet bulb air temperatures, water temperature, relative humidity, cloud cover, wind index, moon index, level of night light, rainfall, other weather notes, habitat conditions and any other factors that may affect the results of the census.

5.1.3 Survey results

The potential habitat modelling (Laidlaw & Butler 2021) revealed that in the study area, 28% of likely habitat for Fleay's barred frog and 26% for the cascade tree frog was impacted by the 2019–2020 bushfires across GWHA (Table 21).

The surveys show both species persisted and bred in burnt landscapes across the Queensland portion of the GWHA following the 2019–2020 bushfires. Fleay's barred frog was detected at 11 of the 12 visual encounter survey sites and at an additional 12 sites incidentally. The species was not observed at Lamington NP, though only one site, at which the species had not been previously detected, was surveyed. Whilst Lamington NP supports significant populations of Fleay's barred frog, the vast majority of known habitat within the park was outside the extent of the 2019–2020 bushfires (Hines *et al.* 2020, H.B. Hines unpubl. data). Cascade treefrog was detected at all 12 sites where visual encounter surveys were conducted, as well as an additional 11 sites incidentally (Figure 35). Both species were found at sites with a range of fire impacts, including one site in Mt Barney NP with High to Catastrophic Landscape PEI (Figures 34, Figure 36). Egg masses of Fleay's barred frog (Figure 32) were observed at three sites in Main Range NP and tadpoles were observed at six sites in Main Range NP and one site in Mt Barney NP (Table 22). Although the presence of tadpoles confirms post-fire persistence of Fleay's barred frog, the long development time of tadpoles (likely well in excess of 6 months - Anstis 2017) of this species means they may have been in the system prior to the fires and would represent the previous season's breeding. Cascade treefrog eggs were not observed, but tadpoles of this species typically metamorphose within two to three months of egg laying (Anstis 2017), so observations of recently metamorphosed individuals at most survey sites indicate post-fire breeding. At several burnt sites in Main Range NP large numbers of recently metamorphosed individuals, up to 209 in a single 100-metre stream section, were observed.

Table 21: Area of modelled potential habitat (PH) for the two species of stream frogs and the estimated proportion burnt in the 2019–2020 bushfires.

Scientific name	Common name	PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
Mixophyes fleayi	Fleay's barred frog	28,424	59	8,022	28
Litoria pearsoniana	cascade treefrog	33,107	17	8,590	26

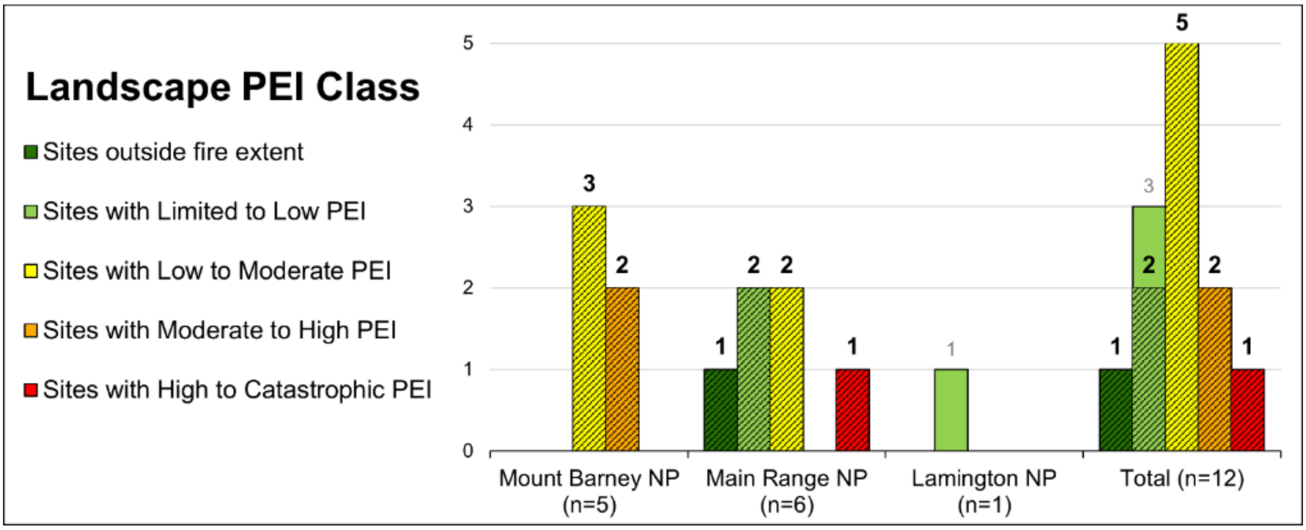

Figure 34: The number of sites surveyed for Fleay's barred frog in each of the Landscape PEI classes across the three NPs, and in total. Hatched bars and bold numbers indicate the number of sites where Fleay's barred frog was detected.

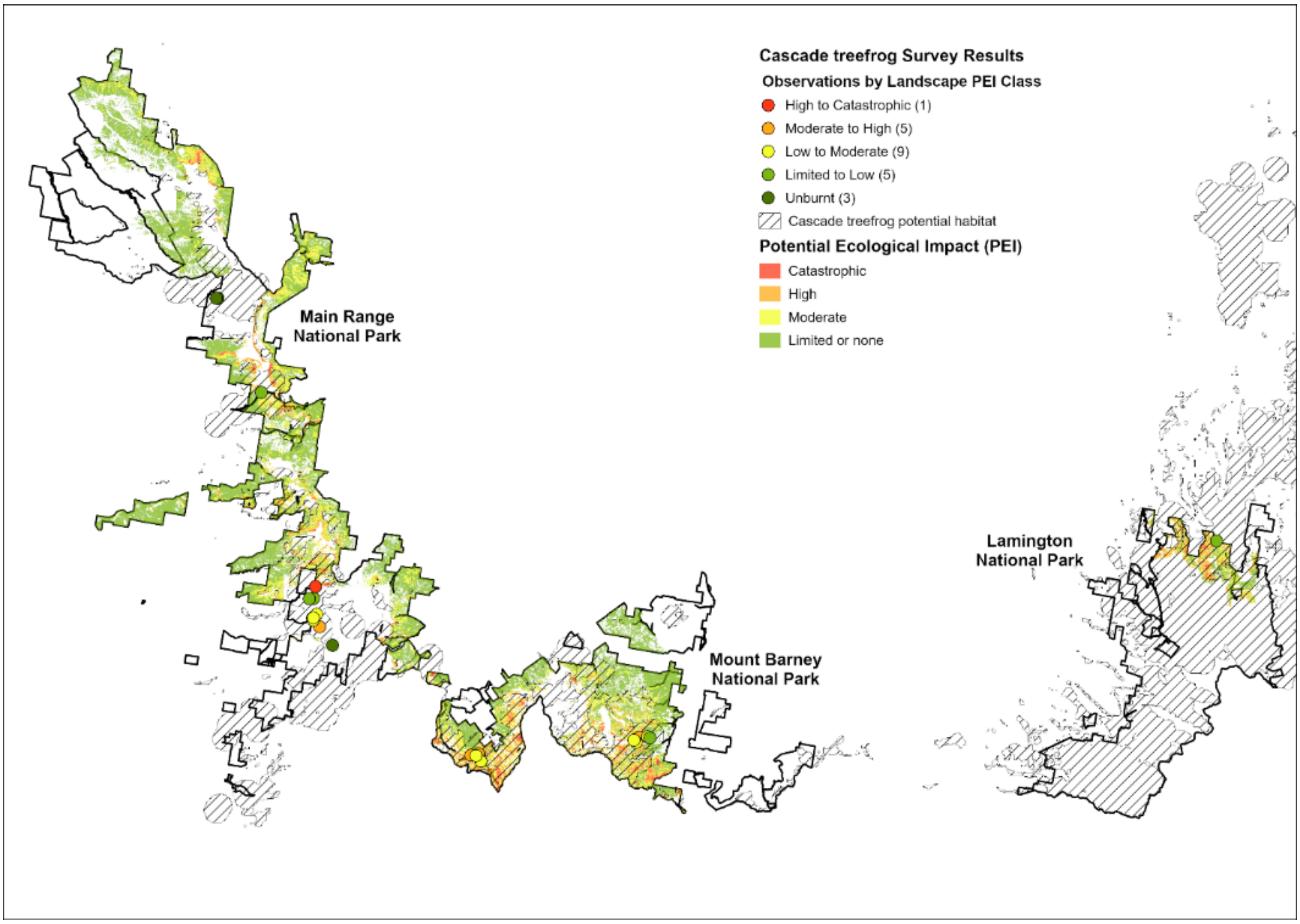

Figure 35: The potential habitat (DES 2021) of the cascade treefrog across GWHA with records from visual encounter surveys and incidental observations and the PEI of the 2019–2020 bushfires. Each record is colour coded according to the Landscape PEI class.

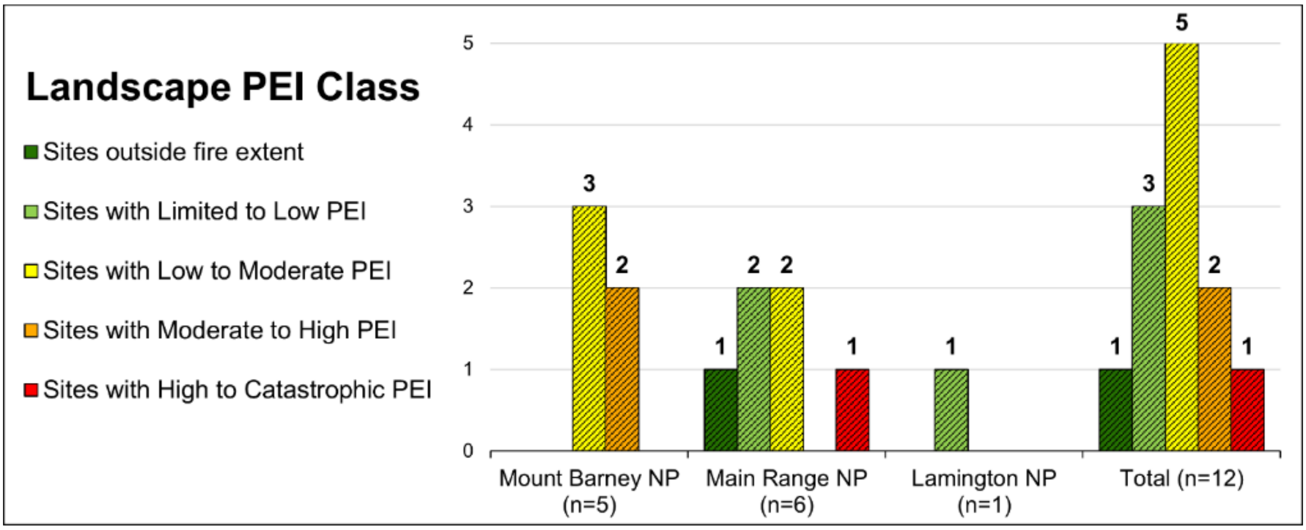

Figure 36: The number of sites surveyed for the cascade treefrog in each of the Landscape PEI classes across the three NPs, and in total. Hatched bars and bold numbers indicate the number of sites where cascade treefrog was detected.

Table 22: Summary of targeted surveys of threatened stream frog species.

		Fleay's barred frog		**Cascade treefrog**	
Site reference	**Landscape PEI Class**	# surveys (# surveys detected); life stages detected	Last survey detected pre-fire	# surveys (# surveys detected)	Last survey detected pre-fire
Lamington NP					
FT170	Limited to Low	2 (0)	Not detected pre-fire	2 (2)	Jan 2010
Mt Barney NP					
FT236	Low to Moderate	4 (2); Adult only	Oct 2000	4 (3)	Jan 2001
FT237	Low to Moderate	4 (1); Adult only	Oct 2006	4 (3)	Oct 2006
FT242	Moderate to High	4 (3); Adult only	Jan 2000	4 (3)	Not detected pre-fire
FT304	Low to Moderate	4 (2); Adult, juvenile & metamorph	No data pre-fire	4 (2)	No data pre-fire
FT303	Moderate to High	3 (3); Adult & tadpole	No data pre-fire	3 (3)	No data pre-fire
Main Range NP					
FT001	Limited to Low	8 (8); Adult, tadpole & eggs	Mar 2019	8 (6)	Mar 2019
FT003	No Fire Impact	4 (4); Adult, juvenile, tadpole & eggs	Mar 2019	4 (4)	Mar 2019
FT011	**High to Catastrophic**	3 (2); Adult & tadpole	Jan 2002	3 (2)	Sept 2001
FT012	Limited to Low	4 (4); Adult. juvenile & tadpole	Jan 2002	4 (4)	Jan 2002
FT128	Low to Moderate	4 (4); Adult & tadpole	No data pre-fire	4 (4)	No data pre-fire
FT129	Low to Moderate	5 (5); Adult, metamorph, tadpole & eggs	No data pre-fire	5 (5)	No data pre-fire

5.1.4 Discussion

There are no pre-fire baseline data for some survey sites (Table 22). Most other survey sites had very limited pre-fire baseline data, with previous surveys mostly many years prior to the 2019–2020 bushfires. These surveys have confirmed post-fire persistence of both species across their known distribution within the Queensland portion of the GWHA, in a range of fire severities and PEIs. Both species have bred following the drought and 2019–2020 bushfires: Fleay's barred frog egg masses were observed at three sites and large numbers of newly metamorphosed cascade treefrogs were observed at several sites.

Fire impacts may not be apparent this soon after fire, particularly for Fleay's barred frog. Tadpoles of this species observed within the first year of the fire may have been from breeding events pre-fire. Females and juveniles of this species live in the forest, typically well away from streams, making them vulnerable to the impacts of the preceding drought as well as the direct impacts of the subsequent fires. Therefore, recruitment over the next few seasons needs to be assessed to understand the fire impacts more fully.

Drought conditions prior to the 2019–2020 bushfires could have impacted population size through direct mortality from desiccation and starvation (frogs feed on arthropods, biomass of which is driven by rainfall) and/or by reducing available breeding habitat and recruitment. If populations were already impacted by drought, which seems likely, it will be difficult to disentangle fire impacts from drought effects. Little to no evidence of recent pig activity was found along surveyed streams, although pigs or signs of pigs were detected within the study area: Burnett Creek catchment in Mt Barney NP and Dalrymple Creek catchment in Main Range NP. Pigs are a significant threat to riparian ecosystems and these species and should be a focus for ongoing targeted control to prevent significant incursions into habitat of threatened frogs within the study area.

Cattle were observed impacting stream frog habitat in the Burnett Creek catchment in Mt Barney NP, the Pinchgut/Steamer/Emu/Cryptocarya Creeks of Main Range NP and the lower Coomera River in Lamington NP.

Weeds were abundant within burnt streams. Most of these are short-lived species which are unlikely to cause long-term ecosystem change and may well have provided significant cover post-fire. However, significant weeds such as lantana *Lantana camara*, Crofton weed *Ageratina adenophora* and mistflower *A. riparia* were observed in burnt and unburnt riparian areas.

5.1.5 Recommendations

Reducing ongoing threats

- Protect habitat from fire

  The unburnt frog habitat areas within or adjacent to recently burnt areas need to be protected from further fires to provide refugia from fire-related impacts and support recovery of populations.

- Reduce impacts of pigs and cattle

  Monitor, control or exclude invasive herbivores to support recovery of stream frog populations. Pig control is a priority in areas including Upper Burnett Creek in Mt Barney NP and the Mistake Mountains/Goomburra area of Main Range NP. Remove and exclude cattle from Burnett Creek in Mt Barney NP and from Pinchgut/Steamer/Emu/Cryptocarya Creeks in Main Range NP.

- Reduce impacts of weeds in core habitat areas

  The significant incursion of weeds threatens the integrity of frog habitat, such as through dominance of invasive grasses. Weeds can also elevate the risk of bushfire and fires of high severity.

Ecological monitoring

- Continue monitoring for stream frogs

  Ongoing monitoring is required to track post-fire recovery from the baseline surveys undertaken for this project. The same methods can be applied annually in spring and summer targeting post- stream flow events, a known trigger for breeding of Fleay's barred frogs. Dip-net surveys of tadpoles will assess breeding status.

Ecological research

- Broader surveys to complete the understanding of the distribution of stream frogs across GWHA.

  Collate species occurrence and population data from QPWS and external sources (e.g. ALA, universities) to make them available in WildNet in order to support conservation decision making.

5.2 Mountainfrogs

5.2.1 Conservation context

Mountainfrogs (genus *Philoria)* (previously *Kyarranus)* comprises seven allopatric species of highly range-restricted frogs. Six of the seven species occur as scattered mountain-top endemics within the GWHA with three of these species occurring in Queensland. The red-and-yellow mountainfrog *P. kundagungan* (Figure 37) is listed as Endangered under both the NCA and the EPBC. The Mt Ballow mountainfrog *P. knowlesi* (Figure 37) was only described in early 2022 and is not currently listed under the NCA or EPBC but meets criteria for listing as Endangered (Mahony *et al.* 2022). There is no conservation or recovery plan for either species. Both species are found in rainforest or wet sclerophyll forest, primarily in headwater drainages and seepages, where breeding occurs (Knowles *et al.* 2004, Anstis 2013, Mahony *et al.* 2022).

In Queensland, *P. kundagungan* occurs primarily in Main Range NP as far north as the uplands of Mistake Mountains (Bolitho *et al.* 2021) and may occur in the western section of Mt Barney NP near Mt Clunie, while the Mt Ballow mountainfrog occurs in Mt Barney NP and Lever's Plateau (Mahony *et al.* 2022). Threats to these species include habitat degradation and erosion by non-native ungulates (pigs, cattle, deer), predation by feral predators (cats, pigs, red foxes), weeds, which limit regeneration of native vegetation, impact cover and bank stability and increase future fire risk, drought (Hines *et al.* 1999), climate change and potentially disease. Fire-related threats to the species may include direct mortality, loss of shelter sites and food resources, post-fire runoff leading to altered hydrology and water chemistry, increased sediment and charcoal load and bank destabilisation (Alexandra & Finlayson 2020, Lyon & O'Connor 2008), increased temperature, substrate desiccation and evaporation from an open canopy, and the opening of habitat, allowing increased incursion of pest animals and weeds.

Figure 37: The red-and-yellow mountainfrog at Main Range NP (left) and the Mt Ballow mountainfrog at Mt Barney NP (right). (Photos: H.B. Hines)

5.2.2 Survey sites and methods

Philoria species are highly cryptic and are only reliably detected when males are calling in spring and early summer. The survey design was largely guided by the as yet unpublished results of an ongoing PhD study by Liam Bolitho (Southern Cross University) on *P. kundagungan* as well as two published papers, one by Bolitho *et al.* (2021) on the distribution of *P. kundagungan* and one by Willacy *et al.* (2015) on the calling phenology of the closely related and geographically proximate *P. richmondensis*, as well as data subsequently published on *P. knowlesi* by Mahony *et al.* (2022).

Passive acoustic monitoring and/or diurnal aural surveys were conducted for *Philoria* species at 27 sites across Main Range and Mt Barney NPs (Figure 38). Nine of the surveyed sites in Main Range NP were established pre-fire in 2016–2017 by Bolitho *et al.* (2021), but the remainder were selected largely based on the criteria of that study:

- within the established range of the species
- contain a headwater stream or creek >100 metres in length
- start at the first expression of surface water
- in rainforest or within 500 metres of rainforest
- >500 metres from another site, to ensure site independence
- <2 kilometres from a road or operational fire trail to facilitate efficient access
- within the extent of the 2019–2020 bushfires or within unburnt refuges.

Incidental observations of calling *Philoria* species were also made whilst ecologists were conducting surveys for other priority taxa (Figure 39).

In this report the results of departmental-led surveys of *Philoria* species are summarised. Results of the department's diurnal aural surveys were included in a broader collaboration funded through the National Environmental Science Program (NESP) Threatened Species Recovery Hub on northern *Philoria* species (hereafter referred to as the NESP *Philoria* project). Detailed results, analyses and discussion of the combined datasets on northern *Philoria* species are provided in the NESP project report (Heard *et al.* 2021). Note in that report the *Philoria loveridgei* western McPherson Range population refers to the recently described *P. knowlesi*.

Figure 38: Habitat of the Mt Ballow mountainfrog impacted by low-moderate severity fire, Mt Barney NP. An acoustic monitor (AudioMoth) is attached to the palm tree within the ephemeral drainage line. (Photo: A.H. McCall)

Passive acoustic monitoring

Generally, one AudioMoth was deployed at each survey site, but at six sites, three at Mt Barney and three at Main Range, a Bioacoustic Audio Recorder (BAR) was also deployed to allow for comparisons between the two devices. In total, 29 AudioMoths and 11 BAR deployments occurred at 21 sites (Table 23). Each unit was set to make a 10-minute recording, on the hour. AudioMoths were set to record during a morning calling window (04:00–09:00hrs, inclusive) and a late afternoon calling window (15:00–20:00hrs, inclusive), while the BARs recorded on the hour, every hour. Recorders were deployed in September and were collected several months later, targeting the known peak calling season for these species (Bolitho unpubl. data, Willacy *et al.* 2015, Mahony *et al.* 2022).

A subset of the recordings was analysed via visual inspection of spectrograms and manual verification using the software Audacity®. 13,723 recordings from 14 sites were analysed using automatic detection in Kaleidoscope Pro (Wildlife Acoustics) using a recogniser developed by Liam Bolitho of Southern Cross University.

Diurnal aural surveys

Nineteen of the 21 sites surveyed by Passive Acoustic Monitoring were also surveyed by diurnal aural surveys (Table 24). Thirty-five surveys at 18 sites in Main Range NP were conducted to target red-and-yellow mountainfrog and 11 surveys at seven sites were conducted at Mt Barney NP targeting *P. knowlesi* (Table 24). Each site comprised two 50m transects abutting each other. Methods followed guidelines established in Bolitho *et al.* (2021). Surveys were completed during daylight hours as male calling activity is minimal at night. Each transect was surveyed moving downstream for a minimum of 15 minutes, performing call playback using recordings on a small handheld speaker or vocal mimicry at least every 10m, to elicit a response if frogs were not spontaneously calling. The number of calling males and their positions along the transect were recorded. Weather and site/habitat conditions, fire severity covariates and incidental sightings of other taxa were also recorded for each site visit. Photographs of each transect were taken to document general habitat characteristics as well as fire, weed or feral animal impacts.

Table 23: Summary of passive acoustic monitoring survey effort for *Philoria* by each recorder type in each of the project area NPs.

	Mt Barney NP		Main Range NP		Total
	AudioMoth	BAR	AudioMoth	BAR	
Number of sites	5	3	14	5	**21[1]**
Number of deployments	7	5	22	7	**40**
Total recording days	602	487	1,035[2]	624	**2,748[2]**
Mean recording days per deployment	86	97.4	73.9[2]	89.1	**-**
Total recordings	7,269	7,652	15,160	11,528	**41,609**
Total recording time (hours)	1,212	1,275	2,527	1,921	**6,935**

[1]Some sites had both an AudioMoth and a BAR, to enable comparison of technologies

[2] The number of recording days for 8 AudioMoth deployments could not be calculated due to a technical issue.

5.2.3 Survey results

Red-and-yellow mountainfrog

Red-and-yellow mountainfrogs were detected at 11 of 20 surveyed sites with incidental detections at a further eight sites (Figure 39, Table 24). Of the surveyed sites, red-and-yellow mountainfrog were detected at four sites in unburnt areas, four sites within the Limited to Low Landscape PEI Class, two sites within the Low to Moderate Landscape PEI Class and one site within the Moderate to High Landscape PEI Class (Figure 39, Table 24). At occupied survey sites the number of calling males ranged from one to seven with an average of fewer than three individuals (Table 24). Detections at three of the 11 sites were from acoustic recorders only. An additional 22 calling males were detected incidentally at eight sites (six sites in unburnt areas, one site within the Limited to Low Landscape PEI Class and one site within the Low to Moderate Landscape PEI Class). These sites averaged slightly over two individuals per site (Figure 39, Table 24).

Mt Ballow mountainfrog

Mt Ballow mountainfrog were detected at five of seven surveyed sites with incidental detections at a further three sites (Figure 39, Table 24). Of the surveyed sites, *P. knowlesi* were detected at three sites within the Limited to Low Landscape PEI Class and two sites within the Low to Moderate Landscape PEI Class (Figure 39, Table 24). Similar to red-and-yellow mountainfrog, low numbers of calling males were detected at any one site, ranging from one to six with an average of just over three individuals per occupied site (Table 24). An additional six calling males and one female were detected at incidentally at three sites (two sites in unburnt areas and one site within the Limited to Low Landscape PEI Class. These sites averaged slightly over two individuals per site (Figure 39, Table 24).

The potential habitat modelling (Laidlaw & Butler 2021) revealed that in the study area, 27% of likely habitat for the two *Philoria* species was impacted by the 2019–2020 bushfires across GWHA (Table 25).

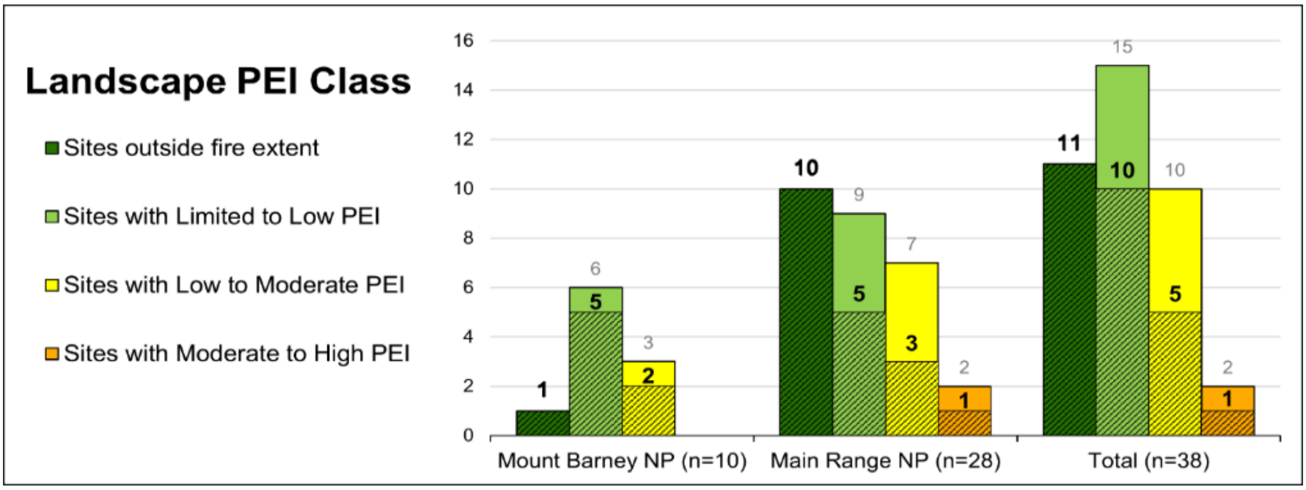

Figure 39: The number of sites surveyed for *Philoria* species in each Landscape PEI class across the three NPs, and in total. Hatched bars and bold numbers indicate the number of sites where *Philoria* species were detected.

Table 24: Summary of detections for the two *Philoria* species with survey effort across sites within Mt Barney and Main Range NPs that were classified in one of four Landscape-scale PEI classes.

	Site Code	Landscape PEI Class	Number of surveys (Surveys detected)	Maximum individuals detected during a single survey
Mt Barney ***Philoria knowlesi***	MBNP001	Low to Moderate	1 (1)	6
	MBNP004	Limited to Low	2 (0)	0
	MBNP006	Limited to Low	2 (2)	5
	MBNP010	Low to Moderate	2 (1)	1
	MBNP011	Limited to Low	2 (2)	3
	MBNP033	Limited to Low	1 (1)	1
	MBNP034	Low to Moderate	1 (0)	0
Main Range ***Philoria kundagungan***	MRNP001	Limited to Low	2 (0)	0
	MRNP002	No Fire Impact	2 (1)	1
	MRNP003	Limited to Low	4 (1)	1
	MRNP004	Low to Moderate	AudioMoth only	0
	MRNP005	Low to Moderate	3 (0)	0
	MRNP007	No Fire Impact	AudioMoth & BAR only	1
	MRNP008	Limited to Low	3 (0); detected in recording only	1
	MRNP011	Limited to Low	3 (0); detected in recording only	1
	MRNP014	No Fire Impact	2 (1)	5
	MRNP015	Limited to Low	2 (0)	0
	MRNP016	Limited to Low	2 (0)	0
	MRNP018	Low to Moderate	2 (0)	0
	MRNP020	Limited to Low	2 (0)	0
	MRNP021	Low to Moderate	2 (0)	0
	MRNP050	Low to Moderate	1 (1)	7
	MRNP051	Moderate to High	1 (1)	3
	MRNP052	Moderate to High	1 (0)	0
	MRNP053	Low to Moderate	1 (1)	1
	MRNP054	No Fire Impact	1 (1)	5
	MRNP055	Limited to Low	1 (1)	5

Table 25: Area of modelled potential habitat (PH) for the two species of *Philoria* and the estimated proportion burnt in the 2019–2020 bushfires.

PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
11,111	70	2,973	27

*PH is combined for both species (as the taxonomy was not resolved at the time of modelling).

5.2.4 Discussion

There is no pre-fire baseline data for either species at most sites. Some sites for red-and-yellow mountainfrog had pre-fire baseline data from the breeding season of 2016–2017 (Bolitho *et al*. 2021, Heard *et al*. 2021). Departmental surveys have confirmed post-fire persistence of both species across their known distribution within the Queensland portion of the GWHA, in a range of fire severities and PEIs.

Weeds were abundant within some burnt *Philoria* habitat. Most of these are short-lived species unlikely to cause long-term ecosystem change and may well have provided significant cover post-fire. However, significant weeds such as lantana *Lantana camara*, Crofton weed *Ageratina adenophora* mistflower *A. riparia* were observed in burnt and unburnt riparian areas.

The data presented here represent a portion of the sites surveyed as part of the larger NESP *Philoria* Project which has undergone detailed analyses and discussion (Heard *et al.* 2021). Key points arising from that project relevant to Queensland populations of red-and-yellow mountainfrog and *P. knowlesi* are that 'during the 2020–2021 breeding season, 48 sites, including 20 of the sites in this report, were surveyed for red-and-yellow mountainfrog across their range in Queensland and NSW, and five sites in Queensland, all contained in this report, were surveyed for *P. knowlesi*' (Heard *et al.* 2021).

Populations of both *Philoria* species discussed in this report are likely breeding at sites where several males were observed calling strongly from suitable breeding and nesting habitat, though little direct evidence was found of breeding as females are cryptic and nests are well-hidden and highly sensitive to disturbance. Likewise, recruitment is difficult to measure as juveniles are also highly cryptic.

It is difficult to disentangle the fire impacts from the impacts of pre-fire drought, but modelling has shown a significant impact of the fires on both occupancy and the number of calling males (Heard *et al.* 2021). The taxonomic status of some populations of *Philoria* remain unresolved despite recent work (Mahony *et al.* 2022), which has implications for understanding the distribution, conservation status and management of these species.

5.2.5 Recommendations

Reducing ongoing threats

- Protect habitat from fire

  Protect breeding and suitable habitat shelter, foraging and dispersal by excluding fire.

- Reduce impacts of pigs, cattle and deer

  Monitor, control or exclude invasive herbivores to protect mountain frogs and their habitats. Control pigs in the Goomburra and Mistake Mountains area of Main Range NP where they are already significantly impacting red-and-yellow mountainfrog habitat. Control pigs and cattle in the Burnett Creek area of Mt Barney NP before they impact the Mt Ballow mountainfrog. Exclude cattle from the Emu Creek, Steamer Creek, and Mt Superbus areas at the southern end of Main Range NP.

- Reduce impacts of cats and foxes

  Protect mountain frogs from predation with monitoring and appropriate controls of feral predators.

- Reduce impacts of weeds in core habitat areas

  Weeds are abundant within the burnt mountainfrog habitat. Most of these are short-lived species unlikely to cause long-term ecosystem change and may well have provided significant cover post-fire. However, surveillance for potentially ecosystem changing weeds within and adjacent to mountainfrog habitat and control is required.

Ecological monitoring

- Continue monitoring for mountain frogs

  Monitoring a subset of established sites to track population changes, evaluate threats and assess the efficacy of management actions is advised.

Ecological research

- Broader surveys to enhance the understanding of distribution patterns, taxonomy and population genetics
- Improve knowledge of the prevalence of pathogenic fungus *Batrachochytrium dendrobatidis*, as a key threat to the global frog populations, including in southeast Queensland, through collaborative fungal sampling projects.
- Update the model of potential habitat for red-and-yellow mountainfrog using the improved dataset
- Create a model of potential habitat for the Mt Ballow mountainfrog.

5.3 Three-toed snake-tooth skink

5.3.1 Conservation Context

The three-toed snake-tooth skink *Coeranoscincus reticulatus* (TTSTS) is listed as Vulnerable under the EPBC. In Queensland, it was downgraded from Rare to Least Concern under the NCA in 2014, on the basis that it was secure in large reserves and not known to be in decline in those areas (Borsboom 2009).

The TTSTS is a relatively large, burrowing lizard with a head and body length typically 195mm but up to 250mm (Wilson & Swan 2021, Sparks 2022) and a thick, long tail. Body colouration is highly variable. The long body and tiny limbs, each with three clawed toes, are an adaptation for its burrowing lifestyle (Cogger 2014, Hutchinson *et al.* 2021). Long, recurved teeth allow the TTSTS to grip the earthworms and beetle larvae that it feeds on (McDonald 1977, Greer & Cogger 1985, Ehmann 1987).

The TTSTS occurs from K'gari (Fraser Island) in the north, south to Crescent Head in North East NSW, however, most records are centred on the rainforests and wet sclerophyll habitats of northern NSW and the Border Ranges in Queensland (Atlas of Living Australia 2022). In Queensland, the populations are highly disjunct, with the species seemingly absent from suitable habitat in the D'Aguilar Range (Wilson 2005) but present in upland areas of the Blackall and Conondale Ranges (Borsboom 2009, ALA 2022). By contrast, the northernmost population is found in lowland rainforests to heathlands on sandy substrate in Cooloola and K'gari (Fraser Island) (Borsboom 2009, ALA 2022, Hobson pers. comm. 2022).

Areas of suitable habitat for TTSTS burnt during the 2019–2020 bushfires, initially estimated to be approximately 2109ha of potential habitat, and 25% of its Queensland range (Hines *et al*. 2020, 2021). As an inhabitant of deep leaf litter in rainforest and wet-sclerophyll habitats, it was presumed to be adversely affected by fire.

Key threats for TTSTS are thought to be clearing, removal of fallen logs and leaf litter through frequent fire, loss of leaf litter and soil compaction from grazing, habitat degradation from pigs *Sus scrofa*, and loss of habitat from fire (NSW Office of Environment and Heritage 2013). No targeted conservation actions for this species are currently being undertaken in Queensland.

5.3.2 Survey sites and methods

Due to its burrowing habits, TTSTS is seldom seen, and the species is not reliably detected using standard active search and pitfall trapping techniques recommended for the species by Sadlier and Shea (2011) (Greenlees *et al.* 2018). At the commencement of the study, there had been no new records in Queensland protected areas in corporate databases for a decade (WildNet 2022). Numerous previous surveys conducted in suitable habitat have had no, or very low numbers detected (Smith *et al.* 1989a, NSW NPWS 1994, Krieger & Lehmann 2004, Hobson 2008) while others have been more successful, with TTSTS recorded at 27–40% of sites (Smith *et al.* 1989b, Goomburra survey of Eyre *et al.* 1998), and five in 335 pitfall trap nights at one site (Gynther *et al.* unpublished, Appendix 3 - Figure A3.1). The species is rarely detected using other survey methods, such as Elliott trapping (one in 6,780 trap nights, Catling *et al.* 1997) or funnel trapping (one in 900 trap nights, McGregor & Burnett 2014). Successful detections often coincided with rainfall events (Appendix 3, Table A3.2).

The previously low and temporally patchy rate of TTSTS detection in pristine habitat suggested that surveys in burnt habitat, which were experiencing dense understorey regrowth in many areas, would be unsuccessful. To optimally support the ongoing conservation of the TTSTS, efforts during this project aimed to:

- Collate the available data, including records outside of corporate databases
- Refine the TTSTS potential habitat model (Laidlaw & Butler 2021) using the collated data set
- Confirm TTSTS persistence in unburnt habitat in GWHA with targeted active searches in known localities
- Trial an innovative method to increase the ability to detect TTSTS, using camera trapping along a drift fence. If successful, this technique would be suitable for future deployments in burnt areas and use as a monitoring tool.

Site selection

Existing TTSTS data were collated using the Queensland Government's WildNet database (n = 55) and the Atlas of Living Australia (n = 72) (Atlas of Living Australia 2022). To supplement and expand on these records, additional records were sought via an information request directly to herpetologists, naturalists and ecological consultants known to work within the range of TTSTS. Naturalists and citizen scientists were directly approached who had photographic records posted on the iNaturalist, Flicker and FlickRiver platforms, for the location and ecological information associated with the image and their observations.

Site selection for the on-ground survey focussed on the Goomburra Section of Main Range NP (Figure 40), chosen for its concentration of historic records and proximity of these to burnt habitat. Many of these historic records were from a 1997 fauna survey which employed active reptile searches at series of discrete sites (Eyre *et al.* 1997). The current survey sought to replicate a subset of the reptile-focussed search effort from the 1997 survey.

Field survey

Two zoologists from the Queensland Herbarium and Queensland Museum conducted the TTSTS survey between 22–24 February 2022. Diurnal active searches involved area and time-limited searches (1ha for 1 person-hour, typically 2 people for 30 minutes) where long-handled, 3-pronged rakes were used to search leaf litter and soil underneath logs and rocks, as per the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (Eyre *et al.* 2022). These were undertaken in daylight hours in fine weather or light drizzle. Walking transects were also employed as a survey technique due to the number of incidental encounters along bushwalking tracks in collated dataset (often during, or after, rainfall). Walking transects were undertaken along roads and formed walking tracks; watching for TTSTS and/or movement in the leaf litter, and occasionally searching adjacent habitat, for example, where a log or pile of deep litter was next to the track. These transects were undertaken by day and night, in fine weather and during light-to-moderate rainfall. Driving transects were also undertaken by day and night, in fine weather to light-to-medium rain, on gravel and bitumen substrate, travelling slowly (10–40 km/hr) watching for animals crossing the road.

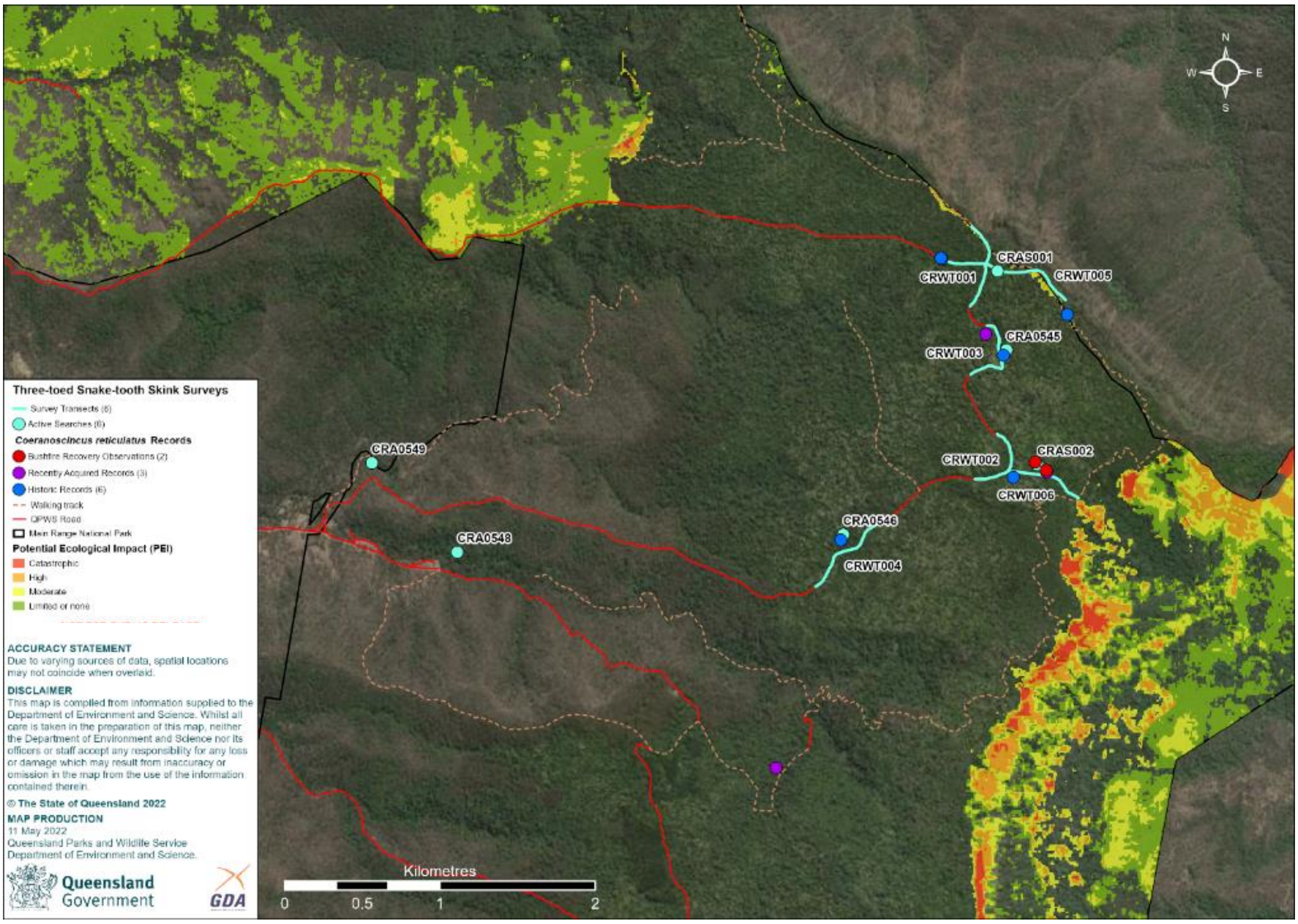

Figure 40: Goomburra section of Main Range NP showing survey sites and TTSTS historic and recent locations. The eastern 50m of CRWT006 was burnt, near Sylvester's Lookout, and the burnt area around CRWT005 is also more extensive than indicated by the mapping which has been clipped to the park boundary.

Camera Trapping

A camera trapping array (Figure 41) was established on the site of an historical pitfall trap line which had captured TTSTS on multiple occasions (Gynther *et al.* unpubl.). The orientation and overall length of drift fence approximately followed the historical pitfall trapping plan. The array consisted of a linear arrangement of 16 camera traps secured to metal posts or trees, connected by sections of flyscreen mesh (3m long and 30cm height) secured with metal stakes and sunk into a shallow trench (Figures 42 and 43). Fence sections were punctuated with 50cm breaks for camera trap focal zone (Figure 42). Typical wildlife cameras with a passive infrared (PIR) sensor, are designed to detect larger-bodied animals via the combination of motion and a thermal differential to the background (either warmer or colder). Camera settings were adjusted to have the maximum chance of detecting small-bodied ectotherms ('cold-blooded' animals) by using timelapse photography with one image taken every minute over 24hrs. To conserve battery power and memory storage space the PIR sensitivity was set to 'low' to reduce the number of images of birds and small mammals. Focal length was modified to 70cm on 10 cameras to provide improved resolution for small subjects. Cameras deployed were 6 x Enduro Swift black flash cameras with modified focal length of 70cm, six Enduro Swift (standard focal length of 5m, but are operational at >130cm), and four close-focus, white flash cameras: Scout Guard (three) and Wingscapes BirdCam (one) (Figure 41). White flash cameras were located at either end of the array (in case the white flash caused disturbance) and the black-flash cameras alternated between close and standard-focal length (Figure 41). The camera array was in complex notophyll vine forest at approximately 920m elevation. Cameras were deployed on 9 March 2022, and images downloaded and batteries changed on 22 March, 6 April and 27 April 2022 (Appendix 3, Table A3.2).

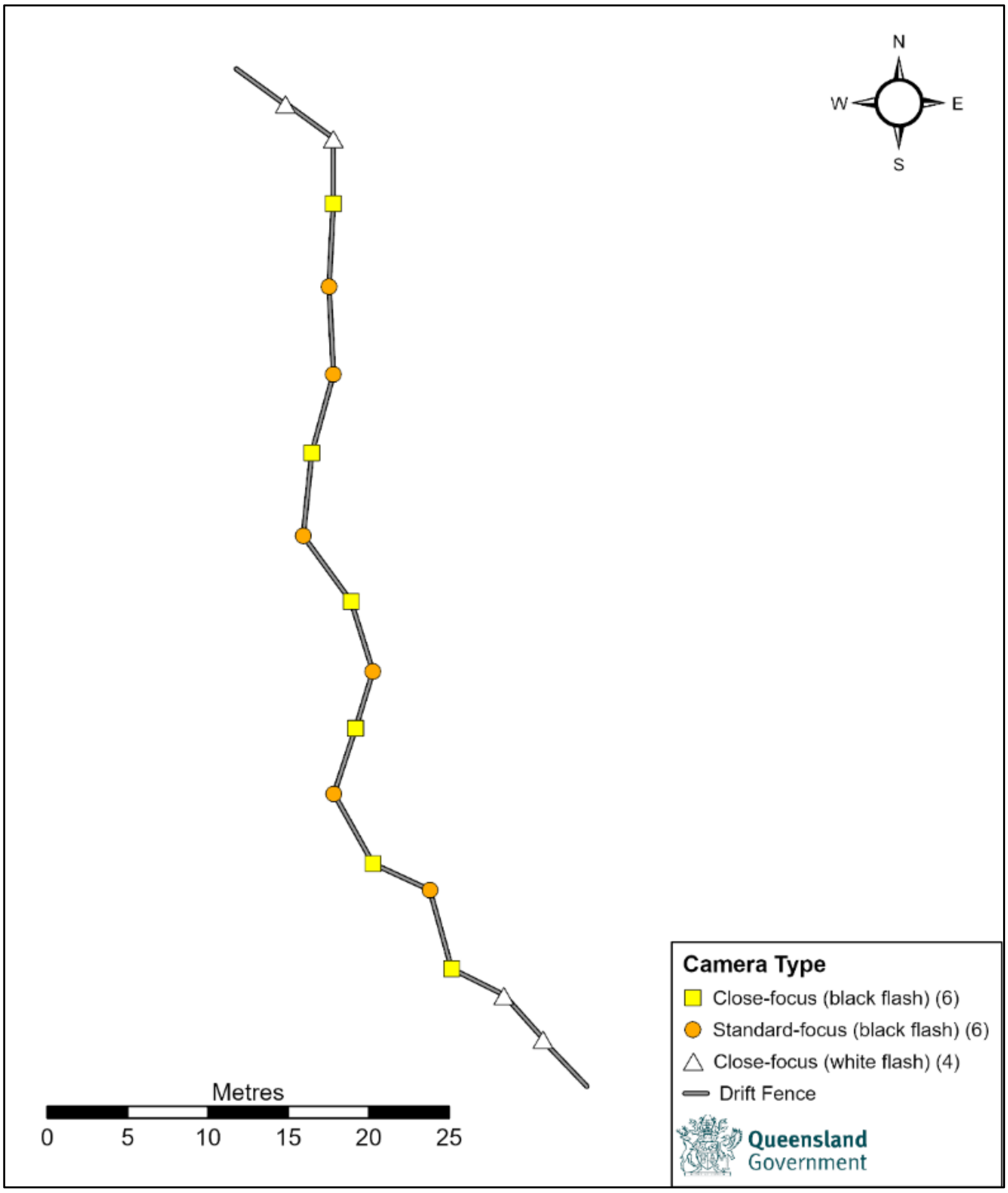

Figure 41: Camera trapping transect showing the layout of different camera types along a drift fence. Historical captures of TTSTS were made in close proximity to this site during annual pitfall trapping efforts spanning 2006–2014 (Gynther *et al.* unpubl. data).

Images were manually processed by viewing downloaded images with IrfanView software, examining image differences for the presence and number of any vertebrate fauna. Instances of a particular species appearing within 10 minutes (unless clearly a different individual from size or markings) were considered to be part of the same 'event' for recording purposes. Images of vertebrate fauna were reviewed and identified to species level where possible. Image identifications were checked by multiple observers and had reliability ratings of 'definite', 'probable' and 'possible' assigned.

Figure 42: Close-focus black-flash camera trap on drift-fence. Note the break in the fly-wire drift fence and cleared leaf litter in the camera's focal zone. (Photo: M. Venz)

Figure 43: A close-focus white flash Scout Guard camera (left) and a standard focus black-flash camera (right). (Photos, left to right: D. Sparks; M. Venz)

5.3.3 Survey results

Data collation

Data for 27 new TTSTS records were collated, including photograph-backed sightings from platforms iNaturalist and Flicker, and observations solicited from naturalists, herpetologists and ecological consultants. Locational accuracy of some historic records was improved through contact with the original collectors or cross-referencing locality descriptions with digital mapping. Duplicate records were removed. The final TTSTS dataset included 299 records, of which 74 occur in Queensland. Sixty-five of these Queensland records, with location accuracy of better than 2000m, were used to develop the TTSTS potential habitat model (Table 26) for Queensland using the methodology detailed by Laidlaw & Butler (2021). Also incorporated were new records collected during the current project (Table 27). The potential habitat model (DES 2021) identified 3,157ha of potential TTSTS habitat burnt in the 2019–2020 bushfires, which is 33% greater than the area originally estimated to have been impacted (Table 26).

Table 26. Area of modelled potential habitat (PH) for the three-toed snake-toothed skink and the estimated proportion burnt across the study area in the 2019–2020 bushfires.

PH in study area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
26,097	41	3,157	12

Table 27: The details and number (#) of three-toed snake-toothed skinks recorded from surveys.

Area	Date	Time	Method	Rain within 24-48hrs	#
Main Range NP (Goomburra)	23/02/2022	10:50,14:20	active search	yes	2
Lamington NP	5/11/2020	11:15	heard and captured	no	1
	6/11/2020	15:30	incidental	yes	1
	9/04/2022	7:07	camera trapping	yes	1
	10/04/2022	16:26	camera trapping	yes	1*

*may be same individual as 9/04/2022

Field surveys

A total of 12 sites were surveyed, including active searches of six 1ha sites and six walking transects (each approx. 500m) were conducted along roads or formed tracks (Figure 40, Appendix 3). Habitat surveyed was mostly unburnt complex notophyll vine forest (rainforest), with only ~300m of walking transects occurring through burnt habitat. Two sites were in wet sclerophyll forest. A driving transect of approximately 6 km, (along Lookout Rd, from Dalrymple Creek to Winder Track) was traversed seven times between 22–24 February 2022.

Two TTSTS (1 subadult, 1 juvenile) were detected during active searches at Goomburra in montane rainforest following heavy showers overnight (Figure 44). No TTSTS were found active on the surface during walking transects or driving transects at Goomburra. One animal (adult) was hand captured at Green Mountains close to the camera trapping array (Figure 44) using a novel method: an observer (P. Oliver) watching sunlit patches on the rainforest floor heard rustling leaf litter next to the track in a patch of ferns (*Lastreopsis* sp.) and captured an adult. This was the only detection during the current survey work which occurred during dry weather. An additional juvenile was observed on a walking track during other bushfire recovery field work at Lamington NP (M. Laidlaw pers. comm.) (Figure 44). Genetic samples collected from three individuals captured is contributing to the resolution of taxonomic issues with this species, as well as providing a resource for monitoring population genetic diversity.

Camera trapping

The camera trapping array of 16 cameras operated between 9 March–27 May 2020, (Appendix 3). One adult TTSTS was photographed on a black flash camera on 9 April 2022 at 7:07 am (Figure 45). On the same camera on the following day, a TTSTS was seen briefly at the end of a 15-minute sequence of rippling soil surface (i.e., where a discrete rise in the soil surface moves position in the next one-minute frame) at 4:26pm. The TTSTS travelled approximately 80cm underneath the soil surface in 15 minutes. The photographic dataset contained other similar sequences, but without a TTSTS emerging in frame (conservatively, at least six), indicating a need for a sub-soil barrier in future refinements of this method. Similarly, some images of fossorial reptiles partially buried could not be confidently identified to species level (e.g. adult *Ophioscincus truncatus*, juvenile TTSTS or blind snake *Anilios* sp.).

Figure 44: Colour variation in three-toed snake-tooth skinks: subadult from Goomburra (left); banding typical of juvenile (centre); and adult at Green Mountains (right). (Photos: left to right: D. Sparks; M. Laidlaw; M. Venz)

Figure 45: Camera trap image of a three-toed snake-tooth skink, centre-right of frame, with edge of drift fence on upper left.

5.3.4 Discussion

This assessment confirms that TTSTS persists in unburnt habitat within Main Range and Lamington NPs following the 2019–2020 bushfires. As only limited survey effort was undertaken in burnt habitat, it is difficult to assess the impact of the 2019–20 bushfires on the TTSTS. Ecological and conservation requirements for this species are still poorly understood, as is the case for fossorial reptiles in general (Tingley *et al.* 2016). Likewise scant data exists for reptile responses to fire in non-fire prone ecosystems, although possible responses include (at least short-term) loss from severely burned rainforest (Kinnard & O'Brien 1998), reduced abundance (McLeod & Gates 1998) or reduction in body condition (Fenner & Bull 2007). The indirect fire effects of increased predation in disturbed habitat tend to be stronger than direct effects for most reptiles (Certini *et al.* 2021).

There is some evidence that the species can suffer direct mortality during bushfire: a single record from Cooloola of an animal 'killed by bushfire' on a track (C. Lawton pers. comm. 2022). If the species spends much of its time in the litter or the top few centimetres of soil (as per the camera footage from this trial), then it was expected that both direct (mortality) and indirect effects (impacts on food resources and soil chemistry) from very hot bushfires. Recent investigations from destructive sampling during a land resumption project indicated that most TTSTS were found within plant roots, and within the top 5cm of soil (n = ~50) (D. White unpubl. data. 2022): a zone where direct heat and desiccation effects are greater (DeBano *et al*. 2000, Penman *et al.* 2006). However, the species may burrow more deeply, particularly during dry periods, to depths greater than 5cm providing insulation from the direct effects of fire.

The species is known to persist in heathy habitats at Cooloola which are subject to regular cool burns (R. Hobson, pers. comm. 2022). It is also known to persist in some disturbed habitats such as garden beds and cleared areas where soil moisture and structure are maintained e.g., Maleny and Grafton townships (Lewis 2016) and a riparian revegetation area (Barung Landcare 2008). This suggests that the species has some resilience to disturbance and habitat modification.

Fire is likely to have affected food resources of TTSTS. A review by Certini *et al.* (2021) found earthworms were impacted for time periods of months to years depending on the system, fire intensity and species. The duff layer (decomposing organic material between the litter layer and the mineral soil layer) is likely to be extremely important for this species and extent to which the duff layer burnt in the 2019–2020 bushfires may be significant for local populations of TTSTS. As well as playing an important role in maintaining soil moisture content, the duff layer also provides a significant insulating effect for the depth at which lethal temperatures are reached in the soil (Valette *et al.* 1994). This then leads to compounding effects for soil fauna in the GWHA areas which burnt twice.

In summary, the greatest impacts on the species are expected from more severe fires in habitats which rarely burn. TTSTS may have capacity to persist where fires are cooler if other requirements (shelter, soil moisture, food resources) are not, or only lightly, impacted. However, removal of the leaf litter layer, and loss of log and plant cover by fire would also be predicted to reduce soil moisture also leave the species more vulnerable to feral predators.

5.3.5 Recommendations

Reducing ongoing threats

- Protect habitat from fire

  The ground layer microhabitat and associated food resources are vulnerable to impacts from even low severity fires in rainforests, particularly after drought and need to be protected to support conservation of the species.

- Reduce impacts of pigs and cattle

  Monitor invasive herbivores and implement appropriate controls to reduce damage to microhabitats, prey resources, trampling and predation. Pigs preferentially forage in shallow, friable soil and leaf litter occupied by TTSTS and target slow-moving reptiles (Wishart *et al.* 2015, Risch *et al.* 2021). Pigs are likely to be major predators of both TTSTS and its food resources (earthworms and other soil macroinvertebrates).

- Reduce impacts of cats and foxes

  Monitor cats and foxes and implement appropriate controls to reduce predation, especially in fire-impacted areas within the range of TTSTS. Cats are known to prey on TTSTS (McHugh & Robyns 2020) and to preferentially forage in burnt areas (Macgregor *et al.* 2014, 2017). Foxes would also predate on TTSTS when active above the soil surface.

- Reduce impacts of weeds in core habitat areas

  The control of flammable weeds on rainforest margins (e.g. lantana *Lantana camara* and high-biomass grasses) will reduce the risk and severity of future fires and incursion into burnt habitats.

Ecological monitoring

- Continue monitoring for three-toed snake-tooth skinks

TTSTS is very challenging to detect due to its fossorial habit and tendency to occur in the soil amongst plant roots (D. White, pers. comm. 2022), where it is difficult to rake or dig without destroying the plant. Detections above ground appear to be frequently influenced by rainfall and subsoil barriers (including tracks or roads), making standard herpetofauna survey methods extremely difficult.

The results of this survey support the hypothesis that the species is more detectable within 24–48 hours of rain events (Appendix 3). Therefore, it is recommended that surveys using standard techniques (active searching or pitfall trapping) be undertaken following rain or coincide with predicted rainfall, wherever possible. Active searching remains the most cost-effective detection technique and is optimal between October to March with consideration of weather conditions.

Camera trapping using time-lapse settings is a valid technique for detecting TTSTS and would benefit from further improvements. Firstly, by undertaking surveys during the warmer months of October to March when TTSTS activity is higher. Secondly, by burying a sub-soil barrier (from soil surface to >5 cm depth) in the camera's focal zone to direct fossorial reptiles up to the soil surface. Better-quality white-flash cameras may also improve the number of species-level identifications of fossorial reptiles. Ongoing progress in the field of machine learning for image analysis would also reduce (human) processing time and costs for large numbers of images. Ideally, the development of an active trigger mechanism (as per Hobbs & Brehme 2017) would replace the time lapse setting and thus reduce the number of images to process and extend deployment duration with less drain on memory storage. However, the camera trapping method will be most viable in areas not suitable for active searching techniques (e.g. heavy understorey regrowth or lacking 'searchable' features such as logs and deep litter) or for long deployments through dry periods. Camera traps also can provide unbiased detection probabilities across the different habitats in which they occur. This, in turn can be used for abundance modelling in burnt versus unburnt habitat. At a minimum, it is recommended extending the camera trapping trial for 4 weeks in spring-summer with sub-soil barriers included.

As persistence of TTSTS in burnt potential habitat has not yet been established, it is recommended further survey work in Main Range in the coming spring-summer, focusing on burnt areas with, or close to, historical records.

Ecological research

- Broader surveys to improve knowledge of disjunct distribution patterns and to support taxonomic research.

The distributional data summarised here reinforce the disjunct nature of populations of TTSTS in Queensland. As one of 20 reptiles identified as requiring urgent taxonomic work (Catullo & Moritz 2021), there is a pressing need to resolve suspected cryptic diversity within TTSTS. A recent morphological examination suggests some differentiation between southern and northern populations e.g. trends towards larger size and lack of black eye spots in the north (Sparks 2022). Genetic data further indicates differentiation of these populations (P. Oliver pers. comm.). Identification of new species or subspecies would also warrant production of new potential habitat models and conservation status assessments.

6 Priority invertebrates

6.1 Pelican spiders

6.1.1 Conservation context

Pelican spiders of the family Archaeidae (genus *Austrarchaea*) were identified as high priority spider taxa for this project. Archaeids are of high phylogenetic, taxonomic and conservation significance with ancient origins and a relictual distribution across Australia, southern Africa and Madagascar (Rix & Harvey 2012). In Queensland, species of *Austrarchaea* are restricted to the rainforests and upland wet sclerophyll forests of the Great Dividing Range extending from the southern Border Ranges north to the Wet Tropics (Rix & Harvey 2011, 2012, Rix *et al.* 2022). Pelican spiders are short range endemics and occupy a unique ecological niche, living in a complex matrix of suspended leaf litter where they prey solely on other spiders (Rix *et al.* 2022). They have a uniquely modified carapace to accommodate their elongated chelicerae with distal fangs, creating a pelican like appearance (Figures 46 & 47).

Across the fire-impacted sections of GWHA, three described species of pelican spiders were targeted for survey efforts: the Main Range pelican spider *A. cunninghami*; the Gold Coast Hinterland pelican spider *A. dianneae*; and the McPherson Range pelican spider *A. nodosa*. These species had previously not been considered of conservation concern, given their occurrence in World Heritage-listed protected areas (Rix & Harvey 2011). However, by occupying a suspended and flammable microhabitat in a relatively stable rainforest ecosystem, pelican spiders are vulnerable to disturbance, including low severity fires (Rix *et al.* 2022). The unexpected extent of fire incursion into rainforest during the 2019–2020 bushfires (for Queensland see Hines *et al.* 2020, 2021 & 2022) and the potential structural and compositional changes in vegetation from ecosystem-transforming weeds and canopy loss, presents new threats to archaeid conservation. Similarly, the predictions of escalating impacts from climate change with increasing droughts and risk of fire, higher temperatures and lower humidity have implications for pelican spider populations that are reliant upon stable, moist microhabitats in a rainforest environment. Additional threats to pelican spiders include invasive animals such as pigs and deer which can cause damage to understorey vegetation, disturbing and trampling their localised and specific microhabitats.

The Main Range pelican spider was known only from Cunninghams Gap section of Main Range NP prior to 2020 (Rix & Harvey 2011, 2012). The Gold Coast Hinterland pelican spider was known from the Tamborine Plateau and Lamington NP, with four locality records prior to 2020 (Rix & Harvey 2011). The McPherson Range pelican spider was known from the eastern 'Scenic Rim' of South East Queensland and North East NSW occurring across Lamington, Border Ranges and Wollumbin NPs (see Rix & Harvey 2011), with eleven locality records prior to 2020 (see Rix & Harvey 2011).

During surveys for this project, a new species of pelican spider was discovered in the northern section of Main Range NP which has now been described as the Mistake Mountains pelican spider *Austrarchaea laidlawae* (Rix *et al.* 2022). This species is also range-restricted, known only from high altitude rainforest on the Mistake Mountains, north of Cunninghams Gap. This discovery highlights the importance of ongoing survey and monitoring efforts to improve knowledge of biogeographically significant invertebrate species and current threats to their conservation. The survey results for *A. laidlawae* are included in this report.

6.1.2 Survey sites and methods

Invertebrate surveys were undertaken at Main Range and Lamington NPs, with surveys at Mt Barney NP not feasible due to logistic constraints. Invertebrate survey sites were stratified with respect to fire severity to represent three different levels of bushfire impact in rainforest: unburnt, moderately burnt and severely burnt, based on the post-fire assessment analysis (section 2, Hines *et al.* 2020, 2021). At both Main Range NP and Lamington NP, these three sites were established at two different areas that varied with altitude, resulting in a total of 12 sites (Table 28, Figures 48 & 49, Appendix 4). At Main Range NP, the three sites in the Cunninghams Gap area were at 810–830m elevation, whereas the three sites in the Mt Cordeaux area were at 1130–1140m. At Lamington NP, the three sites in the Yandooya area were at 270–280m elevation, with the comparable sites at Binna Burra at 785–795m. At Yandooya, the sites utilised were surveyed between 2006–2008 for invertebrates through the global *Investigating the Biodiversity of Soil and Canopy Arthropods* project (IBISCA) program, led by Professor Roger Kitching at Griffith University. A total of 20 permanent rainforest plots were established across an altitudinal gradient at Lamington NP (Kitching *et al.* 2011), with the Yandooya sites for this project representing the lowest altitude.

Standardised invertebrate survey methods were used at each of these 12 survey sites: 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 (see details in Appendix 4). The standardised survey method for pelican spiders was a specifically designed 'archaeid extraction' technique that could be applied to collections of their suspended leaf litter microhabitats (Appendix 4).

In addition, 'targeted surveys' were conducted for pelican spiders in suitable rainforest habitat across another 13 sites (see Table 29 for details). By increasing the number of locality records, modelling the likely habitat of pelican spiders was possible to enhance the current understanding of their distribution and conservation priorities. Potential habitat modelling (Laidlaw & Butler 2021) was undertaken post-survey using collection records for *A. cunninghami* (5 individuals), *A. dianneae* (18)*, A. nodosa* (17) and *A. laidlawae* (11).

To identify juvenile pelican spiders, mitochondrial DNA barcoding was used, as outlined by Rix & Harvey (2011).

6.1.3 Survey results

At the established invertebrate surveys sites, pelican spiders were collected in low numbers using the arachaeid extraction technique.

At Main Range NP, a single Main Range pelican spider was recorded from the unburnt site in the vicinity of Cunninghams Gap (Table 28). No Main Range pelican spiders were recorded from the two burnt sites on the nearby Mt Mitchell Track. Nor were spiders of this species found at the high-altitude sites near Bare Rock and Morgan's Walk (Table 28). However, the newly discovered Mistake Mountains pelican spider was recorded from the unburnt site south-east of Bare Rock, and from the severely burnt site at Morgans Walk (directly adjacent to unburnt forest), both at high altitude (Table 28).

At Lamington NP, surveys at the higher altitude sites at Binna Burra, collected a single McPherson Range pelican spider from the unburnt site. The Gold Coast Hinterland pelican spider was not recorded from any of these burnt or unburnt sites at Binna Burra (Table 28). At the lower altitude sites, one Gold Coast Hinterland pelican spider was recorded from the unburnt site, with none found at the burnt sites using the archeid extraction method (Table 28). However, a juvenile of this species was collected in a pitfall trap at the moderately burnt site, replicating results from surveys in 2007 at the same site (see remarks in Table 28, Rix & Harvey 2011). The McPherson Range pelican spider was not recorded any of these lower altitude sites (Table 28).

Table 28: The number of pelican spiders (#) and age class (♀ = female; juv. = juvenile) collected using the archaeid extraction method across 3 survey sites (representing different levels of fire severity) at each of 2 locations at both Main Range NP (20–21 October 2020) and Lamington NP (24–26 November 2020).

	Fire severity	Duration hrs:mins	Species	#	Remarks
Main Range NP					
Cunninghams Gap	Unburnt	00:55	*A. cunninghami*	**1** ♀	Female with eggsac; young returned after hatching
	Moderately burnt	01:01	-	-	
	Severely burnt	00:51	-	-	
Mt Cordeaux	Unburnt	01:16	*A. laidlawae*	**1** ♀	
	Moderately burnt	01:12	-	-	
	Severely burnt	01:03	*A. laidlawae*	**1** juv.	Collected from edge of adjacent unburnt zone
Lamington NP					
Yandooya	Unburnt	01:10	*A. dianneae*	1 juv.	Composite survey over two separate days
	Moderately burnt	00:50	-	-	Juveniles of *A. dianeae* were collected in an invertebrate pitfall trap, and previously in 2007#
	Severely burnt	00:50	-	-	
Binna Burra	Unburnt	01:00	*A. nodosa*	**1** ♀	
	Moderately burnt	01:00	-	-	
	Severely burnt	00:50	-	-	

#See Rix & Harvey 2011: 23

Targeted surveys

During the additional targeted surveys at Main Range NP, two more Main Range pelican spiders were collected from separate sites (Table 29). At the higher altitudes, another three Mistake Mountains pelican spiders were found at three different sites (Table 29), which has augmented the understanding of the distribution of this new species.

At Lamington NP and a neighbouring Conservation Park, seven more individuals of the Gold Coast Hinterland pelican spider were collected at separate sites (Table 29). At Binna Burra, another McPherson Range pelican spider was captured during the targeted survey efforts (Table 29).

Potential habitat modelling

The localities for pelican spiders collected during this project, and subsequently over the summer of 2020–21, were incorporated into quantitative potential habitat modelling (see Laidlaw & Butler 2021) which has significantly enhanced our understanding of the geographic distributions of species of *Austrarchaea* across GWHA and the impacts of the 2019–2020 bushfires (Table 30).

Table 29: The number of pelican spiders (#) and age class (♂ = male; juv. = juvenile) collected during additional targeted surveys at sites at Main Range NP (22–23 October 2020) and Lamington NP and a local Conservation Park (26–27 November 2020). Identification confirmed DNA indicated (✓). MR# codes denote unique specimen identifiers.

Code	Latitude	Longitude	Species	#	DNA	Locality
Main Range NP						
MR266	-28.04878333	152.3925056	*A. cunninghami*	**1** juv.	-	NW. of Cunninghams Gap (near unburnt site)
MR274	-28.03940833	152.3883056	*A. cunninghami*	**1** juv.	✓	Bare Rock-Mt Cordeaux Track
MR271	-28.02926667	152.3873278	*A. laidlawae*	**1** juv.	✓	Bare Rock unburnt site
MR272	-28.03278333	152.3878472	*A. laidlawae*	**1** juv.	✓	Bare Rock-Mt Cordeaux Track
MR273	-28.03486389	152.3892222	*A. laidlawae*	**1** juv.	✓	Bare Rock-Mt Cordeaux Track
Lamington NP and nearby protected area						
MR310	-28.14747500	153.1363639	*A. dianneae*	**1** juv.	✓	IBISCA IQ-300-A
MR312	-28.20073056	153.1847500	*A. dianneae*	**1** juv.	✓	Binna Burra, Caves Circuit
MR313	-28.20060556	153.1841944	*A. dianneae*	**1** juv.	✓	Binna Burra, Caves Circuit
MR314	-28.19569722	153.1841778	*A. dianneae*	**1** juv.	✓	Binna Burra, Caves Circuit
MR315	-28.11583056	153.2038500	*A. dianneae*	**1** juv.	✓	Rosins Lookout Conservation Park
MR316	-28.11539722	153.2045139	*A. dianneae*	**1** ♂	-	Rosins Lookout Conservation Park
MR317	-28.15084722	153.1965833	*A. dianneae*	**1** juv.	✓	Binna Burra Road
MR311	-28.20002778	153.1864306	*A. nodosa*	**1** juv.	✓	Binna Burra, Caves Circuit

Table 30: Area of modelled potential habitat (PH) for the four species of pelican spiders and the estimated proportion burnt in the 2019–2020 fires.

Scientific name	**Common name**	**PH in study area (ha)**	**% Queensland PH in study area**	**Total PH burnt (ha)**	**% burnt in study area**
Austrarchaea cunninghami	Main Range pelican spider	10,822	79%	5,938	55%
Austrarchaea dianneae	Gold Coast hinterland pelican spider	10,750	54%	749	7%
Austrarchaea nodosa	McPherson Range pelican spider	5,396	78%	239	4%
Austrarchaea laidlawae	Mistake Mountains pelican spider	5,432	88%	3,297	61%

Figure 46: Female *Austrarchaea cunninghami* from Main Range NP holding an egg sac. (Photo: M. Rix)

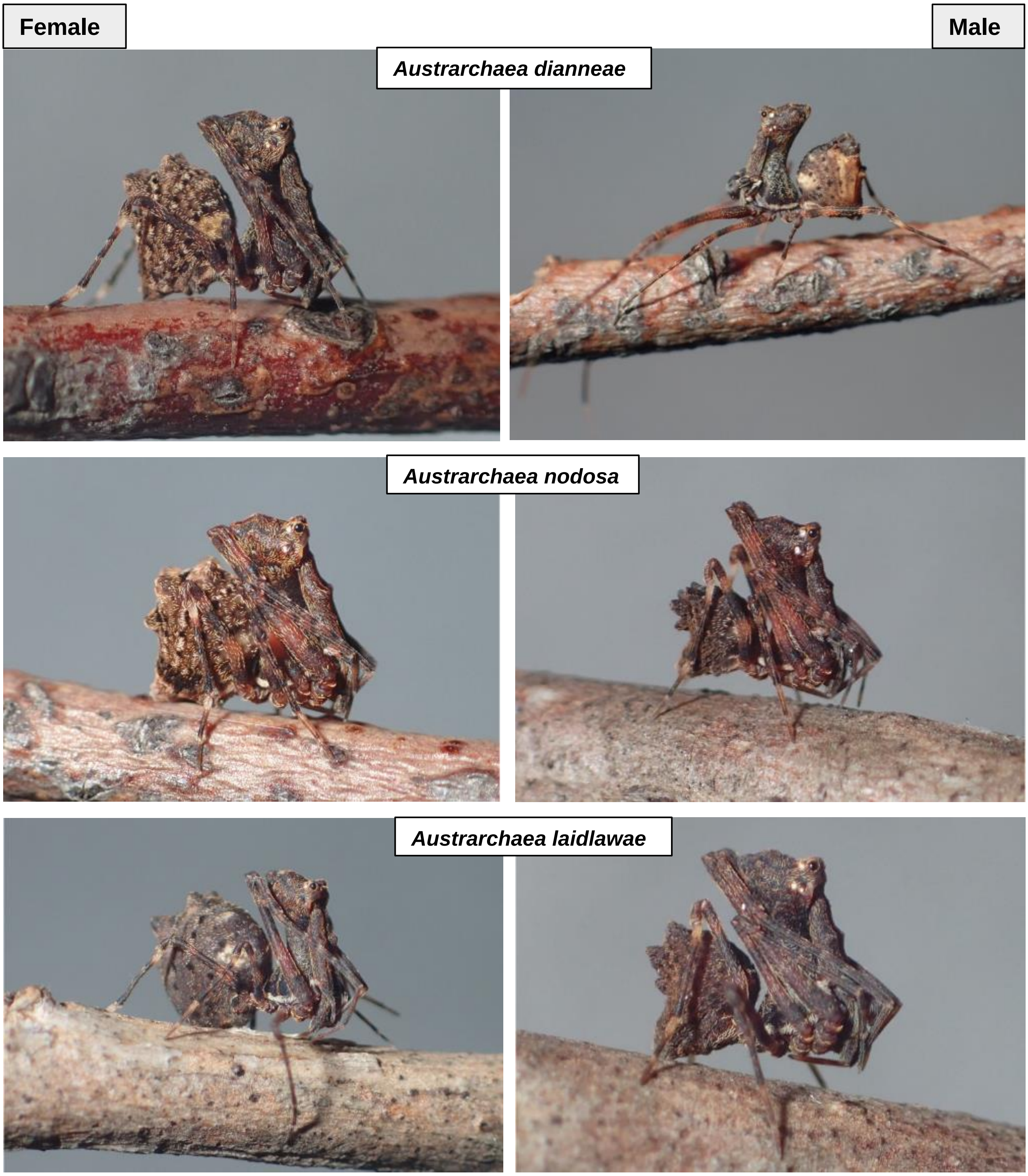

Figure 47: Female and male spiders of *Austrarchaea dianneae, A. nodosa and A. laidlawae*. (Photos: M. Rix)

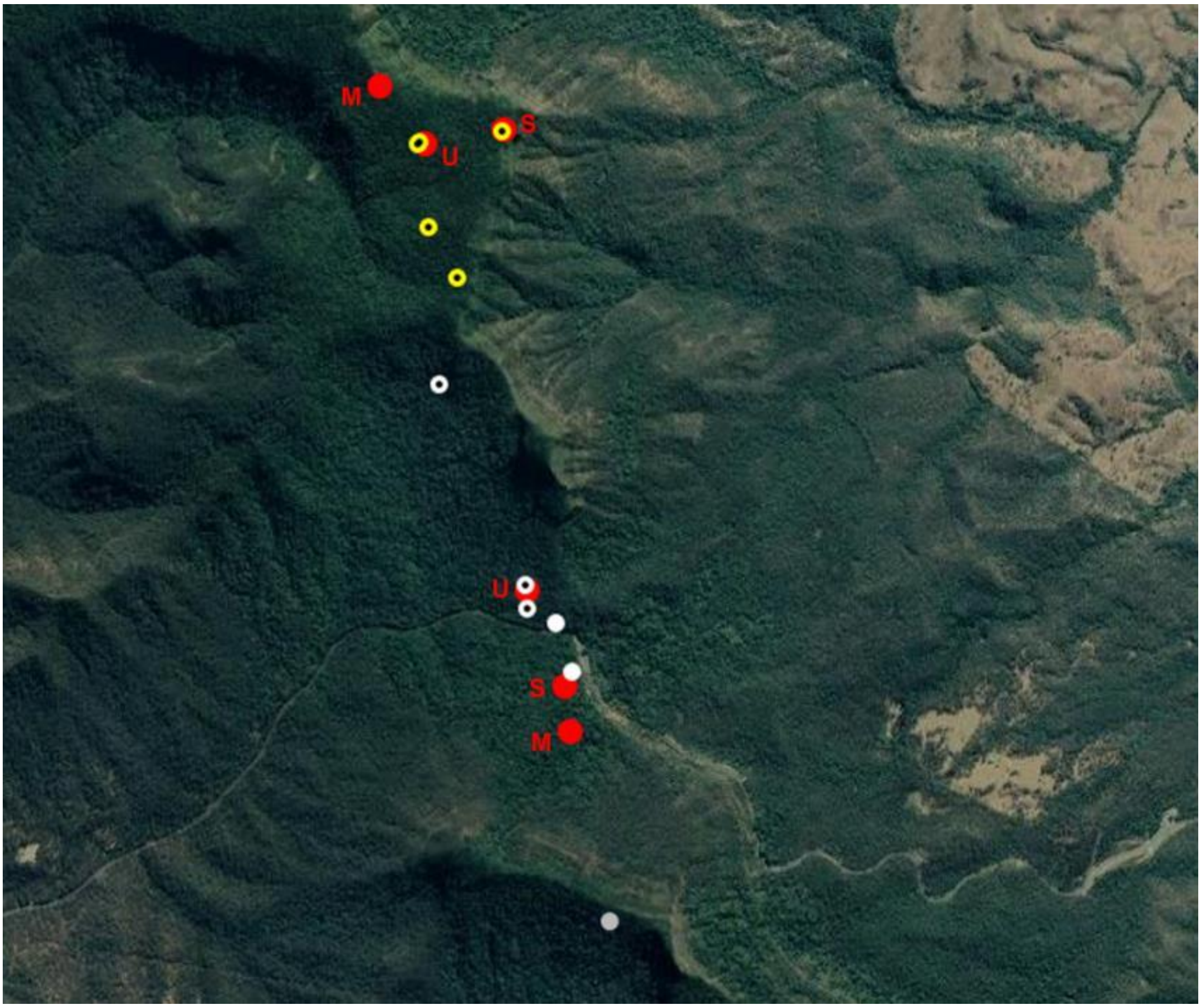

Figure 48: Main Range NP with the 3 survey sites (red) representing different levels of fire severity (unburnt=U; moderately burnt=M; severely burnt=S), at each of two locations (Cunningham's Gap and Mt Cordeaux). Sites of additional collections shown for *A. cunninghami* (white), *A. laidlawae* (yellow), and indeterminate species (grey), including new records (black centre). Satellite map was created using the Atlas of Living Australia Spatial Portal (https://www.ala.org.au/) and reproduced under a Creative Commons Attribution 3.0 Australia Licence.

6.1.4 Discussion

The assessment of pelican spider species revealed that there was a range of impacts from the 2019–2020 bushfires. The recovery of archaeid spider populations in burnt rainforest habitats will depend on the severity and/or mosaic nature of the fire impacts which influences the post-fire availability of suitable microhabitat. Patches of remaining suspended leaf litter can provide critical source populations for re-colonisation, with recovery otherwise dependant on adjacent unburnt forest. The higher levels of fire severity had greater impacts on the subcanopy and canopy vegetation, which reduces the ongoing provision of new leaf litter and plant debris to create new microhabitats for pelican spiders, as well as the shade essential for a cool and moist habitat.

The Main Range pelican spider *A. cunninghami* was heavily impacted by fire in Main Range NP, with 55% of modelled potential habitat in the study area burnt (Table 30). Spiders of this species were not recorded from one severely burnt site at which they had previously (Rix & Harvey 2011), and recently, been collected (near the severely burnt site on the Mt Mitchell track), indicating actual on-ground impacts. As no individuals were recorded approximately one year after the bushfires in rainforest, the potential for the recovery of populations of *A. cunninghami* is of concern.

The Gold Coast Hinterland pelican spider *A. dianneae* experienced limited impacts in Lamington NP from the 2019–2020 bushfires with only 7% of the modelled potential habitat in the study area burnt (Table 30). Whilst pelican spiders were not recorded from the moderately burnt site at Yandooya, the discovery of a juvenile spider approximately one year after the bushfires (Table 28) is encouraging, indicating dispersal from adjacent unburnt rainforest. The extent

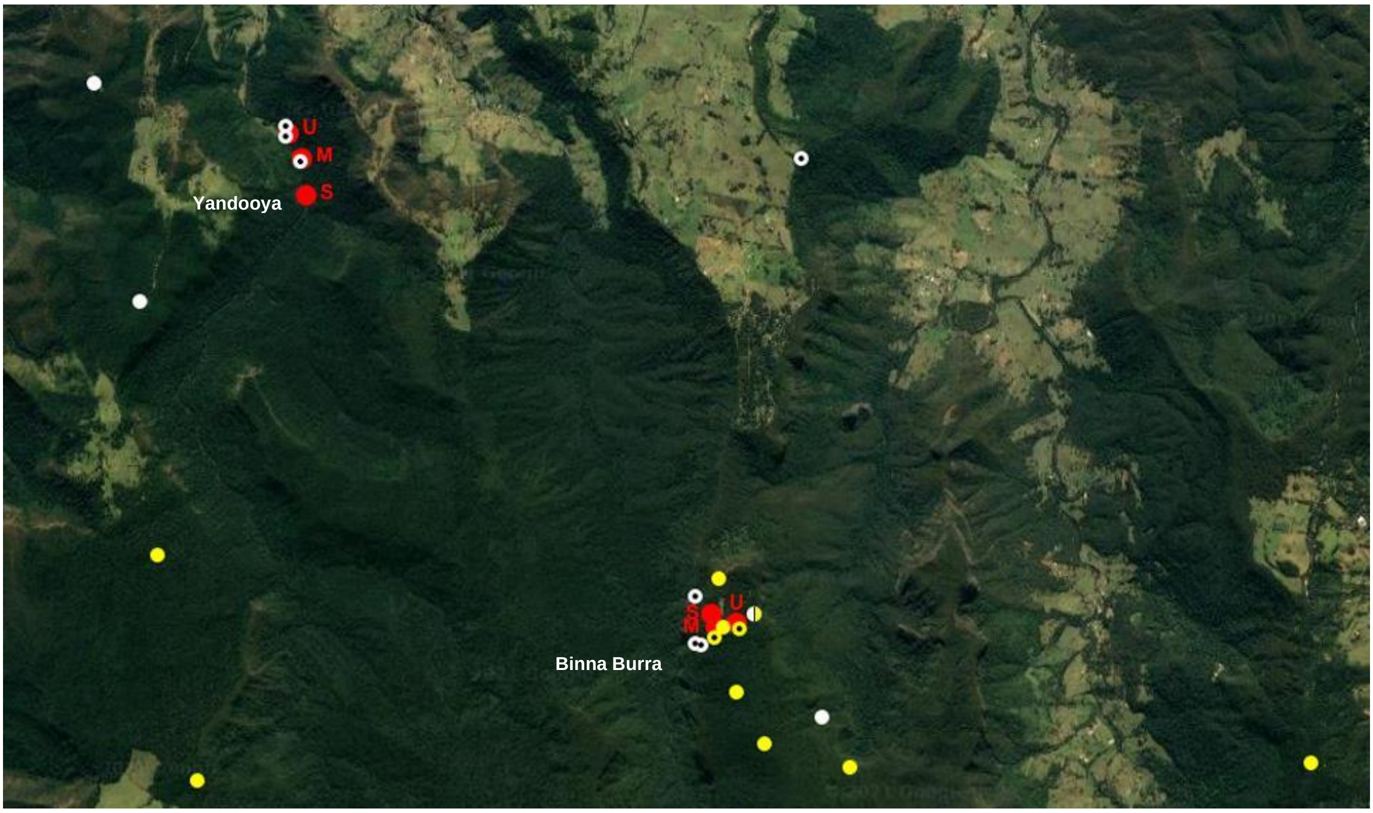

Figure 49: Lamington NP with the 3 survey sites (red) representing different levels of fire severity (unburnt=U; moderately burnt=M; severely burnt=S), at each of two locations (Yandooya and Binna Burra). Sites of additional collections shown for *A. dianneae* (white) and *A. nodosa* (yellow), including new records (black centre). Satellite map was created using the Atlas of Living Australia Spatial Portal (https://www.ala.org.au/) and reproduced under a Creative Commons Attribution 3.0 Australia Licence.

of rainforest within Lamington NP and the discovery of new populations of *A. dianneae* in unburnt rainforest during targeted surveys (Table 29) suggests that source populations are available. In addition to the modelling of potential habitat showing that nearly 93% remained unburnt (including additional potential habitat on the Tamborine Plateau), the conservation status of *A. dianneae* is not considered to be critical.

The McPherson Range pelican spider *A. nodosa* experienced limited impacts in Lamington NP with only 4% of the modelled potential habitat burnt in the 2019–2020 bushfires (Table 30). Across burnt rainforest sites, no spiders of this species were found after one year, and hence the potential for population recovery is unknown. However, with high altitude rainforest still widespread throughout Lamington NP, and nearly 96% of modelled potential habitat for *A. nodosa* remaining unburnt, the conservation status of *A. nodosa* is likely not currently of concern.

The newly discovered Mistake Mountains pelican spider *A. laidlawae* was heavily impacted by the 2019–2020 bushfires in Main Range NP, with 61% of modelled potential habitat burnt (Table 30). This species was not located on the moderately burnt site at higher elevations, however, the discovery of a juvenile spider immediately adjacent to the severely burnt site implied dispersal from adjacent unburnt forest. High altitude microphyll fern forest is still widespread in the northern section of Main Range NP and the discovery of other populations of this new species in unburnt habitat north of Mt Cordeaux suggests that the conservation status of *A. laidlawae* is not yet critical.

6.1.5 Recommendations

Reducing ongoing threats

- Protect rainforest from fire

  Fire presents a direct and indirect threat, with even low fire severity likely to burn the critical suspended leaf litter microhabitat of pelican spiders, and reduce the required high levels of humidity and moisture in rainforests.

- Reduce impacts of weeds

  Improving the rate of rainforest regeneration, retention of natural ground cover and restoration of microhabitats is critical for the recovery and persistence of pelican spiders across the landscape.

- Reduce impacts of pigs and deer

  Invasive animals such as pigs and deer can damage or destroy suspended leaf litter microhabitats.

Ecological monitoring

- Ongoing monitoring of pelican spiders is required to track successful recolonisation of burnt rainforest habitats and improve an understanding of threats from climate change. The archaeid extraction method is highly effective.

Ecological research

- An assessment of the conservation status of *A. cunninghami*, *A.dianneae, A. nodosa* and *A. laidlawae* is warranted under the NCA. These species may be of conservation significance under the IUCN's Criterion B 'Geographic Range', given their limited extent of occurrence and area of occupancy, and the 'continuing decline observed, estimated, inferred or projected in: (ii) area of occupancy; and (iii) area, extent and/or quality of habitat' (IUCN Red List Categories and Criteria V3.1; see https://www.iucnredlist.org/resources/summary-sheet). A better understanding of their fine-scale distribution is required, with further surveys across Lamington and Main Range NPs recommended.

6.2 Moss bugs

6.2.1 Conservation context

Moss bugs in the family Peloridiidae were identified as high priority insect taxa for this project given their dependence on the GWHA rainforests and high phylogenetic and biogeographic significance. Peloridiid bugs are assigned to their own suborder, the Coelorrhyncha, within the order Hemiptera. Peloridiids are minute and flightless relicts of a comparatively rich, world-wide fauna and are now restricted to temperate and subantarctic rainforests of New Caledonia, New Zealand, southeastern Australian and southern South America (Burckhardt 2009). In Australia, moss bug species are highly range-restricted being endemic to high elevation localities across the Great Dividing Range.

Moss bugs have a specialised ecological role feeding on the moss that is associated with moist rainforest microhabitats, making them vulnerable to disturbance, including low severity fires, especially after an extensive drought. The historic incursion of the 2019–2020 bushfires into rainforest and the associated adverse change to their habitat (for Queensland see Hines *et al.* 2020, 2021 & 2022) introduces a new threat to the conservation of moss bugs. Predictions of escalating impacts from climate change, with longer periods of drought, enhanced risk of fires, higher temperatures and lower humidity have significant implications for moss bug populations that rely on a consistently moist rainforest environment. Additional threats to moss bugs include invasive animals such as pigs and deer which can trample and damage mossy substrates with moss bugs.

The moss bug species *Hackeriella echina* is known only from the McPherson Range in South East Queensland and the Wiangaree area in North East NSW. In both Queensland and NSW, the species has been recorded from rainforest at elevations above 1000m (Burckhardt 2009). In Queensland, all previous locality records for the species were in Lamington NP, only two of which were reliable. The moss bug species *Hackeriella veitchi* (Figure 50) is known only from the Lamington Plateau and Springbrook Plateau in South East Queensland and the Wiangaree area in North East NSW (Burckhardt 2009). The Queensland Museum collections have additional specimens identified as *H. veitchi* from Mt Roberts and from Mt Superbus in the extreme south of Main Range NP. In both Queensland and NSW, the species has been recorded from rainforest at elevations above 1000m (Burckhardt 2009) with eight reliable records of the species in Queensland prior to this project.

6.2.2 Survey sites and methods

Invertebrate surveys were undertaken at Main Range and Lamington NPs, with surveys at Mt Barney NP not feasible due to logistical constraints. At each location, invertebrate survey sites were stratified with respect to fire severity unburnt, moderately and severely burnt) and across two areas that varied with altitude, resulting in a total of 12 sites (see details in Appendix 4). However, for moss bugs the three sites in the Cunninghams Gap area of Main Range NP were outside the known range of *Hackeriella echina and H. veitchi*.

Standardised invertebrate survey methods were used at each of these 12 survey sites (see details in Appendix 4). Of these methods, bark sprays, and to a lesser degree, leaf litter extracts would target moss bugs.

Potential habitat modelling (Laidlaw & Butler 2021) was undertaken for *Hackeriella veitchi* pre-survey using eight locality records but was not possible for *H. echina* given the limited number of reliable locality records.

Figure 50: The moss bug *Hackeriella vietchi*. (Photo © Queensland Museum, J. Wright)

6.2.3 Survey results

For *Hackeriella veitchi*, pre-survey potential habitat modelling revealed that 46% of the modelled Queensland distribution is within the protected area estate, and that <1% of its modelled habitat within the estate was impacted by the 2019–2020 bushfires.

Analysis of the results of all invertebrate survey methods, including bark sprays and leaf litter extraction showed that no individuals of *Hackeriella echina* or *H. veitchi* were recovered from these survey efforts.

6.2.4 Discussion

Bark sprays and leaf litter extractions have proven to be the most effective sampling methods for peloridiid bugs (G.B. Monteith pers. comm.). The selected methodology cannot therefore explain the lack of moss bugs in survey collections for this project. In Lamington NP, previous records of moss bugs indicate that they are restricted to higher elevation microphyll fern forest which was not burnt in the 2019–2020 bushfires and not represented by the invertebrate survey sites. At Main Range, the known range of *H. veitchi* includes Mt Roberts (1,330m elevation) and Mt Superbus (1,375m) which are of a higher altitude than Mt Cordeaux (1,135m) which was the focus of this project.

The absence of moss bugs from the project surveys is more likely due to unsuitable habitat at elevations below 800m. Moss bug populations at Lamington NP are therefore not of conservation concern given the on-ground impacts of the 2019–2020 bushfires. The moss bug populations at Mt Superbus, however, may be at risk, given the unexpected impacts of the 2019–2020 bushfires (Hines *et al.* 2021) and are worthy of additional survey efforts. The predicted impacts of climate change include a lifting of the cloud base and declines in moisture condensation, which threatens moss dependant species with mortality from desiccation and microhabitat loss, as well as from future fires. This is an increasing risk to the conservation of GWHA relictual taxa such as peloridiid bugs, making this group a suitable indicator group for monitoring ecological change and understanding climate change impacts.

6.2.5 Recommendations

Reducing ongoing threats

- Protect rainforest from fire

  Future fire presents a direct threat to the mossy habitats of moss bugs, particularly after significant periods of drought. Fires of even low severity are likely to burn their specialised moisture dependant microhabitats.

- Reduce impacts of pigs and deer

  Invasive animals such as pigs and deer can damage or destroy the unique mossy microhabitats in which moss bugs live, and which are often close to the rainforest floor.

Ecological monitoring

- Further surveys at known locations

  Establishing the fine scale distribution, both spatial and elevational, of *Hackeriella echina* at Lamington NP and *H. veitchi* at Main Range NP provides a critical baseline from which to monitor change in populations, alongside key environmental and climate variables. A focus on unburnt localities is advised. The survey techniques used in this project of bark sprays and litter extraction are appropriate.

Ecological research

- Research into the ecology and biology of moss bugs would provide a greater understanding of their unique attributes, requirements, threats to their persistence and options to support their ongoing conservation.

6.3 Wingless dung beetle

6.3.1 Conservation context

The wingless dung beetle *Amphistomus macphersonensis* of the family Scarabaeidae (Figure 51), was identified as high priority species for this project given its biogeographic significance. As a small (4–6mm) and flightless beetle this species is range-restricted, occurring only in the Border Ranges, south from Mt Nardi in the Nightcap Ranges of NSW, west to Nothofagus Mountain in the Scenic Rim, east to Springbrook and on the Lamington Plateau. The species was originally described using multiple specimens from near Woodenbong (NSW) and one from Lamington NP (Matthews 1974), with the extensive collecting activities of Geoff Monteith having since clarified its broader distribution. A total of 28 reliable locality records in Queensland were derived from the Queensland Museum collections prior to this project that served to guide the best locations for survey efforts.

The wingless dung beetle *A. macphersonensis* is nocturnal and plays a specialised ecological role, being coprophagous, consuming the faecal material of native vertebrates, as well as using it to create brood balls in which to develop their larvae. Due to their burrowing behaviours, they aerate and enhance the organic content of soils, supporting decomposer nutrient cycles and plant growth. Dependant on the stability of a rainforest habitat, and the moist ground layer, the wingless dung beetle is vulnerable to unexpected disturbance, including low severity fires. The extent to which the 2019–2020 bushfires penetrated rainforest was historic (e.g. Hines *et al.* 2021) and highlights the increasing threats from climate change to rainforest endemics, especially those species with low or no dispersal ability. Additional threats to the wingless dung beetle are introduced animals such as pigs and deer which can trample dung beetles, destroy the fragile soil environment and introduce novel faecal material and potential pathogens.

Figure 51: Wingless dung beetle *Amphistomus macphersonensis*. (Photo © Queensland Museum, G. Thompson)

6.3.2 Survey sites and methods

Invertebrate surveys were undertaken at Main Range and Lamington NPs, with surveys at Mt Barney NP not feasible due to logistic constraints. At each location, invertebrate survey sites were stratified with respect to fire severity unburnt, moderately and severely burnt) and across two areas that varied with altitude, resulting in a total of 12 sites (for details refer to section 6.1.2 and Appendix 4). The six survey sites at Main Range NP were outside the known range of *A. macphersonensis*.

Standardised invertebrate survey methods were used at each of these 12 survey sites (see details in Appendix 5: section A5.2, Figures A5.3, A5.4 and A5.5). The methods that best targeted *A. macphersonensis* were pitfall traps baited with wallaby dung, followed by traps baited with mushroom, unbaited pitfall traps and leaf litter extracts.

Potential habitat modelling (Laidlaw & Butler 2021) for *A. macphersonensis* was undertaken pre-survey using 28 reliable collection locality records.

6.3.3 Survey results

Potential habitat modelling for *A. macphersonensis* showed that 80% of the species' modelled Queensland distribution is in the protected area estate, with 3% impacted by the 2019–2020 bushfires.

Survey efforts using all methods, including baited pitfall traps, did not produce any *A. macphersonensis* individuals.

6.3.4 Discussion

Within Lamington NP, *A. macphersonensis* has previously been recorded from mid to high elevations. At Green Mountains on the IBISCA-Queensland transect (Kitching *et al.* 2011), it was collected from sites as low as 700m and as high as 1,100m and was most common at sites at 900m. At Binna Burra, *A. macphersonensis* has been collected as low as 780m, however, it occurs as low as 335m in rainforest remnants in nearby Beechmont.

The absence of *A. macphersonensis* from the low elevation sites was expected as it was not recorded from any of the 300m sites which had surveyed for dung beetles during the IBISCA-Queensland Project of 2006–2008 (see Kitching *et al.* 2011). Its absence from the higher elevation sites at Binna Burra, however, particularly the unburnt site, was unexpected. Between 2009 and 2016 (excluding 2011), dung beetles were surveyed each February within rainforest at Binna Burra, using pitfall traps with either dung or mushroom baits. Survey sites were in relatively close proximity to the Binna Burra sites surveyed in this study. Individuals of *A. macphersonensis* were collected every year, mostly in dung-baited pitfall traps (C. Burwell, unpubl data). However, post-fire dung beetle sampling at Binna Burra collected *A. macphersonensis* from unburnt rainforest along the Cave Circuit (Kathy Ebert *pers. comm.*), so the species persists in Lamington NP. The wingless dung beetle is also very likely to persist at higher elevations in the Lamington NP. The absence of this species from survey collections at the unburnt site at Binna Burra may in part be due to effects of the prolonged drought that preceded the 2019–2020 bushfires.

6.3.5 Recommendations

Reducing ongoing threats

- Protect rainforest from fire

  Future fire presents a direct threat to the moist rainforest substrate on which wingless dung beetles depend, especially after drought. Fires of even low severity are likely to impact their food resources and soil conditions.

Ecological monitoring

- Further surveys at known locations

  Establishing the fine scale distribution, both spatial and elevational, of *A. macphersonensis* at Lamington NP provides a critical baseline from which to monitor change in populations, alongside key environmental and climate variables. In particular, re-surveys of the sites used during the IBISCA-Queensland Project (see Kitching *et al.* 2011) is recommended to enable a comparison of data from over a decade ago. The survey techniques used in this project of dung and mushroom baited pitfall traps are appropriate.

Ecological research

- Research into the ecology and biology of wingless dung beetles would improve the understanding of their unique attributes, requirements, threats to their persistence and options to support their ongoing conservation.

7 Priority plant species

7.1 Open forest/woodlands

7.1.1 Conservation context

Three threatened plant species were of concern following the 2019–2020 bushfires across GWHA, and targeted for surveys: *Brachyscome ascendens, Coopernookia scabridiuscula* and *Hibbertia monticola*.

The Binna Burra daisy *Brachyscome ascendens* in the family Asteraceae, is a perennial daisy to 35cm tall with 2-3cm wide mauve, lilac or lavender flowers. It is endemic to the McPherson Range and nearby areas on the Queensland/NSW border and has been recorded in Main Range, Mt Barney and Lamington NPs. Eight Queensland specimens are held at the Queensland Herbarium, five from within the project area (Figure 52). The species is listed as Vulnerable under the NCA. The known Queensland distribution of *Brachyscome ascendens* is largely within the protected area estate and no specific conservation actions are currently being undertaken. Identified and likely threats to this species include weed invasion (e.g. mistflower), track maintenance works, climate change and inappropriate fire regimes (Department of Environment and Heritage Protection 2011a).

Coopernookia, *Coopernookia scabridiuscula* in the family Goodeniaceae, is a weak branching shrub to 1m tall restricted to South East Queensland. It's known distribution extends from Mt Walsh NP near Biggenden, south to Mt Barney NP. Ten specimens are held at the Queensland Herbarium, two of which are from Mt Barney NP (Figure 52). The species is listed as Vulnerable under both the NCA and EPBC. Most of the Queensland distribution of *Coopernookia scabridiuscula* is within the protected area estate and no specific conservation actions are being undertaken. Threats likely include weed invasion, climate change and inappropriate fire regimes (Department of Environment and Energy 2008a).

The mountain guinea flower *Hibbertia monticola* in the family Dilleniaceae, is an erect shrub growing to 1.5m tall. It's known distribution is between Mt Barney north to Mt Moffatt in Queensland. Specimens from sixteen locations are held at the Queensland Herbarium, ten of which are from within the project area, including eight collected from Mt Barney and two from Main Range NPs (Figure 52). This species is listed as Near Threatened under the NCA. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

7.1.2 Survey sites and methods

To prioritise the location of field surveys for the three priority open forest/woodland species (Figure 52), their known collection sites, with a 250m buffer, were spatially intersected with fire severity maps. Most of the habitat for *Brachyscome ascendens* is within Lamington NP, with no known locations impacted by the 2019–2020 bushfires. Whilst one known location within each of Main Range and Mt Barney NPs was fire impacted, these were not targeted for surveys due to their remoteness and minimal habitat overlap with other priority species. One known location for *Coopernookia scabridiuscula* and four for *Hibbertia monticola* were found to be fire impacted within Mt Barney NP.

To survey priority species, traverses through their known locations and similar habitat across all fire severity classes were conducted on Mt Barney, Mt Ernest (Figure 53) and elsewhere within Mt Barney NP in October 2020. Specimens of priority species and other flora were collected, identified and where appropriate, lodged at the Queensland Herbarium. A BioCondition reference plot (Eyre *et al.* 2017) was established on the flanks of Mt Barney within RE 12.11.6 (*Corymbia citriodora* subsp. *variegata, Eucalyptus crebra* woodland on metamorphics +/- interbedded volcanics) to track post-fire recovery of open woodlands. The potential ecological impact incurred by each priority open forest/woodland species was assessed by intersecting PEI mapping (Laidlaw *et al.* 2022) with buffered known locations for each species.

7.1.3 Survey results

Surveys were conducted on Mt Barney and Mt Ernest in October 2020 and 2021, and on Mt Maroon in March 2022.

At the time of the post-fire field surveys, no specimens of *Brachyscome ascendens* were located at fire-impacted locations within Mt Barney NP, however a new location for *Brachyscome ascendens* was found at Binna Burra, Lamington NP, constituting a new easterly range extension for this species. Almost one-third (31%) of buffered *Brachyscome ascendens* habitat within the project area appears to have burnt (Table 31). A majority of the habitat burnt is likely to have experienced limited or no ecological impact (Figure 54).

Almost half (47%) of buffered *Coopernookia scabridiuscula* habitat within the project area appears to have burnt (Figure 53, Table 31) with a majority of the habitat likely to have experienced a range of moderate to catastrophic ecological impacts (Figure 54). At the time of the post-fire field survey, two individual plants of *Coopernookia scabridiuscula* were located on Mt Barney, within Mt Barney NP.

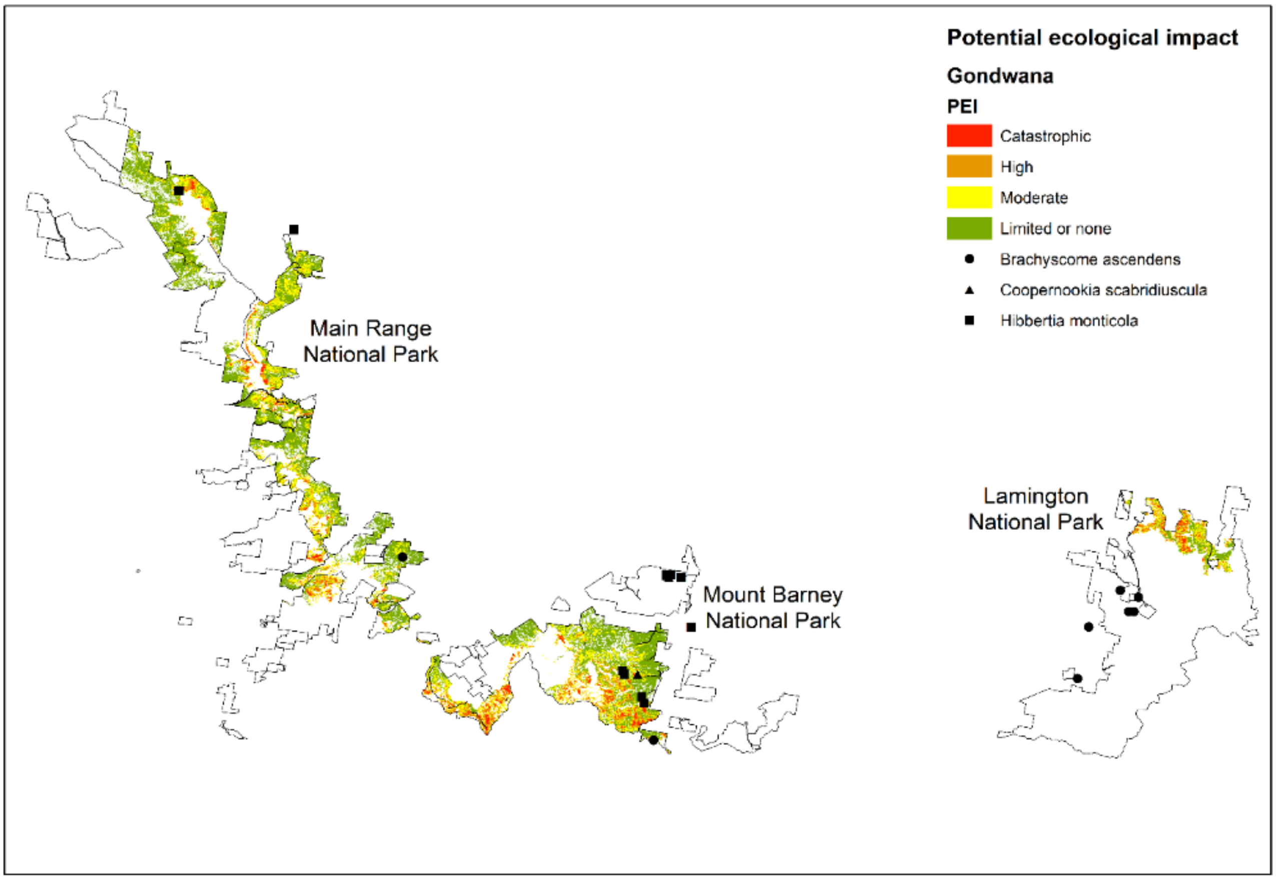

Figure 52: Known locations of the priority open forest/woodland plants and PEI in GWHA.

Figure 53: Mt Ernest summit experienced extreme fire severity (left) and flowering *Coopernookia scabridiuscula* on Mt Barney in October 2021 (right). (Photos: M. Laidlaw)

Almost half (49%) of buffered *Hibbertia monticola* habitat within the project area appears to have burnt (Table 31), however almost one half of that burnt habitat is likely to have experienced limited or no ecological impact (Figure 54). At the time of the post-fire field survey, two specimens of *Hibbertia monticola* were located at fire-impacted locations within Mt Barney NP.

In addition to the priority species, two specimens of the Near Threatened species *Acacia acrionastes* were also collected from Mt Ernest and Mt Barney within Mt Barney NP.

Table 31: Modelled potential habitat (PH) for priority open forest/woodland plant species with impacts from the 2019–2020 bushfires.

Scientific name	Common name	Buffered habitat within project area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
Brachyscome ascendens	Binna Burra daisy	125	79	38	31
Coopernookia scabridiuscula	Coopernookia	41	27	19	47
Hibbertia monticola	mountain guinea flower	154	61	75	49

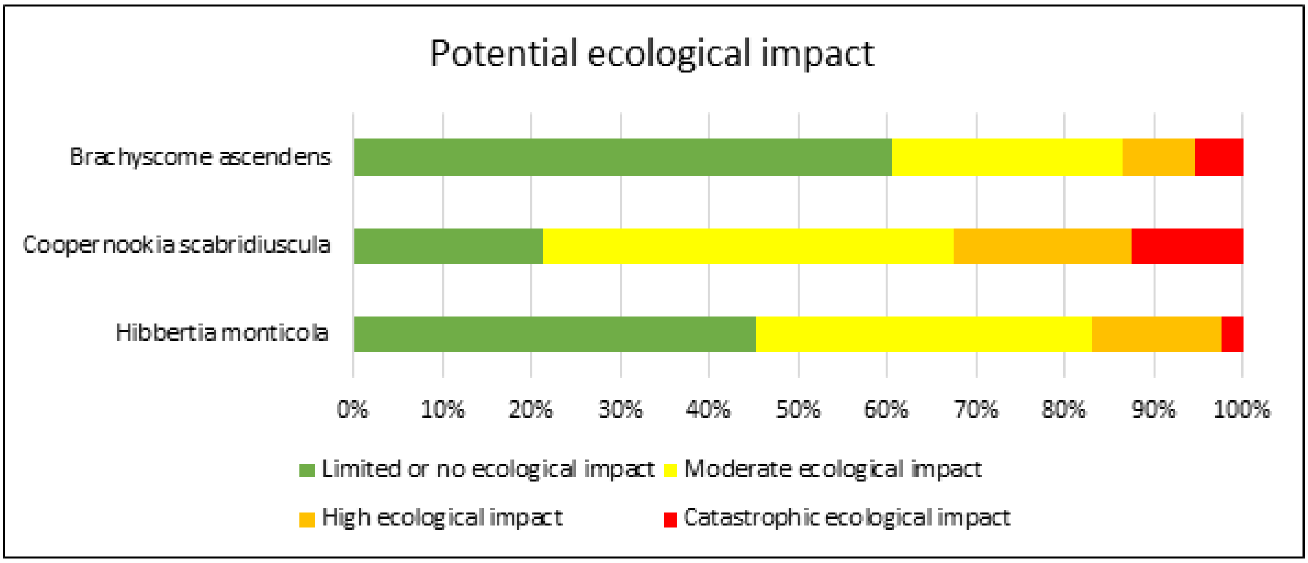

Figure 54: Percentage of four PEI classes for three priority open forest/woodland plant species.

7.1.4 Discussion

The ability to assess bushfire impacts to the *Brachyscome ascendens*, *Coopernookia scabridiuscula* and *Hibbertia monitcola* is limited by a lack of data. Relatively little is understood about the distribution and ecology in Queensland, as a basis to interpret their ability to survive and recover following bushfire. The distribution of all three species within flammable regional ecosystems suggest that they likely have the capacity to persist within an appropriate fire regime. Finding limited numbers of individuals of all three species within areas exposed to fires in 2019–2020 suggests that they have some capacity to regenerate post-fire.

7.1.5 Recommendations

Reducing ongoing threats (Mt Barney NP)

- Protect priority species from frequent fire

  Burn in accordance with the planned burn guidelines for Open forests/woodlands (grassy/shrubby, 3–25 years) (Department of National Parks, Recreation, Sport and Racing 2012).

- Reduce impacts of pigs and deer.
- Reduce impacts of weeds

  Prioritise control of ecosystem transforming species (e.g. Lantana, high-biomass grass and smothering vines). Control mistflower and Crofton weed incursions.

- Prevent human impacts

  Flag known locations of threatened species and train staff in their identification, to prevent accidental damage or loss from track or fireline maintenance and herbicide application or drift by staff or contractors.

  Restrict visitor access where possible to avoid trampling and illegal collecting of priority species.

Ecological monitoring

- Establish monitoring plots and undertake further targeted surveys for *Coopernookia scabridiuscula* within its known range on Mt Barney and Mt Maroon.

  Coopernookia scabridiuscula is the most likely of the open forest/woodland priority species to have been impacted by the 2019–2020 fires (based on the two Queensland Herbarium specimens available).

Ecological research

- Further research into the distribution and ecology of *Brachyscome ascendens, Coopernookia scabridiuscula* and *Hibbertia monticola* across their range in Queensland is required.

  Hibbertia monticola currently has enough collections (n≥10) to allow Maxent habitat modelling and subsequent analyses, however to date, Near Threatened species have not been prioritised. One more collection of *Coopernookia scabridiuscula* and two more collections of *Brachyscome ascendens* are required to facilitate Maxent modelling and risk analyses.

7.2 Montane heath

7.2.1 Conservation context

Fourteen threatened montane heath plant species were of concern following the 2019–2020 bushfires across GWHA, and targeted for surveys: *Agiortia cicatricata, Bertya ernestiana, Comesperma breviflorum, Euphrasia bella, Gonocarpus hirtus, Grevillea linsmithii*, *Leionema elatius* subsp. *beckleri, Leptospermum barneyense, Philotheca obovatifolia, Pimelea umbratica, Pseudanthus pauciflorus* subsp. *pauciflorus, Pultenaea whiteana, Tetramolopium vagans* and *Zieria montana.*

The beard heath *Agiortia cicatricata* in the family Ericaceae, is a slender, erect shrub to 60cm tall known to occur between the southern Queensland border south to approximately Taree, NSW in montane heathland communities on shallow soils and rock outcrops. Three Queensland specimens are held at the Queensland Herbarium, two of which were collected from within the project area at Mt Barney NP (Figure 55). The species is listed as Near Threatened under the NCA. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, inappropriate fire regimes and climate change.

The Mt Ernest Bertya *Bertya ernestiana* in the family Euphorbiaceae, is a tall, open shrub to 1.5m tall with a known distribution restricted to Mt Barney NP and its surrounds. Six Queensland specimens are held at the Queensland Herbarium, four of which were collected from within the project area at Mt Barney NP (Figure 55). The species is listed as Vulnerable under both the NCA and EPBC. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species include inappropriate fire regimes (including annual burns), weed invasion, climate change and interactions between these threats (Department of Environment and Energy 2011).

In the family Polygalaceae, *Comesperma breviflorum* is a subshrub to 50cm tall known to occur north from Woodenbong in NSW to near Boonah in Queensland. Thirteen Queensland specimens are held at the Queensland Herbarium, five of which are from within the project area at Mt Barney NP (Figure 55). The species is listed as Near Threatened under the NCA. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken for this species. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

Lamington eyebright *Euphrasia bella* in the family Orobanchaceae, is an erect perennial herb growing to 30cm tall. It's known distribution is from Border Ranges NP in NSW, Lamington and Main Range NPs in Queensland. Nine Queensland specimens are held at the Queensland Herbarium, all from within the project area (five from Lamington and three from Mt Barney NPs) (Figure 55). The species is listed as Endangered under both the NCA and EPBC. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Threats to this species have been identified as habitat loss due to weed invasion (e.g. mistflower and Crofton weed), trampling and illegal collecting (Department of Environment and Energy 2008b). Other likely threats include climate change and inappropriate fire regimes.

In the family Haloragaceae, *Gonocarpus hirtus* is a weak, scrambling sub-shrub to 70cm tall, known to occur from north of Tamworth in NSW to Moogerah Peaks in Queensland. Five Queensland specimens were held at the Queensland Herbarium prior to this study, two from within the project area (one each from Main Range and Mt Barney NPs) (Figure 55). The species is listed as Vulnerable under the NCA as it is endemic to Queensland and has a narrow geographic distribution due to restricted habitat requirements. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Identified threats to this species include inbreeding depression due to small population sizes, pressure from weeds and pathogens, as well as inappropriate fire regimes (however *Gonocarpus hirtus* may require fire to regenerate) (Department of Environment and Heritage Protection 2009a). Climate change is also likely to pose a threat to this species.

In the family Proteaceae, *Grevellia linsmithi* is a spreading shrub to 2m tall found on the rocky slopes and cliff edges of Mt Barney, Main Range and Moogerah Peaks NPs. Ten specimens are held by the Queensland Herbarium (Figure 55). Its known Queensland distribution is largely within the protected area estate and three records are from within the project area at Mt Barney and Main Range NPs. The species is listed as Endangered under the NCA and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

In the family Rutaceae, *Leionema elatius* subsp. *beckleri* is a shrub growing to 5m tall. It is known to occur north of Bulahdelah NSW to Springbrook NP in Queensland. Specimens from three Queensland locations are held at the Queensland Herbarium, two from within the project area from Mt Barney NP (Figure 55). The species is listed as Endangered under the NCA. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

Iin the family Myrtaceae, *Leptospermum barneyense* is a shrub to 2.5m tall, endemic to Mt Barney and Mt Maroon in southern Queensland. Seven specimens are held at the Queensland Herbarium, all from within Mt Barney NP (Figure 55). The species is listed as Vulnerable under the NCA. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species include weed invasion (e.g. mistflower and Crofton weed), climate change, inbreeding depression within small and fragmented populations and inappropriate fire regimes (Department of Environment and Heritage Protection 2011b).

In the family Rutaceae, *Philotheca obovatifolia* is a shrub to 2m tall known from the rocky ridges of Mt Barney NP in Queensland, Werrikimbe NP and Mt Boss State Forest in NSW. Seven specimens were collected from within the project area at Mt Barney NP between 1931 and 2009 and are held at the Queensland Herbarium (Figure 55). All known locations are within the protected area estate. This species is listed as Least Concern under the NCA and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

In the family Thymelaeaceae, *Pimelea umbratica* is a many-branched shrub to 1m tall. It is endemic to the Tweed and McPherson Ranges along the Queensland–NSW border. Specimens from nine Queensland locations are held at the Queensland Herbarium, including five collected from within the project area at Main Range NP (Figure 55). The species is listed as Near Threatened under the NCA. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

In the family Picrodendraceae, *Pseudanthus pauciflorus* subsp. *pauciflorus* is a shrub to 60cm tall, known to occur between Port Macquarie NSW north to D'Aguilar NP in South East Queensland. Specimens from ten Queensland locations are held at the Queensland Herbarium, seven of which are from within the project area at Mt Barney NP (Figure 55). The species is listed as Near Threatened under the NCA. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

The Mt Barney bush pea *Pultenaea whiteana* in the family Fabaceae is a small, woody shrub to 2m tall and is endemic to Queensland's Scenic Rim. Eight specimens were held at the Queensland Herbarium, all from within the study area at Mt Barney NP (Figure 55). The species is listed as Vulnerable under the NCA. Its known Queensland distribution is entirely within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species likely include collecting, trampling, inbreeding depression, pathogens, weed invasion, climate change and inappropriate fire regimes (Department of Environment and Heritage Protection 2009c).

In the family Asteraceae, *Tetramolopium vagans* is a small woody shrublet to 20cm tall which grows on rhyolite or trachyte cliffs. It is endemic to the peaks of Mt Barney, Mt May, Mt Maroon and Mt Ernest within Mt Barney NP (Figure 55). Specimens from six locations within Mt Barney NP are held at the Queensland Herbarium. The species is listed as Vulnerable under the NCA. Its known Queensland distribution is entirely within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species likely include illegal collecting, trampling, inbreeding depression, climate change, pathogens and inappropriate fire regimes (Department of Environment and Heritage Protection 2009d).

The Mt Barney stink bush *Zieria montana* in the family Rutaceae, is a shrub to 2.5m endemic to the rock pavements and outcrops of Mt Barney, in Mt Barney NP. Nine specimens from this location are held at the Queensland Herbarium (Figure 55). The species is listed as Critically Endangered under the NCA. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species likely include inappropriate fire regimes, inbreeding depression, climate change, stochastic disturbance, weed invasion (e.g. mistflower), illegal collecting and trampling (DES 2019).

7.2.2 Survey sites and methods

To prioritise the location of field surveys for the montane heath species (Figure 55), their known collection sites, with a 250m buffer, were spatially intersected with fire severity maps. The habitat for two species, *Euphrasia bella* and *Leionema elatius* subsp. *beckleri,* is known from unburnt areas of Lamington NP. Two other species, *Pimelea umbratica* and *Gonocarpus hirtus,* possibly have limited habitat within Main Range NP. A vast majority of priority species records are, however, known from areas of upland rock pavement within Mt Barney NP and as such, these areas were prioritised for survey.

To survey the priority plant species traverses through their known locations and similar habitats were conducted across all fire severity classes on Mt Barney, Mt Ernest, Mt Maroon and elsewhere within Mt Barney NP between October 2020 and March 2022. Similar habitats were traversed on Mt Cordeaux, Bare Rock and Mt Mitchell within Main Range NP across all fire severity classes in October 2020. Specimens of priority species and other flora were collected, identified and where appropriate, lodged at the Queensland Herbarium. The potential ecological impact incurred by each priority montane heath species was assessed by intersecting PEI mapping with buffered known locations for each species.

7.2.3 Survey results

While a majority (91%) of known *Agiortia cicatricata* habitat occurs within the project area, only 15% of buffered habitat appears to have burnt (Table 32). It is predicted that a majority (70%) of this area is likely to have experienced moderate to catastrophic ecological impacts (Figure 56). At the time of the post-fire field survey, no specimens of *Agiortia cicatricata* were found at fire-impacted known locations within Mt Barney NP or elsewhere.

Almost half (43%) of buffered known *Bertya ernestiana* habitat within the project area appears to have burnt (Table 32), although almost 80% habitat burnt is likely to have experienced limited or no ecological impact (Figure 56). At the time of the post-fire field surveys, approximately 50 young *Bertya ernestiana* specimens were found at fire-impacted known locations on Mt Ernest, within Mt Barney NP (Figure 57).

Buffered known *Comesperma breviflorum* habitat within the project area represents around 40% of its known distribution, 64% of which is likely to have burnt (Table 32). Over half of this is likely to have experienced limited or no ecological impact (Figure 56). At the time of the post-fire field survey, no specimens of *Comesperma breviflorum* were found at fire-impacted known locations within Mt Barney NP or elsewhere.

Only 6% of buffered *Euphrasia bella* habitat within the project area is likely to have burnt, despite almost two thirds of its Queensland habitat occurring within the project area (Table 32). Of the buffered habitat that did burn, over half is expected to have experienced limited or no ecological impact, with no catastrophic impacts predicted (Figure 56). At the time of the post-fire field survey, no specimens of *Euphrasia bella* were found at fire-impacted known locations within Mt Barney NP. One specimen was photographed at an unburnt site on Mt Ballow, Mt Barney NP, but could not be collected due to the topography.

Two resprouting specimens of *Gonocarpus hirtus* were found within fire-impacted areas during post-fire field surveys, both within Mt Barney NP. Over half (64%) of all known *Gonocarpus hirtus* habitat within GWHA is likely to have burnt, however over three-quarters is likely to have experienced limited or no ecological impact (Figure 56).

Grevillea linsmithii is likely to have experienced limited impacts from the 2019–20 bushfires according to our analysis. Buffered known habitat within the project area represents approximately one third (29%) of its known distribution (Table 32). Of this, just over half (54%) was impacted by fire. Almost 90% of the area burnt is likely to have experienced limited or no ecological impact (Figure 56), with 11% of the burnt area experiencing moderate ecological impacts. Less than 1% of the area burnt is likely to have experienced a high degree of ecological impact. No specimens of *Grevillea linsmithii* were found during post-fire surveys within Mt Barney NP or elsewhere.

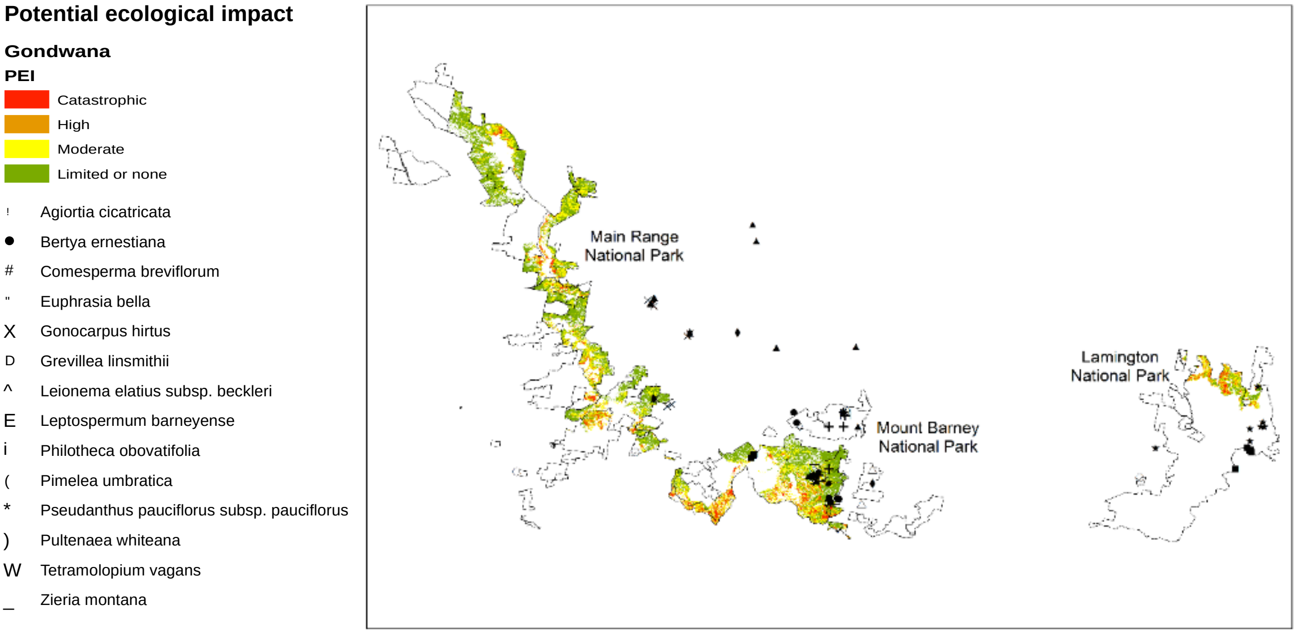

Figure 55: Known locations of the priority montane heath species and PEI across GWHA.

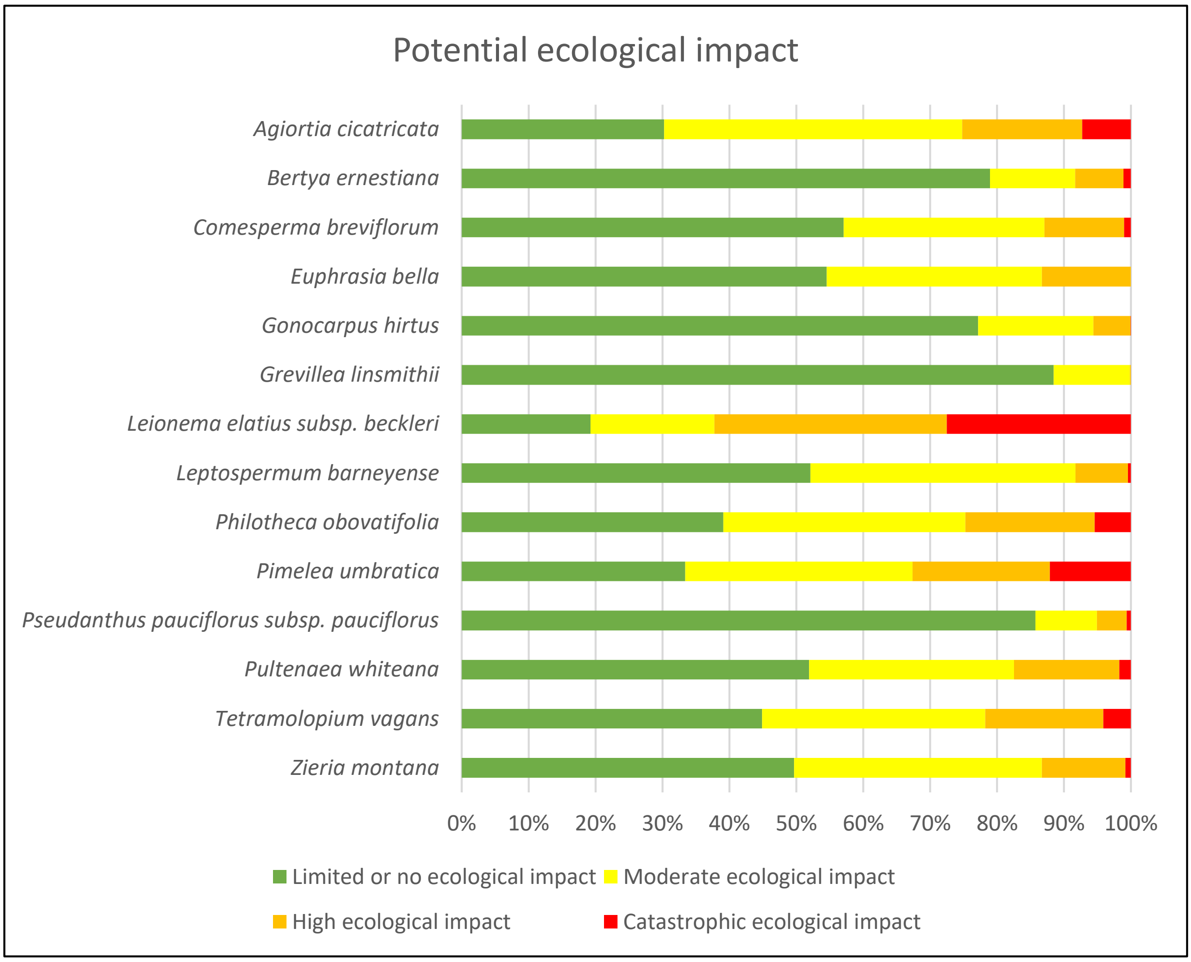

Figure 56: Percentage of each PEI class for the priority montane heath plant species.

Figure 57: *Bertya ernestiana* seedlings on Mt Ernest (left & centre) and flowering *Philotheca obovatifolia* on Mt Barney (right), October 2021. (Photos: M. Laidlaw)

Table 32: Modelled potential habitat (PH) for priority montane heath plant species with impacts from the 2019–2020 bushfires.

Scientific name	Common name	Buffered habitat within project area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% study area PH burnt
Agiortia cicatricata		215	91	32	15
Bertya ernestiana		70	64	30	43
Comesperma breviflorum		98	40	63	64
Euphrasia bella	Lamington eyebright	75	63	5	6
Gonocarpus hirtus		57	41	36	64
Grevillea linsmithii	Moogerah peaks Grevillea	48	29	26	54
Leionema elatius subsp. *beckleri*		30	51	26	86
Leptospermum barneyense		140	100	50	36
Philotheca obovatifolia	Barney peaks waxflower	120	95	95	79
Pimelea umbratica		97	38	64	66
Pseudanthus pauciflorus subsp. *pauciflorus*		117	66	51	44
Pultenaea whiteana	Mt Barney bush pea	123	100	60	49
Tetramolopium vagans		139	97	48	34
Zieria montana	Mt Barney stink bush	69	100	56	81

The montane heath species most impacted by the 2019–2020 bushfires appears to be *Leionema elatius* subsp. *beckleri.* Half of its known habitat occurs within Mt Barney NP and of this, 86% is predicted to have burnt (Table 32). Over 80% of this is likely to have experienced moderate or worse ecological impacts (Figure 56), and around one quarter of known habitat may have experienced catastrophic ecological impacts. At the time of the post-fire field survey, no specimens of *Leionema elatius* subsp. *beckleri* were found at fire-impacted known locations within Mt Barney NP or elsewhere.

Resprouting specimens of *Leptospermum barneyense* were sighted and collected from its known distribution on the summit of Mt Barney, Mt Barney NP. All known habitat for this species occurs within Mt Barney NP and over one third is likely to have burnt (Table 32). Approximately half of the known habitat is likely to have experienced moderate to catastrophic ecological impact (Figure 56).

A majority (95%) of buffered known habitat for *Philotheca obovatifolia* is found within the project area (Table 32). Of this, 79% was bunt in 2019–20. Over 60% of the burnt area experienced moderate or worse ecological impacts, with 5% of known habitat likely to have suffered catastrophic ecological impacts (Figure 56). Two young plants were located at two locations near the summit of Mt Barney during surveys in late 2021 (Figure 57). These were not seen during earlier post-fire assessments indicating delayed post-fire recovery.

Approximately one third (38%) of *Pimelea umbratica* known buffered habitat is found within the project area (Table 32) and two thirds of this is likely to have burnt. Of the habitat burnt, a further two thirds are likely to have experienced moderate or worse ecological impacts, with over 10% of buffered known habitat possibly experiencing catastrophic ecological impacts (Figure 56). At the time of the post-fire field survey, no specimens of *Pimelea umbratica* were found at fire-impacted known locations within Main Range NP or elsewhere.

Two-thirds of known buffered *Pseudanthus pauciflorus* subsp. *pauciflorus* habitat is found within GWHA. Of this, approaching half (44%) is likely to have been burnt. A majority of burnt habitat is likely to have experienced limited or no ecological impact, however (Figure 56). At the time of the post-fire field survey, no specimens of *Pseudanthus pauciflorus* subsp. *pauciflorus* were found at fire-impacted known locations within Mt Barney NP or elsewhere.

Three specimens of *Pultenaea whiteana* were collected from Mt Barney during post-fire surveys. Mt Barney NP supports the entire known population of *Pultenaea whiteana* and it appears that one half (49%) of its buffered known habitat burnt (Table 32). Approximately half of burnt *Pultenaea whiteana* habitat is likely to have experienced moderate, high or catastrophic ecological impacts (Figure 56).

Approximately a dozen specimens of *Tetramolopium vagans* were found persisting on Mt Ernest, within Mt Barney NP, during post-fire surveys. All were on inaccessible cliff-faces and were unable to be collected, however a count was made, and their locations noted. Almost all (97%) of buffered known habitat for this species occurs within the project area, one third of which appears to have burnt (Table 32). Over half of buffered known habitat for this species is likely to have experienced moderate to catastrophic ecological impacts (Figure 56).

Zieria montana is only known to grow on Mt Barney within Mt Barney NP. Over 80% of its habitat appears to have been burnt (Table 32) with half of the buffered known records being subjected to moderate, high or catastrophic ecological impacts (Figure 56). After two post-fire field surveys, no specimens of *Zieria montana* were found at fire-impacted known locations within Mt Barney NP or elsewhere.

In addition to these 14 priority montane heath species, collections of three additional threatened or Near Threatened montane heath species were made during field surveys: *Acacia saxicola* (Endangered) on Mt Maroon, Mt Barney NP. (fourth collection for the Queensland Herbarium), *Banksia conferta* (Vulnerable) on Mt Barney, Mt Barney NP and *Westringia rupicola* (Vulnerable) from Binna Burra, Lamington NP.

7.2.4 Discussion

The ability to assess bushfire impacts to priority montane heath plant species is limited by difficult terrain and a lack of data. Relatively little is understood about their distribution and ecology in Queensland, let alone their individual ability to survive and recover following fire. The distribution of all 14 species within flammable regional ecosystems suggest that they have the capacity to persist when appropriate fire regimes are applied. There is also evidence that some species are obligate seeders (eg. *Gonocarpus hirtus*), requiring fire to regenerate.

Six of the priority species that were detected as persisting post-fire (*Bertya ernestiana*, *Gonocarpus hirtus, Leptospermum barneyense, Philotheca obovatifolia, Pultenaea whiteana and Tetramolopium vagans*) are likely regularly exposed to fire and appear to have capacity to regenerate either via seed or vegetative resprouting. Post-fire recovery was found to be more advanced on the tops of peaks where the influence of low cloud provides additional moisture inputs. Mid-slope habitats were much drier by comparison with less regeneration seen.

7.2.5 Recommendations

Reducing ongoing threats (Mt Barney and Main Range NPs)

- Protect priority species from frequent fire

  Burn in accordance with the planned burn guidelines for montane heaths (15-50 years) (Department of National Parks, Recreation, Sport and Racing 2012).

- Reduce impacts of pigs and deer.
- Reduce impacts of weeds

  In particular, control mistflower and Crofton weed incursions on rocky outcrops.

- Prevent human impacts

  Flag known locations of threatened species and train staff in their identification, to prevent accidental damage or loss from track / fireline maintenance and herbicide application / drift by staff or contractors

  Restrict visitor access across rocky pavements, outcrops and cliff tops to avoid trampling, illegal collecting and nutrient additions (food waste/excrement).

Ecological monitoring

- Additional surveys to assess the persistence and distribution of *Leionema elatius* subsp. *beckleri*

  This species is the most likely of the montane heath priority species to have been significantly impacted by the 2019–2020 fires (based on the two Queensland Herbarium specimens available).

Ecological research

- Further research into the distribution and ecology of the priority montane heath plant species across their range.

  Only two species, *Comesperma breviflorum* and *Pseudanthus pauciflorus* subsp. *Pauciflorus* currently have enough independent collections (n≥10) to allow Maxent habitat modelling, however to date, Near Threatened species have not been prioritised. Additional collections of *Pultenaea whiteana* from this study will be used to investigate additional Maxent modelling and analyses for this species. One additional spatially independent collection each of *Euphrasia bella, Pimelea umbratica* and *Zieria montana* are required to facilitate Maxent modelling and risk analyses.

7.3 Rainforest and dry vine forests

7.3.1 Conservation context

Seven threatened rainforest and dry vine forest plant species were of concern following the 2019–2020 bushfires and targeted for surveys: *Bulbophyllum weinthalii* subsp. *weinthalii, Dendrobium schneiderae* var. *schneiderae, Sarcochilus hartmannii, Sarcochilus weinthalii*, *Clematis fawcettii, Muellerina myrtifolia* and *Phlegmariurus varius*.

Orchids—Family Orchidaceae

The small epiphytic orchid *Bulbophyllum weinthalii* subsp. *weinthalii* has leaves to 3cm long and grows on hoop pine *Araucaria cunninghamii* within subtropical rainforests (particularly RE 12.8.4 complex notophyll vine forest with *Araucaria* emergents). Its known distribution is north from Dorrigo NSW to the rainforests of the Queensland/NSW border. Four Queensland specimens are held at the Queensland Herbarium, three of which are from within the project area (one from Lamington NP and three from Main Range NP) (Figure 58). This species is under-collected in part because it is difficult to survey and collect due its small size and tree-top habitat. It is listed as Vulnerable under the NCA. Its known Queensland distribution is largely within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

The small epiphytic orchid *Dendrobium schneiderae* var. *schneiderae* has leaves to 7cm long and grows on rainforest trees, particularly hoop pine *Araucaria cunninghamii,* within subtropical rainforests (particularly RE 12.8.4 complex notophyll vine forest with Araucaria emergents). Its known distribution is north from Kyogle NSW to the Mt Mistake Queensland. Six Queensland specimens were held at the Queensland Herbarium, including one specimen from within the project area at Mt Barney NP (Figure 58). This species is difficult to survey and collect due its small size and tree-top habitat. It is listed as Near Threatened under the NCA. Its known Queensland distribution is likely largely within the protected area estate and no specific conservation actions are being undertaken. Threats to this species likely include weed invasion, climate change and inappropriate fire regimes.

The waxy Sarcochilus *Sarcochilus hartmannii* is a small ground or epilithic (rock dwelling) orchid with stems to 1m long. It is known north from the Richmond River NSW to Main Range NP in southern Queensland. Specimens from four Queensland locations are held at the Queensland Herbarium, all from the project area (one each from Main Range and Mt Barney NPs and two from Lamington NP) (Figure 58). The species is listed as Vulnerable under the NCA and EPBC. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species include illegal collecting, trampling, habitat loss, weed invasion (including mistflower and Crofton weed), pathogens, climate change and inappropriate fire regimes (Department of Natural Resources 1999, Department of Agriculture, Water and the Environment 2008).

The blotched Sarcochilus *Sarcochilus weinthalii* is a small epiphytic orchid with stems to 3cm, found in the upper branches of rainforest trees. It is known to occur north from the Richmond River NSW to east of the Bunya Mountains in South East Queensland. Specimens from nine Queensland locations are held at the Queensland Herbarium, however none of these are from within the project area (Figure 58). The species is listed as Endangered under the NCA and Vulnerable under the EPBC. Its known Queensland distribution is within the protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species include illegal collecting, habitat loss, weed invasion (including *Lantana camara*), pathogens, climate change and inappropriate fire regimes (Department of Natural Resources 1997, Department of Environment and Energy 2014).

Other families

The stream Clematis *Clematis fawcettii* in the family Ranunculaceae, is a weak climbing vine with stems to 2m in length. Its known distribution extends from Coffs Harbour NSW north to Bunya Mountains NP. Twenty-three Queensland specimens are held at the Queensland Herbarium, eight of which are from within the project area including six collections from Lamington NP and one specimen each from Mt Barney and Main Range NPs (Figure 58). The species is listed as Vulnerable under both the NCA and the EPBC due to the identified and potential threats of land clearing, grazing and weed invasion (eg. *Lantana camara*) (Department of Environment and Energy 2010). Climate change and inappropriate fire regimes are also likely to impact this species. No specific conservation actions are being undertaken for *Clematis fawcettii* however the 'National recovery plan for the semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions ecological community' incorporates habitat for this species in the Brigalow Belt bioregion.

The mistletoe *Muellerina myrtifolia* in the family Loranthaceae, is a parasitic shrub which grows on a diversity of host vines, shrubs and small trees including *Croton* spp., *Parsonsia* spp., *Notelaea* spp., *Kunzea* spp. and *Pandorea jasminoides*. It's known distribution extends from just south of the Queensland/NSW border north to Kroombit Tops NP within rainforest, scrub, wet sclerophyll and sclerophyll communities. Specimens from twenty-one locations are held at the Queensland Herbarium, three of which were collected from within the project area at Main Range NP (Figure 58). The species is listed as Near Threatened under the NCA. Identified and likely threats to this species likely include land clearing and timber harvesting, habitat fragmentation, climate change and inappropriate fire regimes (Department of Natural Resources 1995).

The tassel fern *Phlegmariurus varius* in the family Lycopodiaceae, is a many-branched tassel fern (club moss) growing to 50cm in length. It can be found growing either as a lithophyte in rock crevices or an epiphyte in rainforests. It has a wide distribution from Tasmania to the Queensland/NSW border and New Zealand which likely suggests a widespread distribution prior to rainforest retraction in Australia. Ten Queensland specimens are held at the Queensland Herbarium including four from the project area, one from Mt Barney and three from within Lamington NPs (Figure 58). The species is listed as Vulnerable under the NCA. It's known Queensland distribution is largely within the Protected area estate and no specific conservation actions are being undertaken. Identified and likely threats to this species likely include illegal collecting, inbreeding depression, climate change and vulnerability to stochastic events including storms damage (Department of Environment and Heritage Protection 2009b).

7.3.2 Survey sites and methods

To prioritise the location of field surveys for the seven rainforest and dry vine forest species, their known collection sites, with a 250m buffer, were spatially intersected with fire severity maps (Figure 58). Known habitat for priority species is concentrated in Lamington and Main Range NPs. Due to the dominance of other non-rainforest ecosystems, Mt Barney NP is not a hotspot for priority rainforest and dry vine forest species and surveys were not focussed on this park as a result.

Three long-term research plots (IBISCA – Laidlaw *et al.* 2011) burnt with a range of fire severity were resurveyed at Lamington NP (e.g. Figure 59). Two BioCondition plots (Eyre *et al.* 2017) were established at Main Range NP with low-moderate and high-extreme fire severity. Additional traverses, which included canopy surveys using binoculars, were made through fire-impacted areas of Lamington and Main Range NPs. Rock outcrops were also surveyed for the lithophilic tassel fern *Phlegmariurus varius*. Specimens of priority flora were collected, identified and lodged at the Queensland Herbarium. The potential ecological impact incurred by each priority rainforest and dry vine forest species was assessed by intersecting PEI mapping with buffered known locations for each species.

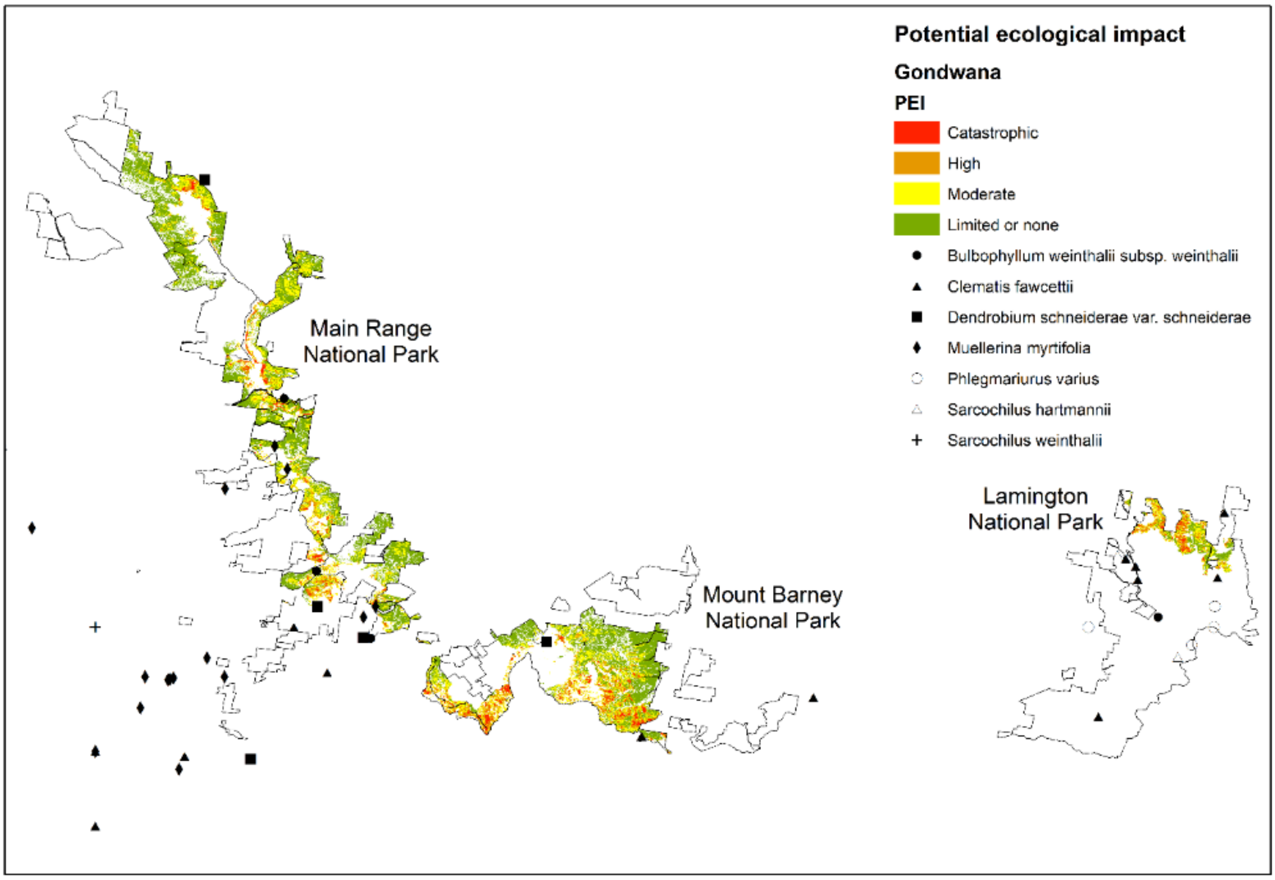

Figure 58: Known locations of the priority rainforest and dry vine forest plant species and PEI across GWHA.

Figure 59: Lowland rainforest burnt with moderate fire severity in Lamington NP. (Photo: M. Laidlaw)

7.3.3 Survey results

Orchids—Family Orchidaceae

A majority of buffered known habitat for *Bulbophyllum weinthalii* subsp. *weinthalii* occurs within the project area (80%) and of this, almost 40% appears to have been burnt (Table 33). Of the area burnt, almost 70% is likely to have experienced at least moderate ecological impacts (Figure 60). At the time of the post-fire field survey, no specimens of *Bulbophyllum weinthalii* subsp. *weinthalii* were located at fire-impacted locations within Lamington or Main Range NPs, or locations surveyed elsewhere.

Two new specimens of *Dendrobium schneiderae* var. *schneiderae* were located within its known range during field surveys in Mt Barney and Main Range NPs. Approximately 40% of buffered known habitat for this species is within the project area. Only 6% of this area appears to have burnt (Table 33), however 100% of that area is likely to have experienced moderate or worse ecological impacts (Figure 60).

Most of the known buffered *Sarcochilus hartmannii* occurs within the project area, with approximately one quarter of this area being burnt (Table 33). Over half of the burnt area is likely to have experienced limited or no ecological impact (Figure 60). At the time of the post-fire field survey, no specimens of *Sarcochilus hartmannii* were located at fire-impacted locations within Lamington or Main Range NPs, or locations surveyed elsewhere.

While *Sarcochilus weinthalii* was proposed as a priority species requiring assessment, it has not been collected within the project area to date, and no new specimens were detected during field surveys within Lamington and Main Range NPs. Orchidaceae curator at the Queensland Herbarium, Michael Mathieson has, however, sighted the species on the Western slopes of Main Range NP within the burnt area. At this stage, the likely impacts of fire on *Sarcochilus weinthalii* within the project area cannot be assessed.

Other families

Approximately one third (34%) of buffered known habitat for *Clematis fawcettii* occurs within the project area. Of this, is appears that only 4% of known buffered habitat burnt (Table 33), mostly resulting in limited or no ecological impact (Figure 60). At the time of the post-fire field survey, no specimens of *Clematis fawcettii* were located at fire-impacted locations within Lamington or Main Range NPs, or locations surveyed elsewhere. The species was previously recorded on one burnt IBISCA plot but was not found during post-fire surveys in January 2020.

A small percentage (14%) of buffered known habitat for *Muellerina myrtifolia* occurs within the project area, but of this, 62% appears to have burnt (Table 33). Just under half of this may have experienced moderate or worse ecological impacts (Figure 60), and around 10% of known habitat may have experienced catastrophic ecological impacts. At the time of the post-fire field survey, no specimens of *Muellerina myrtifolia* were located at fire-impacted locations within Main Range NP, or locations surveyed elsewhere.

Around 40% of known buffered *Phlegmariurus varius* habitat occurs within the project area, however as little as 4% of this may have burnt (Table 33). Approaching 70% of that is likely to have experienced moderate or high levels of ecological impact (Figure 60). At the time of the post-fire field survey, no specimens of *Phlegmariurus varius* were located at fire-impacted locations within Lamington or Mt Barney NPs, or locations surveyed elsewhere.

In addition, specimens of the Critically Endangered species *Rhodamnia rubescens* were also collected from Main Range and Mt Barney NPs. Regrowth of this species following exposure to low severity fire showed significant evidence of Myrtle rust infection.

Table 33: Modelled potential habitat (PH) for priority rainforest and dry forest plant species with impacts from the 2019–2020 bushfires.

Scientific name	Common name	Buffered habitat within project area (ha)	% Queensland PH in study area	Total PH burnt (ha)	% burnt in study area
Bulbophyllum weinthalii subsp. *weinthalii*	blotched Bulbophyllum	63	80	24	39
Clematis fawcettii	stream Clematis	141	34	6	4
Dendrobium schneiderae var. *schneiderae*		54	39	3	6
Muellerina myrtifolia	mistletoe	54	14	34	62
Phlegmariurus varius	tassel fern	64	39	3	4
Sarcochilus hartmannii	waxy Sarcochilus	69	88	18	26
Sarcochilus weinthalii	blotched Sarcochilus	unknown	unknown	unknown	unknown

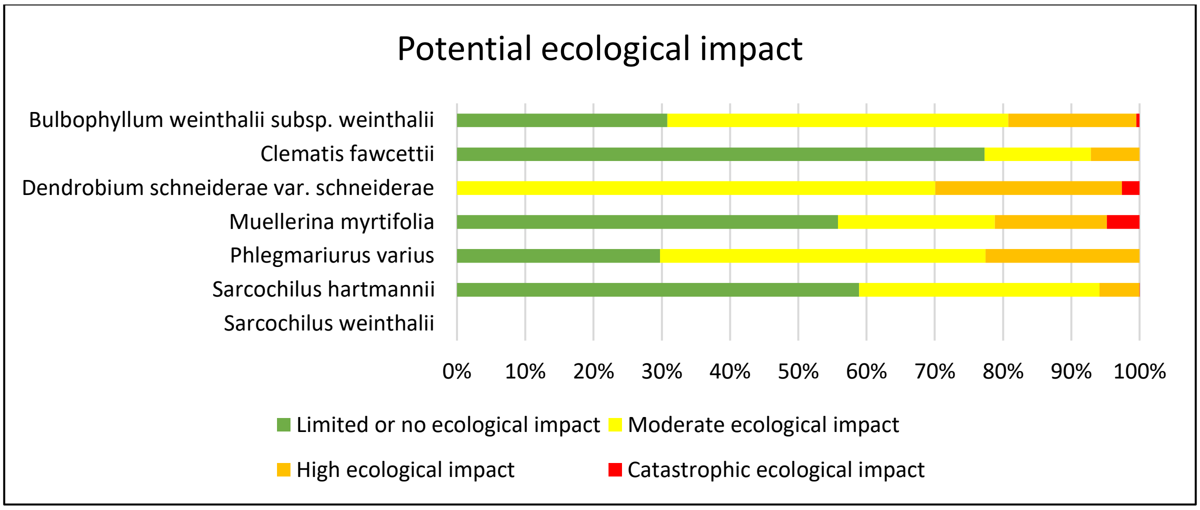

Figure 60: Percentage of PEI class for the priority rainforest and dry vine forest species.

7.3.4 Discussion

The ability to assess bushfire impacts to priority rainforest and dry vine forest plant species is limited by a lack of data. Relatively little is understood about their distribution and ecology in Queensland, let alone their ability to survive and recover following fire. The distribution of all seven species within fire-sensitive ecosystems would suggest that they may have limited or no capacity to persist if directly impacted by fire. This is particularly the case for terrestrial *Clematis fawcettii* and specimens of *Phlegmariurus varius* growing on rock outcrops. The epiphytic habit of other priority species may, however, afford some protection such that they can persist following the passage of fire through the understorey.

At least two priority orchid species are known to be epiphytic on hoop pine *Araucaria cunninghamii*, which is dominant in dryer rainforest ecosystems such as RE 12.8.4 'complex notophyll vine forest with Araucaria emergents'. This drier rainforest regional ecosystem often includes emergent sclerophyll species including brush box *Lophostemon confertus*, an indicator of past fires. It is therefore likely that fire does occasionally impact these forests but is highly variable in terms of its severity, distribution and the length of time between events (possibly centuries). In cases where rainforest and dry vine forest ecosystems burnt in 2019/20, the last fire is likely to pre-date the presence of flammable invasive species including *Lantana camara* and high-biomass grasses in the landscape.

7.3.5 Recommendations

Reducing ongoing threats

- Protect priority species from fire

  Prevent fire encroachment into rainforest and dry vine forest habitats and sustain strategic planned burn programs in surrounding fire-adapted ecosystems to reduce the risk from fire (Department of National Parks, Recreation, Sport and Racing 2012).

- Reduce impacts of pigs and deer.
- Reduce impacts of cattle

  Aim to exclude cattle from rainforest and dry vine forest to avoid trampling and herbivory of regenerating species.

- Reduce impacts of weeds

  In particular, control shade-intolerant weeds such as Lantana and high-biomass grass where canopy cover has been reduced and in sclerophyll ecotones.

- Prevent human impacts

  Flag locations of *Clematis fawcettii* and *Phlegmariurus varius* in Lamington and Mt Barney NPs, and train staff in their identification to prevent accidental damage or loss during track/fireline maintenance by staff or contractors.

  Reduce the risk of illegal collecting of epiphytes, including the priority threatened species *Bulbophyllum weinthalii* and *Dendrobium schneiderae*.

Ecological monitoring

- Establish monitoring plots and undertake further targeted surveys for all priority epiphyte species.

  Dendrobium schneiderae var. *schneiderae* may have been the most impacted by the 2019–2020 fires as the potential ecological impact for this species within it's known habitat (based on the three Queensland Herbarium specimens available) was moderate to catastrophic.

- Sustain annual monitoring in the IBISCA plots at Lamington NP (Laidlaw *et al*. 2011) that were impacted by the 2019–2020 bushfires, and the new BioCondition plots at Main Range NP established during this project.

  The understorey habitat of *Clematis fawcettii* and *Phlegmariurus varius* has likely been impacted by low severity fires, with limited data currently available to assess the extent of ecological impacts.

Ecological research

- The distribution and ecology of all priority rainforest and dry vine forest plants across their range in Queensland.

  The presence of *Sarcochilus weinthalii* within the project area should be confirmed with specimens when possible. *Muellerina myrtifolia* currently have enough independent collections (n≥10) to allow Maxent habitat modelling, however to date, Near Threatened species have not been prioritised. Three more spatially independent specimens of *Phlegmariurus varius* are required to facilitate Maxent modelling and risk analyses. A draft model for *Clematis fawcettii* has been produced.

8 Priority ecosystems

The project area of Lamington NP, Mt Barney NP and Main Range NP protects 52 Regional Ecosystems (REs). A majority of these (42 or 81%) were directly impacted by the black summer bushfires of 2019–20 to differing degrees. While many ecosystems and species are adapted, or reliant upon fire of an appropriate severity and interval for part of their life history, others have a fire-sensitive canopy and/or understorey which may be damaged by fire of any severity. These ecosystems and their dependent species may sustain significant long-term damage resulting from bushfire, including local extinction. To assess the likely impacts of bushfire on REs within the project area, results are described below grouped by their tolerance to fire:

- Priority rainforest ecosystems—have both a fire-sensitive canopy and understorey.
- Priority wet eucalypt open forests and rainforest/eucalypt forest ecotones**—**have a fire tolerant canopy and in the absence of fire, a fire-sensitive understorey.
- Priority dry sclerophyll ecosystems—have both a fire tolerant canopy and understorey.

8.1 Rainforests

8.1.1 Conservation context

Of the 42 REs impacted by the 2019–2020 bushfires, nine are rainforest ecosystems (Table 34). All have a fire-sensitive canopy and understorey (Queensland Herbarium 2021). The deliberate use of fire is not recommended for the management of rainforest REs (Queensland Herbarium 2021). One impacted RE is classed as 'Endangered' under the Queensland *Vegetation Management Act 1999* (VMA) meaning that either less than 10% of its pre-clearing extent across the bioregion remains as remnant vegetation, or 10–30% of its pre-clearing extent remains, and less than 10,000ha of remnant vegetation remains. Three REs are classed as 'Of concern' under the VMA, meaning that remnant vegetation is 10–30% of its pre-clearing extent across the bioregion; or more than 30% of its pre-clearing extent remains, and the remnant extent is less than 10,000ha.

Table 34: The rainforest regional ecosystems (RE) impacted by the 2019–2020 bushfires across GWHA and their classification under the VMA.

RE	VMA class	Short description
12.3.1a	Endangered	Gallery rainforest (notophyll vine forest) on alluvial plains
12.8.3	Least concern	Complex notophyll vine forest on Cainozoic igneous rocks, usually at altitude less than 600m
12.8.4	Least concern	Complex notophyll vine forest with *Araucaria* spp. on Cainozoic igneous rocks
12.8.5	Least concern	Complex notophyll vine forest on Cainozoic igneous rocks, usually at altitude of more than 600m
12.8.6	Of concern	Simple microphyll fern forest with *Nothofagus moorei* on Cainozoic igneous rocks
12.8.7	Of concern	Simple microphyll fern thicket with *Acmena smithii* on Cainozoic igneous rocks
12.9-10.16	Of concern	Araucarian microphyll to notophyll vine forest on Cainozoic and Mesozoic sediments
12.11.1	Least concern	Simple notophyll vine forest often with abundant *Archontophoenix cunninghamiana* (gully vine forest) on metamorphics +/- interbedded volcanics
12.11.10	Least concern	Notophyll vine forest +/- *Araucaria cunninghamii* on metamorphics +/- interbedded volcanics

8.1.2 Survey sites and methods

The distribution of nine bushfire-impacted rainforest REs within the project area was intersected with PEI mapping to map and analyse likely ecological impacts (Figure 61). The areas of each impacted rainforest RE were calculated across Queensland, within the project area and within the burnt extent (Table 35).

An inventory of existing rainforest survey plots established within the project area was undertaken in order to capture any available pre-fire ecosystem data. Of the 30 long-term rainforest plots identified, only three were found to have burnt in the 2019–2020 bushfires at Lamington NP within RE 12.8.4 (moderate-high, high and high-catastrophic PEI – see Laidlaw *et al.* 2022). A fourth burnt plot is located just outside of the study area within RE 12.8.5 in Gambubal State Forest, adjoining Main Range NP. Twenty-four unburnt 20 x 20m long-term survey sites across four REs (12.8.3, 12.8.4, 12.8.5, 12.8.6) were re-located and resurveyed to assess condition, drought impacts and to provide baseline data in the case of future fire impact. Two new BioCondition plots (after Eyre *et al.* 2015) were also established in Main Range NP to monitor the bushfire recovery within RE 12.8.5 subjected to both low-moderate and moderate-high PEI (Figures 61 and 62).

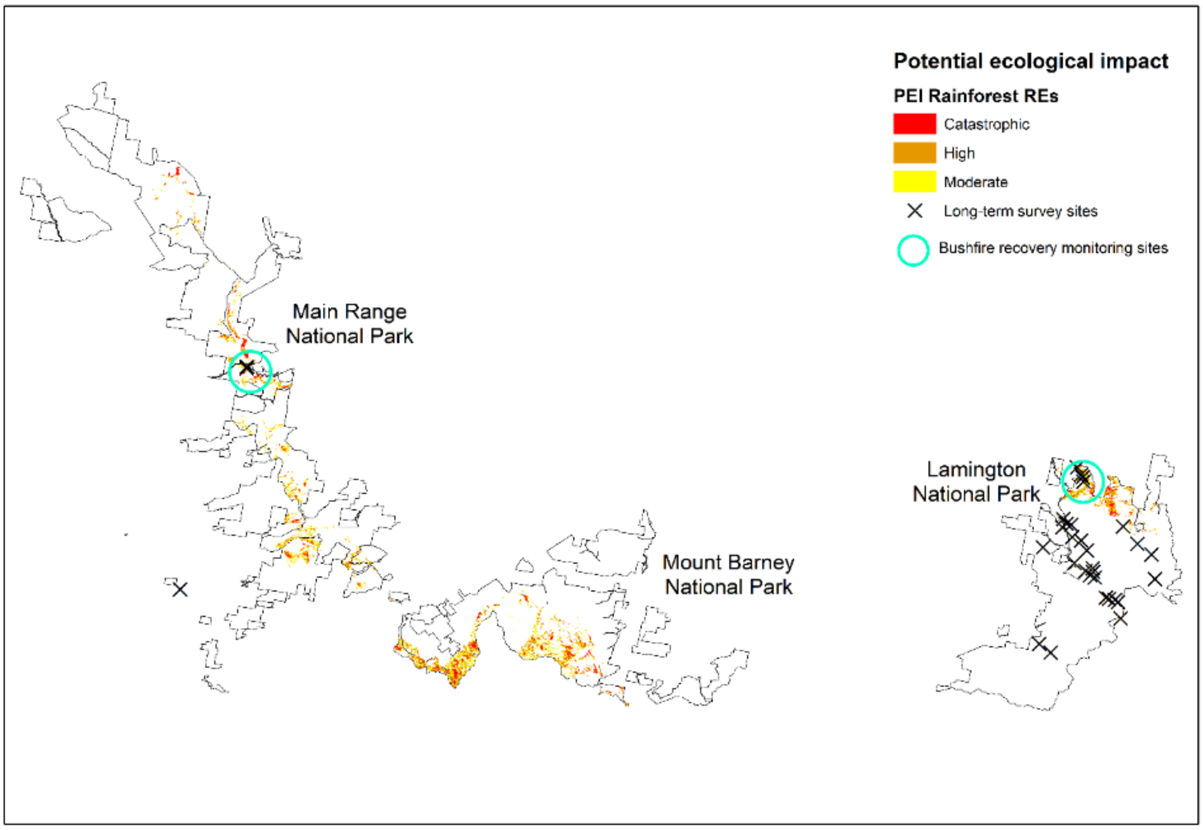

Figure 61: Distribution of fire-impacted rainforest REs coloured by PEI, with locations of long-term survey sites resurveyed between 2020 and 2022.

Figure 62: Regional Ecosystem 12.8.5 at Main Range NP in October 2020 with high to catastrophic potential ecological impacts. (Photo: M.Laidlaw)

8.1.3 Survey results

A total of 3,888ha of rainforest was burnt during the 2019–2020 bushfires. The rainforest REs with the greatest area impacted by bushfire within the project area were 12.8.4 and 12.8.5, however these are widespread REs within the project area and only 13 and 14% (respectively) burnt (Table 35). RE 12.11.1 had 58% of its distribution burnt, but it has a limited distribution within the project area (253ha) representing only 4% of its distribution in Queensland.

As all impacted rainforest REs within the project area are sensitive to fire incursion, all burnt rainforest is considered to have been subjected to at least moderate ecological impacts (Figure 63). Field observations have confirmed that high to catastrophic PEI often relates to a loss of canopy closure, a major disturbance to rainforest communities. The RE with the largest relative 'area of greatest concern' (after Laidlaw *et al.* 2022) and defined as high to catastrophic PEI) was found to be 12.8.7 (simple microphyll fern thicket), with 71% of the area burnt experiencing high to catastrophic impacts. All rainforest REs experienced significant ecological impacts however, as even the RE with the smallest 'area of greatest concern', RE 12.8.6, likely experienced high to catastrophic ecological impacts over 42% of the area burnt (Figure 63). This analysis highlights both the unprecedented impact of this event on rainforest REs and the need for ongoing monitoring and recovery actions to aid recovery.

For detailed information on the fire impacts to wet sclerophyll forest/ecotones in Lamington, Mt Barney NP and Main Range NPs see Hines *et al.* (2020, 2022 & 2021, respectively).

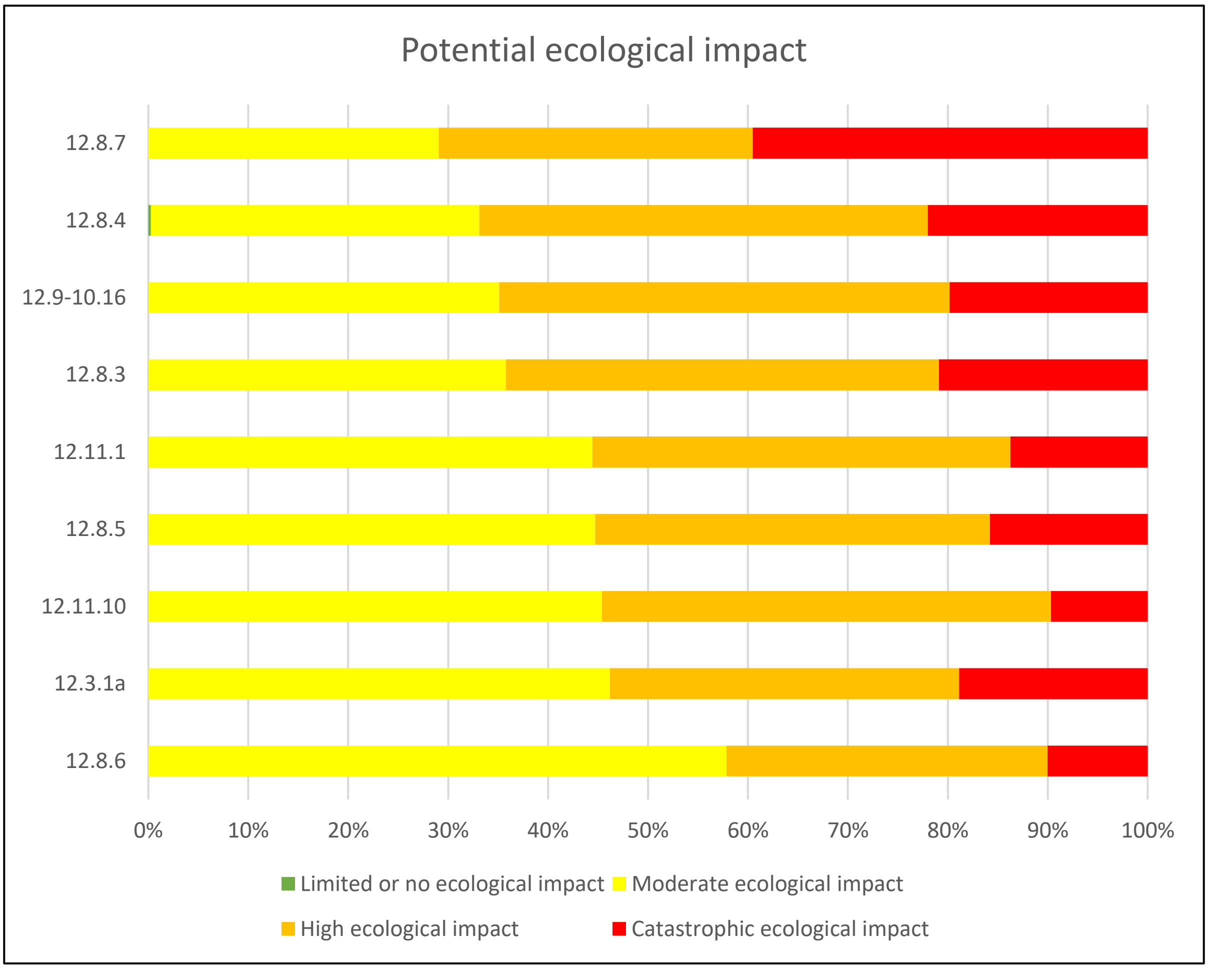

Figure 63: Rainforest REs prioritised by 'area of greatest concern' as defined by high-catastrophic PEI

Table 35: Rainforest REs impacted by the 2019–2020 bushfires in GWHA.

Regional Ecosystem	Area of remnant RE in Queensland (ha)	Area of remnant RE within the project area (ha)	% of remnant RE within project area	Area of remnant RE burnt within the project area (ha)	% of remnant RE burnt within the project area
12.3.1a	4626	29	1	1	2
12.8.3	11,004	4,510	41	17	0.4
12.8.4	13,722	5,852	43	786	13
12.8.5	18,278	15,520	85	2,159	14
12.8.6	867	826	95	11	1
12.8.7	779	664	85	162	24
12.9-10.16	7,958	7,958	100	232	3
12.11.1	10,391	434	4	253	58
12.11.10	43,671	43,671	100	267	1

8.1.4 Discussion

Field surveys of burnt and unburnt plots within REs 12.8.3, 12.8.4, 12.8.5 and 12.8.6 revealed that where rainforest burnt with low to moderate PEI, the canopy largely remained intact. Impacts were significant to the seedling and sapling layer, where mortality and the subsequent loss of diversity was high. Some large trees were also impacted where fire was able to burn out the root ball, causing tree death. In these cases, the pioneer plant response was found to be largely dominated by native species including giant stinging tree *Dendrocnide excelsa*, bleeding heart *Homalanthus populifolius* and the Solanums *Solanum inequilaterum*, *S. vicidum* and *S. aviculare*. At higher PEIs, however, tree damage and death leading to canopy openness facilitated high cover of non-native pioneers including inkweed *Phytolacca octandra*, devil's fig *Solanum torvum* and Lantana *Lantana camara.* Rainforests subjected to these higher-order impacts may take decades, even centuries, to recover. Plots will continue to be monitored to assess their recovery trajectory.

Fire-impacted rainforest REs may also be at risk from:

- a loss of fire-sensitive biodiversity or in extreme cases, transition to a fire tolerant RE
- an increased risk from invasion from fire-promoting weeds, including high biomass vines and *Lantana camara*
- an increased threat from invasive fauna including cats, foxes and cane toads
- risk of incursion from cattle.

Further information on the ecological impacts to ecosystems from the 2019–2020 bushfires is provided by Hines *et al.* (2020, 2021 & 2022) for Lamington, Main Range and Mt Barney NPs, respectively.

8.1.5 Recommendations

Reducing ongoing threats

- Protect rainforest ecosystems from fire

  Reduce the risk of incursion of future fire into rainforest ecosystems through strategic planned burn programs in adjacent sclerophyll communities.

- Reduce impacts of pigs and deer

  Monitor feral pigs and deer and undertake strategic control to support natural regeneration and recovery in fire-impacted rainforest ecosystems.

- Reduce impacts of cattle

  Aim to exclude cattle from rainforest and dry vine forest to avoid trampling and herbivory of regenerating species.

- Reduce impacts of weeds

  Prevent the establishment of invasive high-biomass grasses, vines, herbs and *Lantana camara*, immediately adjacent to and within burnt rainforests, with regular and ongoing treatment in the growing season. Monitor tree and shrub weeds in burnt rainforests and undertake targeted control on a 6–12 month basis.
  Monitor and undertake strategic thinning of native vine, shrub or tree species that inhibit broad-scale post-fire recovery of the fire-impacted rainforest ecosystems.

- Prevent human impacts

  Restoration planting within the World Heritage Area can introduce novel genetic material, invasive plants or fungi (e.g. orange pore fungus *Favolaschia calocera*) and pathogens including myrtle rust (*Austropuccinia psidii*) and is not supported. Soil compaction from repeated visitation to a site is detrimental to rainforest soils and can impact natural regeneration processes.

Ecological monitoring

- Sustain and extend the monitoring program established during this project

  Continue to regularly monitor the fire-impacted IBISCA plots at Lamington NP and the Gambubal plots at Main Range NP to track recovery.

  Establish additional long-term vegetation monitoring plots in other fire-impacted rainforest ecosystems.

  Monitor for pathogens such as myrtle rust.

- Health Checks (Melzer *et al.* 2019) within impacted rainforest communities will facilitate early detection of weeds and enable condition to be evaluated.

Ecological research

- Develop methodology to detect and quantify delayed fire impacts in rainforests

  Low severity understorey fires can have significant ecological impacts in rainforest ecosystems which can be difficult to detect through the initial post-fire assessment process. The remote sensing technique targets the canopy, which may remain intact despite impacts to lower strata, or canopy death may be delayed compared to other forest types. A pilot project to utilise remote sensing tools to detect delayed impacts in rainforest is currently underway and warrants further development.

8.2 Wet sclerophyll forests/ecotones

8.2.1 Conservation context

Wet eucalypt open forests and rainforest/eucalypt forest ecotones (hereafter referred to as wet sclerophyll forests/ecotones) have a fire tolerant canopy and a fire-sensitive understorey (Queensland Herbarium 2021). The understorey may vary to be dominated by grasses, shrubs or rainforest dependent on rainfall, geology, elevation and most notably, time since fire.

Of the 42 REs impacted within the project area, seven are wet eucalypt open forests/ecotones (Table 36). Three REs are classed as ‘Of concern’ under the VMA, meaning that remnant vegetation is 10–30% of its pre-clearing extent across the bioregion; or more than 30% of its pre-clearing extent remains, and the remnant extent is less than 10,000ha.

Table 36: Regional ecosystems (RE) with a fire tolerant canopy and frequently with a fire-sensitive understorey across GWHA and their classification under the VMA.

RE	VMA class	Short description
12.3.2	Of concern	*Eucalyptus grandis* tall open forest on alluvial plains
12.3.7	Least concern	*Eucalyptus tereticornis*, *Casuarina cunninghamiana* subsp. *cunninghamiana* +/- *Melaleuca* spp. fringing woodland
12.3.9	Of concern	*Lophostemon confertus* open forest on Cainozoic igneous rocks
12.8.8	Of concern	*Eucalyptus saligna* or *E. grandis* tall open forest on Cainozoic igneous rocks
12.8.9	Least concern	*Lophostemon confertus* open forest on Cainozoic igneous rocks
12.8.14b	Least concern	*Eucalyptus eugenioides*, *E. biturbinata*, *E. melliodora* +/- *E. tereticornis*, *Corymbia intermedia* open forest on Cainozoic igneous rocks
12.9-10.14a	Least concern	*Eucalyptus pilularis* tall open forest on sedimentary rocks

8.2.2 Survey sites and methods

The distribution of seven bushfire-impacted wet sclerophyll forest/ecotone REs within the project area was intersected with PEI mapping to map and analyse likely ecological impacts (Figure 64). The areas of each impacted RE were calculated across Queensland, within the project area and within the fire extent (Table 37).

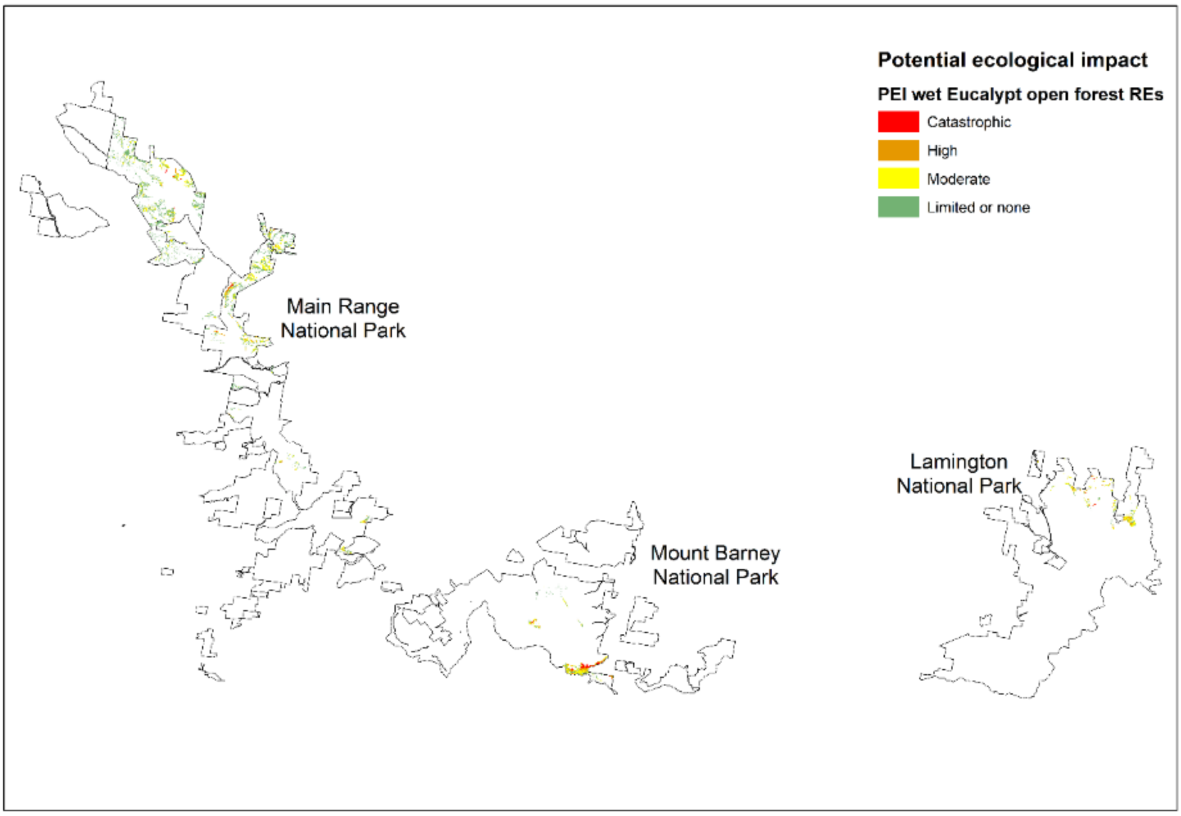

Figure 64: Distribution of fire-impacted wet sclerophyll forest/ecotone REs coloured by PEI.

Table 37: The extent of wet sclerophyll forest/ecotone REs impacted by the 2019–2020 bushfires in GWHA.

RE1	Area of remnant RE in Queensland (ha)	Area of remnant RE within the project area (ha)	% of remnant RE within project area	Area of remnant RE burnt within the project area (ha)	% of remnant RE burnt within the project area
12.3.2	6,584	43	1	12	29
12.3.7	58,552	191	0.3	0.5	0
12.3.9	747	143	19	15	11
12.8.8	4,546	254	6	75	29
12.8.9	11,152	5,028	45	1,169	23
12.8.14b	177	83	47	16	19
12.9-10.14a	1,585	163	10	154	94

8.2.3 Survey results

A total of 1,442ha of wet sclerophyll forest/ecotone was burnt during the 2019–2020 bushfires. Wet eucalypt open forests or rainforest/eucalypt forest ecotone REs are generally of limited mapped extent especially within Lamington and Mt Barney NPs (Figure 64). However, these REs can occur in narrow bands below the scale of RE mapping, meaning that the impacts quantified here are likely to be an underestimate. The RE with the greatest area impacted by bushfire within the project area was 12.8.9, with around a quarter (23%) of its distribution within the project area burnt (Table 37). RE 12.9–10.14a was extensively impacted, with 94% of its distribution within the project area burnt.

All wet sclerophyll forest/ecotone REs burnt within the project area are dominated by tree species which tolerate fire or rely upon it for regeneration (Table 36). The Regional Ecosystem Fire Guidelines (Queensland Herbarium 2021) describe the appropriate burn season, intensity and interval between fires for each of these wet sclerophyll forest/ecotone REs. The RE with the largest relative 'area of greatest concern' within the project area was found to be 12.3.2 (*Eucalyptus grandis* tall open forest on alluvial plains), with 27% of the area burnt experiencing high to catastrophic ecological impacts. For three of the seven impacted wet sclerophyll/ecotone REs (RE 12.3.9, 12.3.7 and 12.8.14b), the 'area of greatest concern' represented less than 1% of the area burnt, with fires generally resulting in limited or no ecological impact (Figure 65). For detailed information on the fire impacts to wet sclerophyll forest/ecotones in Lamington, Mt Barney NP and Main Range NPs see Hines *et al.* (2020, 2022 & 2021, respectively).

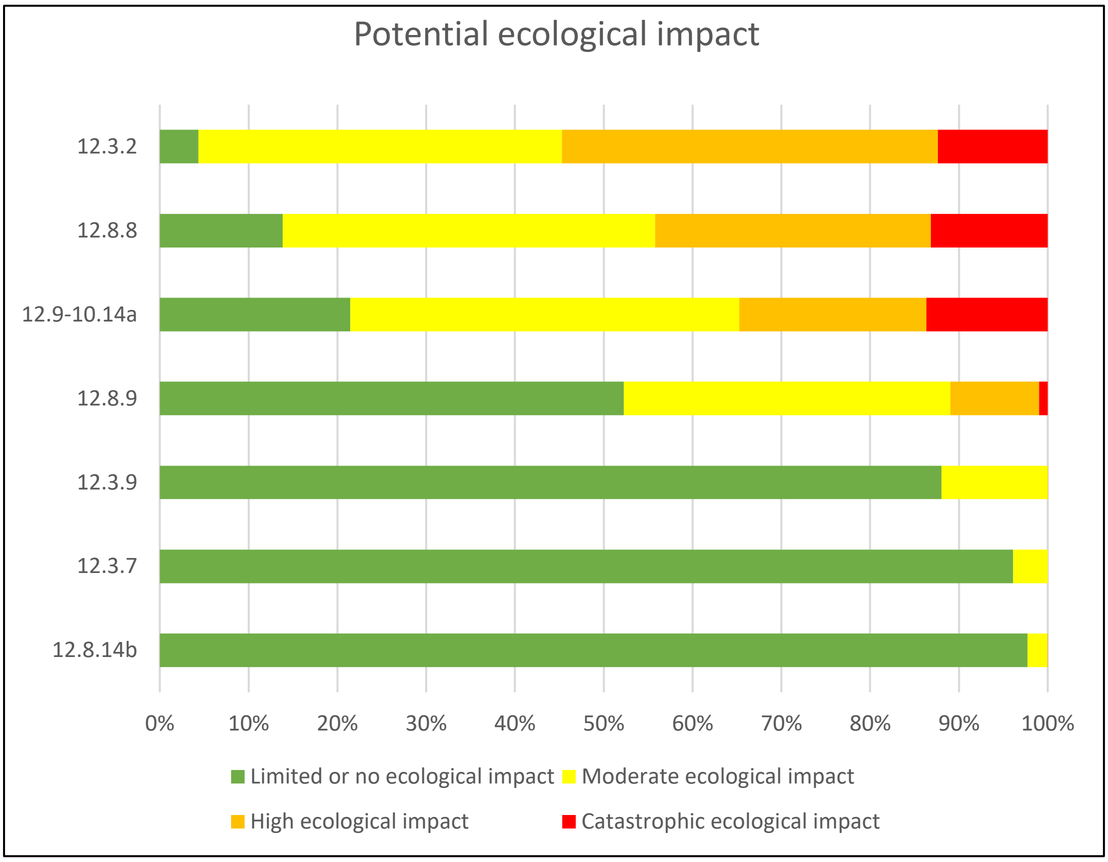

Figure 65: Wet sclerophyll forest/ecotone REs prioritised by 'area of greatest concern' as defined by high-catastrophic PEI levels.

8.2.4 Discussion

Despite the presence of a fire tolerant canopy, the ecological impacts from the 2019–2020 bushfires in wet sclerophyll forest/ecotone REs may result in:

- loss of fire-sensitive flora and fauna, including rainforest-dependent species
- increased risk of incursions of ecosystem transforming weeds, such as high-biomass grasses and *Lantana camara*
- increased flammability due to high biomass regrowth of native and non-native plant species
- increased risk of bell minor associated dieback (BMAD), especially where *Lantana camara* is prevalent
- increased threats from pest animals, including cats, foxes and cane toads.

Further information on the ecological impacts to ecosystems from the 2019–2020 bushfires is provided by Hines *et al.* (2020, 2021 & 2022) for Lamington, Main Range and Mt Barney NPs, respectively.

Figure 66: Regional Ecosystem 12.8.1/12.8.5 ecotone at Mt Barney NP in March 2020 with moderate PEI. (Photo: H. Hines)

8.2.5 Recommendations

Reducing ongoing threats

- Protect recovering wet sclerophyll/ecotone ecosystems from fire

  Review park-level fire strategies and approved planned burns for wet sclerophyll/ecotone ecosystems to allow for the recovery of areas impacted by the 2019–2020 bushfires, and to ensure that a range of fire age classes are maintained, including long-unburnt.

- Reduce impacts of pigs and deer

  Monitor the presence of feral pigs and deer and undertake strategic control to support natural regeneration and recovery in fire-impacted wet sclerophyll/ecotone ecosystems.

- Prevent incursion of cattle into regenerating wet sclerophyll/ecotone ecosystems

  Priority areas for the exclusion or removal of cattle at Main Range NP include Cryptocarya, South Branch of Emu, Steamer, Pinchgut, Reedy, Barney, Swan, Millar Vale, North Branch, Blackfellows, Greenhide and Laidley Creeks. Priority areas at Mt Barney NP include Burnett Ck catchment, and at Lamington NP they include Laheys Tabletop, Canungra and Coomera valleys.

- Reduce impacts of weeds

  Prevent the establishment of invasive high-biomass grasses, vines, herbs and *Lantana camara*, immediately adjacent to burnt wet sclerophyll/ecotone ecosystems, with regular and ongoing treatment in the growing season.

  Monitor tree and shrub weeds in burnt wet sclerophyll/ecotone ecosystems and undertake targeted control on a 6–12-month basis.

  Monitor and undertake strategic thinning of native vine, shrub or tree species that inhibit broad-scale post-fire recovery of burnt wet sclerophyll/ecotone ecosystems.

- Prevent human impacts

  Restoration planting within the World Heritage Area can introduce novel genetic material, invasive plants or fungi (e.g. orange pore fungus *Favolaschia calocera*) and pathogens including myrtle rust (*Austropuccinia psidii*) and is not supported. Soil compaction from repeated visitation to a site is detrimental to rainforest soils and can impact natural regeneration processes.

Ecological monitoring

- Sustain and extend the monitoring program established during this project

  Continue to regularly monitor vegetation of the fire-impacted wet eucalypt plots to track recovery.

  Establish long-term vegetation monitoring plots in wet sclerophyll communities to track recovery and understand fire response.

  Monitor for pathogens such as myrtle rust.

- Health Checks (Melzer *et al.* 2019) within impacted rainforest communities will facilitate early detection of weeds, pest animals and enable condition to be evaluated.

Ecological research

- Investigate the impacts to wet eucalypt forests and ecotones (between rainforests and sclerophyll forests) of a projected increased fire frequency under future climates.

8.3 Dry sclerophyll

8.3.1 Conservation context

'Dry sclerophyll' regional ecosystems are defined here as having both a fire tolerant canopy and understorey and are often reliant upon fire of an appropriate severity and interval for part of their life history (Queensland Herbarium 2021). Of the 42 REs impacted within the project area, 26 are grouped as dry sclerophyll ecosystems (Table 38), incorporating eucalypt open forests and woodlands, montane heaths and grassland. One small patch of fire-tolerant swamp (RE 12.3.8a, 0.2ha) from Main Range NP is also included in this group for ease of reporting. Two of these REs are classed as 'Endangered' under the VMA meaning either that less than 10% of their pre-clearing extent across their bioregion remains as remnant vegetation, or 10–30% of their pre-clearing extent remains, and less than 10,000ha of remnant vegetation remains. Eleven REs are classed as 'Of concern' under the VMA, meaning that remnant vegetation is 10–30% of its pre-clearing extent across the bioregion; or more than 30% of its pre-clearing extent remains, and the remnant extent is less than 10,000ha.

8.3.2 Survey sites and methods

The distribution of 26 bushfire-impacted dry sclerophyll REs within the project area was intersected with PEI mapping to map and analyse likely ecological impacts (Figure 67). The areas of each impacted RE were calculated across Queensland, within the project area and within the fire extent (Table 39).

Four BioCondition (Eyre *et al.* 2015) monitoring plots were established in burnt and unburnt RE 12.11.6 and 12.8.19 across GWHA to monitor bushfire recovery and to provide baseline data in the case of future fires (Figure 67). Montane heath surveys will contribute to forming a new BioCondition benchmark for RE 12.8.19 (Figure 68).

8.3.3 Survey results

A total of 14,747ha of dry sclerophyll REs was burnt during the 2019–2020 bushfires. The dry sclerophyll REs with the largest area of impact from the fires were 12.8.14 and 12.8.1 (Figures 69 and 70). The entire mapped extent of RE 12.11.6 within the project area was burnt, however this constitutes less than 1% of the range of this ecosystem in Queensland (Figure 68). In addition to having a large area burnt, RE 12.8.1 is likely to have experienced the most significant ecological impacts, with 16.2% of the area burnt being 'of concern' (high-catastrophic PEI) (Figures 69 and 70). RE 12.8.12 experienced moderate ecological impacts at a minimum level across the project area (Figure 70). However, only limited areas of moderate to catastrophic ecological impacts were incurred by most dry sclerophyll REs. BioCondition plots will continue to be monitored to assess post-fire recovery (Figure 67).

Table 38: Regional ecosystems (RE) with a fire tolerant canopy and understorey in GWHA and their classification under the VMA.

RE	VMA class	Short description
11.3.23	Of concern	*Eucalyptus conica, E. nobilis, E. tereticornis, Angophora floribunda* woodland on alluvial plains. Basalt derived soils
11.8.8	Least concern	*Eucalyptus albens, E. crebra* woodland on Cainozoic igneous rocks
12.3.3	Endangered	*Eucalyptus tereticornis* woodland on Quaternary alluvium
12.3.8a	Of concern	Swamps with *Cyperus* spp., *Schoenoplectus* spp. and *Eleocharis* spp.
12.8.1	Least concern	*Eucalyptus campanulata* tall open forest on Cainozoic igneous rocks
12.8.2	Of concern	*Eucalyptus oreades* +/- *E. campanulata* tall open forest. Occurs on Cainozoic igneous rocks.
12.8.11	Of concern	*Eucalyptus dunnii* tall open forest on Cainozoic igneous rocks
12.8.12	Of concern	*Eucalyptus obliqua* tall open forest. Occurs on Cainozoic igneous rocks.
12.8.14	Least concern	*Eucalyptus eugenioides*, *E. biturbinata, E. melliodora +/- E. tereticornis, Corymbia intermedia* open forest on Cainozoic igneous rocks
12.8.14a	Least concern	*Eucalyptus eugenioides, E. biturbinata, E. melliodora +/- E. tereticornis, Corymbia* intermedia open forest on Cainozoic igneous rocks
12.8.15	Of concern	*Poa labillardierei* var. *labillardierei* grassland. Occurs on Cainozoic igneous rocks.
12.8.16	Of concern	*Eucalyptus crebra +/- E. melliodora, E. tereticornis* woodland on Cainozoic igneous rocks
12.8.17	Least concern	*Eucalyptus melanophloia +/- E. crebra, E. tereticornis, Corymbia tessellaris* woodland on Cainozoic igneous rocks
12.8.19	Of concern	Heath and rock pavement with scattered shrubs or open woodland on Cainozoic igneous hills and mountains
12.8.20	Of concern	Shrubby woodland with *Eucalyptus racemosa* subsp. *racemosa* or *E. dura* on Cainozoic igneous rocks
12.8.24	Endangered	*Corymbia citriodora* subsp. *variegata* open forest on Cainozoic igneous rocks especially trachyte
12.8.25	Of concern	Open forest with *Eucalyptus acmenoides* or *E. helidonica* on Cainozoic igneous rocks especially trachyte
12.9-10.2	Least concern	*Corymbia citriodora* subsp. *variegata +/- Eucalyptus crebra* open forest on sedimentary rocks
12.9-10.5	Least concern	Woodland complex often with *Corymbia trachyphloia subsp. trachyphloia, C. citriodora subsp. variegata, Eucalyptus crebra, E. fibrosa* subsp. *fibrosa* on quartzose sandstone
12.9-10.5d	Least concern	Woodland complex often with *Corymbia trachyphloia* subsp. *trachyphloia, C. citriodora* subsp. *variegata, Eucalyptus crebra, E. fibrosa* subsp. *fibrosa* on quartzose sandstone
12.9-10.7	Of concern	*Eucalyptus crebra +/- E. tereticornis, Corymbia tessellaris, Angophora* spp. and *E. melanophloia* woodland on sedimentary rocks
12.9-10.17a	Least concern	*Eucalyptus acmenoides, E. major, E. siderophloia +/- Corymbia citriodora* subsp. *variegata* open forest on sedimentary rocks
12.9-10.17e	Least concern	*Eucalyptus acmenoides, E. major, E. siderophloia +/- Corymbia citriodora* subsp. *variegata* open forest on sedimentary rocks
12.11.3	Least concern	*Eucalyptus siderophloia, E. propinqua +/- E. microcorys, Lophostemon confertus, Corymbia intermedia, E. acmenoides* open forest on metamorphics +/- interbedded volcanics
12.11.6	Least concern	*Corymbia citriodora* subsp. *variegata, Eucalyptus crebra* woodland on metamorphics +/- interbedded volcanics
12.12.5	Least concern	*Corymbia citriodora* subsp. *variegata, Eucalyptus crebra* woodland on Mesozoic to Proterozoic igneous rocks

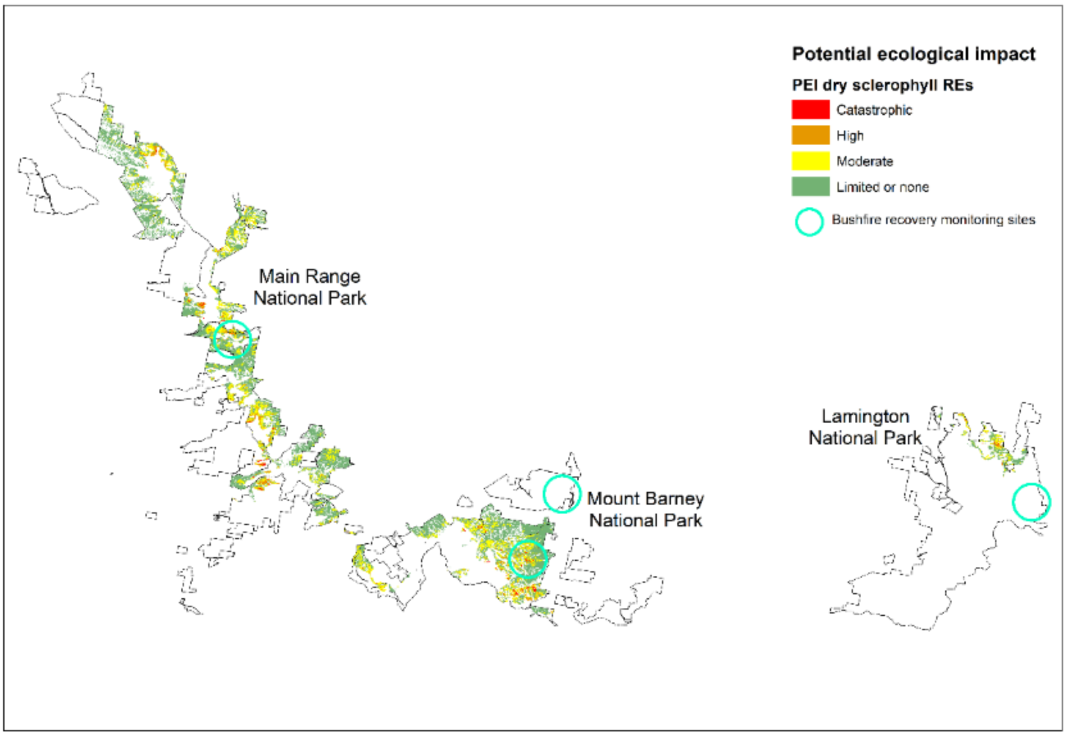

Figure 67: The location of four BioCondition (Eyre *et al.* 2015) monitoring plots established in RE 12.11.6 and 12.8.19 across GWHA.

Figure 68: The summit of Mt Barney with RE 12.8.19 with high PEI level. (Photo: M. Laidlaw, October 2020)

Table 39: The extent of dry sclerophyll REs impacted by the 2019–2020 bushfires in GWHA.

RE	Area of remnant RE in Queensland (ha)	Area of remnant RE within the project area (ha)	% of remnant RE within project area	Area of remnant RE burnt within the project area (ha)	% of remnant RE burnt within the project area
12.3.3	26,790	28	0.1	4	15
11.3.23	662	15	2	3	17
11.8.8	4,546	254	6	0.3	0.1
12.3.8a	6	0.2	3	0.1	91
12.8.1	10,018	8,629	86	3,322	38
12.8.2	345	277	80	237	85
12.8.11	232	185	80	63	34
12.8.12	57	15	26	1	8
12.8.14	44,446	13,029	29	4,533	35
12.8.14a	713	7	1	4	62
12.8.15	654	0.5	0.1	0.4	77
12.8.16	35,647	2,888	8	1,422	49
12.8.17	26,235	3,763	14	1,267	34
12.8.19	2,262	869	38	212	24
12.8.20	7,268	2,812	39	561	20
12.8.24	3,839	1,080	28	109	10
12.8.25	3,349	1,252	37	425	34
12.9-10.2	93,767	1,050	1	314	30
12.9-10.5	3,032	32	1	27	84
12.9-10.5d	1,639	523	32	116	22
12.9-10.7	33,628	528	2	239	45
12.9-10.17a	4,089	201	5	105	52
12.9-10.17e	3,547	1,922	54	720	37
12.11.3	90,041	697	1	444	64
12.11.6	279,893	573	0.2	573	100
12.12.5	194,701	56	0.03	45	79

Figure 69: Regional Ecosystem 12.8.1 on the summit of Mt Ernest in Mt Barney NP in October 2020 with high potential ecological impacts. (Photo: M. Laidlaw)

Figure 70: Dry sclerophyll REs prioritised by ‘area of greatest concern’ as defined by high-catastrophic PEI.

8.3.4 Discussion

Many of the priority species highlighted for survey and monitoring after the 2019–2020 bushfires are montane heath species. As a result, field surveys of burnt and unburnt REs 12.8.19 (heath and rock pavement with scattered shrubs or open woodland on Cainozoic igneous hills and mountains) were prioritised for survey. While fire tolerant, long inter-fire intervals of 20–50 years are recommended for this RE (Queensland Herbarium 2021). The montane heath surveys conducted one year and two years post-fire showed gradual recovery, with little weed incursion. Montane heath subjected to high PEI may take decades to recover. Many of the areas surveyed have been subjected in increased visitation since the 2019–2020 bushfires making trampling and compaction increasing threats. Established monitoring plots will continue to be assessed to track their recovery trajectory.

Additional threats to the recovery of fire-impacted dry sclerophyll REs include: an increased risk from invasion from ecosystem transforming weeds (including high-biomass grasses and *Lantana camara*) and pest animals (such as cats, foxes and cane toads) and a risk of incursion from non-native herbivores including cattle and horses. Further information on the ecological impacts to ecosystems from the 2019–2020 bushfires is provided by Hines *et al.* (2020, 2021 & 2022) for Lamington, Main Range and Mt Barney NPs, respectively.

8.3.5 Recommendations

Reducing ongoing threats

- Protect unburnt montane heath and shrubland refugia

  To allow burnt communities to recover sufficiently, prioritise suppression of bushfires that threaten montane heaths and shrublands. Avoid the use of fire retardants and gels. Limited use of aerial incendiaries may be warranted to reduce fire severity if the unburnt or recovering montane communities come under direct threat of bushfire

  Review park-level fire strategies and approved planned burns within dry eucalypt forests and woodlands, montane heaths and shrublands, to allow for the recovery of areas impacted by the 2019–2020 bushfires, and to ensure that the recommended range of fire age classes are maintained

  Reduce the risk of future fire encroachment into adjacent rainforest and identify and protect long-unburnt dry eucalypt forest refugia.

- Reduce impacts of pigs and deer

  Monitor the presence of feral pigs and deer and undertake strategic control to support natural regeneration and recovery in fire-impacted dry sclerophyll communities.

- Prevent incursion of cattle into regenerating dry sclerophyll communities.
- Reduce impacts of weeds

  Prevent establishment of high-biomass grasses, vines, herbs and *Lantana camara*, especially in areas adjacent to fire-sensitive communities such as rainforest, with regular and ongoing treatment in the growing season. Monitor tree and shrub weeds and undertake targeted control on a 6–12-month basis

  Support the release of biological control agents to reduce impacts from *Ageratina* weed species.

- Prevent human impacts

  Restrict visitor access across rocky pavements, outcrops and cliff tops to avoid trampling, illegal collecting and nutrient additions (food waste/excrement)

  Restoration planting within the World Heritage Area can introduce novel genetic material, invasive plants or fungi (e.g. orange pore fungus *Favolaschia calocera*) and pathogens including myrtle rust *Austropuccinia psidii* and is not supported. Soil compaction from repeated visitation to a site is detrimental to rainforest soils and can impact natural regeneration processes.

Ecological monitoring

- Establish long-term vegetation monitoring plots to evaluate the rate and direction of recovery and to fill knowledge gaps with respect to the fire response of species (Queensland Herbarium and Ecological Assessment Unit with support from Regional Technical Support and Management Unit and/or external researchers).
- Monitor for increased biosecurity risk from pathogens such as myrtle rust (which favours new growth, common post-fire).
- Undertake Health Checks (Melzer *et al.* 2019) to facilitate early detection of pest plants and animals and cattle and enable condition to be evaluated across the estates

Ecological research

- Undertake a basic inventory of the natural values of Swanfels SF (Main Range), in particular to confirm the presence and condition of threatened ecological communities.
- Assess the impacts of feral horses on the natural values of Swanfels SF (Main Range) and undertake control to reduce or remove impacts.

9 Reducing threats to recovery

Reducing threats to the outstanding natural values of the protected areas across GWHA is an ongoing priority for QPWS park management. Key values are identified through the Values Based Management Framework (DES 2020) which guides the development of park management plans and related park strategies, such as for fire and pest management, with the intent to implement an adaptive management approach.

As land managers, QPWS complies with the general biosecurity obligation under the state *Biosecurity Act 2014* to minimise the risks presented by invasive plants and animals. QPWS also works collaboratively with local government and adjoining landholders to achieve a more effective landscape-scale approach to control in line with the Queensland Invasive Plants and Animals Strategy 2019–2024 (Department of Agriculture and Fisheries 2019).

Following the 2019–2020 bushfires, the key threats to the recovery of priority threatened species in the post-fire landscape were identified by experts (Threatened Species Operations 2020). The location and focus of on-ground actions to reduce threats were determined using modelled habitat maps for priority species, park rangers' local knowledge and budget constraints.

9.1 Fire

The broad extent of the 2019 bushfires across GWHA was a result of the prolonged drought, above average temperatures, very low relative humidity and gusty winds that created dangerous fire conditions (Hines *et al.* 2020, 2021 & 2022). It was recognised that any subsequent fire in the near future could be catastrophic for the recovery of threatened species. It was therefore critical to consider immediate actions that could mitigate that risk, as well as those that proactively reduce the threat of unplanned fires in core habitats, over the medium and longer term.

Critical firelines

QPWS park management worked quickly after the 2019–2020 fires to remove hazards along the vehicle track network and restore safe access which would support an emergency response to any subsequent fire. The condition of critical firelines was reviewed in terms of the location of core habitat for priority species, local knowledge from park rangers of the likely fire pathways and the flammability of associated vegetation types. Over 100kms of firelines were upgraded or established across GWHA, with 8km in Lamington NP, 61km in Mt Barney NP and 32km in Main Range NP, alongside maintenance works to other firelines. To support an emergency fire response in the remote sections of Mt Barney NP, two water tanks were installed. These actions have provided more effective access and capability for an emergency response for future bushfire events, and therefore, a greater ability to limit the progression of fire into important habitats for priority threatened species and recovering ecosystems.

Planned burns

QPWS have an ongoing program of planned burns as part of the fire strategy for each park to protect key natural values. Implementation of strategic planned burns in fire-adapted vegetation communities, such as dry eucalypt woodland, serves to reduce the fuel hazard and hence, the potential severity of a bushfire. As a result, park managers have a greater capacity to control bushfire in the landscape and protect core refugia for threatened species populations. The use of planned burns to meet ecological guidelines (Queensland Herbarium 2021) can achieve important conservation outcomes by maintaining ecological health and a diversity of vegetation types across the park. Managing fire frequency can be critical to protecting some threatened species. Planned burns can support the provision of the diverse ecological conditions and resources required by resident wildlife species, such as the grassy woodlands and forests required by the Hastings River mouse (section 3.4). An annual fire management program schedules planned burns in an optimal seasonal window, with the timing determined by suitable fire conditions. Given the extent and severity of the 2019–2020 bushfires, the planned burn program was revised to adapt to the changed conditions, maintain suitable habitat for recovering priority species and mitigate the risk of future fires. Planned burns were conducted across 6,585ha of GWHA in fire-adapted vegetation to reduce the risk of future fires and high fire severity fires (e.g. Figure 71). This included 244ha in Lamington NP, 869ha in Mt Barney NP and 2,123ha across Main Range NP.

Fire strategy

The fire strategy for each national park across GWHA identifies the prioritised 'key values' and the associated objectives of, and approach to, planned fire management across the park. Mapped zones highlight the areas for protecting life and infrastructure, as well as for fire exclusion, conservation and mitigating the potential impacts of bushfire. The development of the strategy is guided by the state-wide QPWS Fire Management Strategy 2021–2026 (DES 2021) and centred on the Values Based Management Framework (DES 2020). Following the 2019–2020 fires, the fire strategies for Lamington, Mt Barney and Main Range NPs were revised to support the recovery of priority threatened species and ecosystems.

Figure 71: A cool planned burn at Mt Maroon, in Mt Barney NP in 2022 to protect montane heath from future fires.

9.2 Pest animals

Key pest animal threats to the recovery of priority threatened species were identified by experts (Threatened Species Operations 2020). Following consultation with park management, pigs, cats and wandering stock were strategically targeted for enhanced control efforts.

Pigs

Feral pigs broadly can cause extensive damage to crucial habitats, including creeklines that provide core habitat for priority frog species and important water sources for other threatened species, especially post-fire. Pigs can also predate upon or trample small vertebrates and invertebrates, and destroy their microhabitats, which can have significant consequences for priority species and endemic invertebrates recovering from the 2019–2020 bushfires. Pig control also mitigates the risk of introducing or dispersing weeds and pathogens, such as myrtle rust.

To detect pigs, outdoor trail cameras were deployed by park rangers at various sites across Mt Barney and Main Range NPs, with a likely chance of pig activity. Feral pigs were also identified on cameras deployed for ecological monitoring, which was relayed to park management to further guide control efforts. Pig traps were established, with pre-feeding of corn to condition pigs to traps, followed by the use of Hoggone® bait in specialised Hoggone® hoppers to specifically target lethal bait uptake by pigs. As a result, a total of 10 pigs at Mt Barney NP and 52 pigs at Main Range NP were removed from the park during the program.

Cattle

The intrusion of significant numbers of cattle into the protected areas of GWHA is an ongoing concern, particularly in a post-fire landscape. Cattle present a threat to the natural regeneration of ecosystems by foraging on, and trampling, regrowth and germinating seedlings, as well as fostering the spread of weeds. Cattle can damage core habitats for priority species and soil critical water sources for wildlife. At Main Range NP a total of 27 cattle were mustered and removed from the park in collaboration with adjoining landholders and graziers. At this park, three exclusion fences were also installed in strategic locations, totalling 4.9km, to exclude wandering cattle and feral horses (e.g. Figure 72). At Mt Barney a 4km cattle exclusion fence was also installed to protect the priority threatened frog species. At Lamington NP, a 1.3km fence was specifically placed to prevent incursion of cattle into fire-impacted lowland sub-tropical rainforest.

Figure 72: A cattle fence with access gate installed at Emuvale, Main Range NP.

Cats

Cats were identified as a threat to priority species, such as the Brush-tailed rock-wallaby, Hastings River mouse and Albert's lyrebird. Where cats were detected on cameras deployed for ecological monitoring, this was relayed to park management staff to guide onground control efforts. At Lamington NP, contractors were engaged to deploy cameras along trails and to set approved cat traps in suitable locations. In addiiton, two Felixer grooming traps were deployed across different locations to control feral cats (Figure 73). Felixers use rangefinder sensors to differentiate cats from non-target wildlife and spray these targets with a lethal dose of 1080 gel (https://thylation.com/). The authorisation for the use of Felixer was acquired through ethics approval and registration with the Australian Pesticides and Veterinary Medicines Authority. To ensure that non-target species would not be targeted, Felixers were first operated in non-toxic mode, which confirmed that local wildlife did not trigger the device. The traps were then set in toxic mode and successfully targeted cats. During the program, a total of 15 cats were controlled at Lamington NP reducing predation pressure on the priority species. At Mt Barney NP, four cats were also controlled with baited traps as part of a newly established control program.

Figure 73: A deployed Felixer device and a cat successfully targeted for lethal control at Lamington NP.

9.3 Invasive plants

After a bushfire, weeds can quickly establish and expand their range, out-competing native species and hindering natural regeneration processes. They can increase fuel hazards and the level of severity of a future bushfire, leading to further changes in vegetation structure, species composition and ecological processes. Identified as threats to the recovery of priority threatened species and their habitats, weeds were targeted though enhanced control efforts over more than 320ha across GWHA by park management staff to support the post-fire recovery of threatened species.

In Lamington NP, strategic control of weeds was undertaken over 57ha for a range of species, in particular: lantana *Lantana camara*, croftonweed *Ageratina adenophora*, mistflower *Ageratina riparia*, wild tobacco *Solanum mauritianum*, devil's fig *solanum torvum*, white passionflower *Passiflora subpeltata*, moth vine *Araujia sericifera,* Easter cassia *Senna pendula*, Mexican twist *Lophospermum erubescens* and groundsel bush *Baccharis halimifolia*.

In Mt Barney NP, over 100ha of weeds were strategically controlled during the progam. The incursion of Palm grass *Setaria palmifolia* in the fire-impacted riparian zone of Cronan Creek was of significant concern and promptly targeted. A range of other weed species were treated such as: tobacco weed *(Nicotiana*), groundsel bush, Easter cassia, ragweed *Ambrosia artemisiifolia* and various species of exotic *Solanum* and paspalum grass (*Paspalum*).

In Main Range NP, a wide range of weed species were controlled across more than 160ha which included: lantana, moth vine, groundsel bush, cat's claw vine *Dolichandra unguis-cati*, fireweed *Chamaenerion angustifolium*, Coolatai grass *Hyparrhenia hirta*, mother-of-millions *Bryophyllum delagoens,* yellow bells *Tecoma stans*, blackberry *Rubus anglocandicans*, and Madeira vine *Anredera cordifolia*.

Pest strategy

The pest strategies for Lamington, Mt Barney and Main Range NPs prioritise the 'key values' and outlines the objectives of, and approach to, the management of invasive animals and plants. Mapped zones highlight the core areas for preventing incursions, eradication, reducing impact or containment of the pest species identified as a threat to key values. The development of each strategy is guided by the Values Based Management Framework (DES 2020) which can implement an adaptive management approach. The 2019–2020 bushfires were extensive across GWHA resulting in significant ecological impacts on key park values (Hines *et al.* 2020, 2021 & 2022) and elevated levels of pest threats, especially to threatened species. As a result, the pest strategies for Lamington, Mt Barney and Main Range NPs were revised to ensure that priorities reflect the ongoing need to support the recovery of fire-impacted threatened species and ecosystems.

10 Summary recommendations for priority species

Reducing threats to recovery

The recommendations for continuing to reduce the key threats to the ongoing post-fire recovery of priority fauna (Table 40) and priority flora and ecosystems (Table 41) are summarised for future reference. For further details, refer to the relevant section in this report for each priority species and contact the scientific experts (Appendix 5) to provide more specific guidance where required.

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

This will optimise the returns from this significant Commonwealth funding investment and continue to provide ongoing protection for the recovery of fire-impacted threatened species.

Ecological monitoring and research

The recommendations for ecological monitoring and ecological research relevant to the priority fauna (Table 42) and priority flora and ecosystems (Table 43) are summarised for future reference. Refer to the relevant section in this report for each priority species or ecosystem for further details and contact the scientific experts (Appendix 5) to provide more detailed guidance where required.

- Sustaining ongoing monitoring of fire-impacted species and ecosystems is essential to track their recovery.

This will optimise the returns from this significant Commonwealth funding in establishing survey protocols, monitoring sites and collecting baseline data, which is essential to support their ongoing conservation, irrespective of the additional threat of future fires with a changing climate.

Table 40: Summary recommendations for reducing ongoing threats to the recovery of priority fauna taxa.

Recommendation	Brush-tailed rock-wallaby	Long-nosed potoroo	Spotted-tailed quoll	Hastings River mouse	New Holland mouse	Albert’s lyrebird	Coxen’s fig-parrot	Glossy black-cockatoo	Eastern bristlebird	Rufous scrub-bird	Stream frogs	Mountain-frogs	TTSTS	Pelican spiders	Insects
Fire															
Protect core habitat from fire			✓			✓	✓	✓		✓	✓	✓	✓	✓	✓
Maintain optimal habitat	✓	✓		✓	✓				✓						
Pest animals															
Reduce impacts from pigs											✓	✓	✓	✓	✓
Reduce impacts from cattle / deer											✓	✓	✓	✓	✓
Reduce impacts of cats and red foxes	✓	✓	✓			✓			✓			✓	✓		
Reduce impacts of cane toads			✓												
Invasive plants															
Reduce impacts of weeds in core habitat	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Other															
Enhance availability of food resources							✓	✓							

Table 41: Summary recommendations for reducing ongoing threats to the recovery of priority plant species and ecosystems.

	Priority plant species			**Priority ecosystems**		
Recommendation	Open forest /woodland	Montane heath	Rainforest and dry vine forest	Rainforest	Wet sclerophyll forests/ecotones	Dry sclerophyll
Fire						
Protect from fire (protect in the short-term)			✓	✓	(✓)	(✓)
Protect from frequent fire	✓	✓				
Pest animals						
Reduce impacts of pigs and deer	✓	✓	✓	✓	✓	✓
Reduce impacts of cattle			✓	✓	✓	✓
Invasive plants						
Reduce impacts of weeds	✓	✓	✓	✓	✓	✓
Human impacts						
Accidental damage from track or fireline maintenance	✓	✓	✓			
Trampling by visitors	✓	✓				✓
Illegal take of threatened plant species	✓	✓	✓			✓
Avoid restoration plantings				✓	✓	✓

Table 42: Recommendations for ecological monitoring and research for priority fauna taxa.

Summary Recommendation	Brush-tailed rock-wallaby	Long-nosed potoroo	Spotted-tailed quoll	Hastings River mouse	New Holland mouse	Albert’s lyrebird	Coxen’s fig-parrot	Glossy black-cockatoo	Eastern bristlebird	Rufous scrub-bird	Stream frogs	Mountain-frogs	TTSTS	Pelican spiders	Insects
Ecological monitoring															
Continue monitoring populations, particularly in fire-impacted sites	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Monitor post-fire habitat recovery				✓	✓										
Update mapping of habitats & refugia	✓								✓			✓			
Ecological research															
Population ecology	✓				✓				✓	✓					✓
Distribution & abundance		✓	✓			✓		✓	✓	✓	✓	✓	✓		✓
Availability of food resources		✓						✓							
Impacts of fire/weeds/other threats		✓	✓		✓	✓			✓	✓		✓			✓
Impacts of pathogens/disease												✓			
Post-fire recovery strategy									✓	✓					
Conservation status/listing														✓	

Table 43: Recommendations for ecological monitoring and research for priority plant species and ecosystems.

	Priority plant species			Priority ecosystems		
Recommendation	Open forest /woodland	Montane heath	Rainforest and dry vine forest	Rainforest	Wet eucalypt open forests	Dry sclerophyll
Ecological monitoring						
Continue established monitoring			✓	✓	✓	
Establish monitoring plots	✓		✓	✓	✓	✓
Survey additional sites	✓	✓	✓			
Monitor for pathogens				✓	✓	✓
Health Checks				✓	✓	✓
Ecological research						
Distribution and ecology	✓	✓	✓			
Detect delayed fire impacts with remote sensing				✓		
Investigate impacts of more frequent fires					✓	
Assess condition of ecological communities						✓
Assess impacts of feral horses						✓

11 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 bushfires. It highlighted a lack of experience in executing an emergency wildlife response to broad-scale ecological impacts across multiple protected areas. With climate change predictions for an increasing frequency and severity of bushfires (Canadell *et al.* 2022) and other natural disasters, 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.

11.1 Risk management

Risks to wildlife

The 2019–2020 bushfires across GWHA were extensive and had broad ecological impacts. In addition to direct mortality of fauna and flora, the fire caused loss and/or degradation of core habitats for some species and elevated the chance of predation. The probability of such events impacting wildlife is likely to increase, given predictions of more frequent and severe fires with a changing climate (Binskin *et al.* 2020). The most vulnerable natural assets are threatened species and fire-sensitive ecosystems and species. To protect threatened species, reduce the risk of more species being listed as threatened and ensure that the legislative requirements of the NCA are met, it is necessary to:

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

Decision making

A risk-based approach was used to prioritise the species to be supported for recovery under the Bushfire Recovery Program at both the state and national level. This depended on information for each threatened species, such as: conservation status; species' traits that increase vulnerability to fire; ecological requirements; and their distribution with respect to the fire extent (Threatened Species Operations 2020, Legge *et al.* 2021). Whilst this methodology is best practice, the availability and reliability of information are currently lacking, especially for threatened, rare, range-restricted species and 'data deficient' species (Threatened Species Operations 2020, Legge *et al.* 2021). This presents a high-level risk that the outcomes of such analyses, and the decisions regarding funding and prioritised on-ground efforts, may *not* be optimal for supporting the post-fire recovery of impacted wildlife and that there is an ongoing risk of extinction for certain species. To better prepare for future natural disasters, it is important to:

- significantly improve the provision and accessibility of reliable ecological information to guide decision making.

Risk framework

This project focussed on supporting the post-fire recovery of impacted wildlife. Reducing the risk to wildlife from bushfire or other adverse events needs to be more strategic and comprehensive. There is an opportunity to apply the globally aligned approach for protecting life and property in Australia through the National Disaster Risk Reduction Framework (AIDR 2009) to the context of protecting wildlife (Legge *et al.* 2021) and ecosystems. This requires consideration of prevention and mitigation, preparedness and response, as well as, of recovery. For wildlife this includes proactively assessing the risk from climate change, developing adaptation plans for at-risk wildlife, strengthening networks and building better information systems to guide decision making, as well as improving the capacity for, and outcomes of, an emergency response. To support the Queensland Strategy for Disaster Resilience (QRA 2022) which says that the state will 'require transformations in what governance systems value and how systemic risk is understood and addressed', it recommended that:

- a proactive and holistic framework is adopted to manage the increasing risks to wildlife from climate change.

11.2 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 for this project and the broader program which need ongoing support to improve future wildlife recovery projects.

Threatened species data

The information required to identify the most fire-impacted threatened species, design species surveys and plan for threat reduction was often limited in its availability, currency and reliability. Where information was available, it was often derived from an expert or a range of data systems (e.g. WildNet, databases at the Queensland Herbarium and Museum). Improving the provision of data for threatened species is essential to support the recovery of populations, particularly after a natural disaster. Previous work has identified gaps in vertebrate fauna data (Smith 2013) which needs to be updated and expanded to assess other taxonomic groups to guide data collection priorities.

This project generated a significant volume of data that will improve the ecological understanding of the priority species, as well as other species. 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, presenting 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 was established to provide guidance in the context of QPWS-managed protected areas (e.g., Hines *et al.* 2020). The methodology incorporated the fire sensitivity of ecosystems which enabled the potential ecological impacts to be mapped (Laidlaw *et al.* 2022) and recovery actions better guided towards the most fire-impacted species and ecosystems. Consequently, 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.

Survey protocols

In this project, the innovative use of bioacoustics to survey the priority bird and frog species was successful and has established this as a suitable methodology for ongoing monitoring. However, recordings were analysed manually to identify calls, which was labour intensive and delayed provision of results to guide further recovery actions. Bioacoustic technology is rapidly evolving (see Sections 8.8 and 9.14 in Eyre *et al.* 2022), with the development of software programs to analyse and identify calls to species. Once this is available for priority species it will support a very cost-effective monitoring approach. It is therefore important to:

- invest in technological advances in survey methods that can optimise efforts and quickly provide resultant data.

Ecological expertise

Due to the extent of the 2019–2020 bushfires, this project was one of four to survey a total of 56 threatened species, in addition to terrestrial invertebrates, across six protected areas. At the same time, the late 2020 fires on K'gari (Fraser Island) also required post-fire ecological assessments and species' surveys. 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, potential habitat was modelled and mapped for species where a minimum set of locality data was available (Laidlaw & Butler 2021). Potential habitat modelling was invaluable to assess fire impacts, design surveys and guide on-ground efforts to reduce threats from pest animals, invasive plants or future fires. Given the value of habitat modelling to improve conservation outcomes for many species, models for 376 threatened species have been made available online through the '*Potential habitat models 2022–Queensland series*' on the Queensland Government QSpatial portal: Queensland Spatial Catalogue: Queensland Government (information.qld.gov.au)

The provision of potential habitat modelling supports consideration of threatened species in emergency planning and response for natural disasters, as recommended by Royal Commission Bushfire Royal Commission into National Natural Disaster Arrangements (recommendation 16.20: Binskin *et al.* 2020). It is therefore recommended that:

- online access to potential habitat modelling for threatened species is maintained, regularly updated and expanded to include additional species where data are available.

11.3 Partnerships and networks

Scientific collaboration

This project was delivered in collaboration with key partners including the Queensland Herbarium, Queensland Museum and Queensland University of Technology (see Appendix 5), which supported mapping, modelling, field surveys of priority taxa, data capture, analysis and interpretation of results, as well as provision of report content with forward recommendations. The ability to secure this expertise for an emergency response was based on 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 to support an emergency wildlife response may be increasingly difficult. To enhance future wildlife recovery projects, it is recommended that:

- formal agreements are established with existing partners to clarify a commitment to supporting wildlife recovery programs, the specific expertise that can be provided and the 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.

The lead time involved in this project to identify the required ecological experts, organise agreements and logistics, as well as initiate surveys, can be improved. As part of establishing formal arrangements with key partners for urgent wildlife recovery, it is advised that:

- pre-approval is provided with respect to permits, site access and ethics within a relevant emergency response context and with appropriate conditions.

Contract land management services

Following the 2019–2020 bushfires, 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 adjoining land managers and local government helped to implement works such as pig control and enhanced firelines. There was an additional need to engage contractors to deliver specific weed and pest animal control activities to protect priority species. After a natural disaster, demand for contract services can be high, limiting contractor availability. This can be further constrained by contractors needing to meet high standards to operate on a protected area and ensure that natural values are not at risk. To enhance capacity to support threatened species' recovery, it is suggested that:

- networks are sustained with a range of suitably qualified local contractors and preferred suppliers to support and prioritise a wildlife disaster response when needed, including First Nations teams whenever possible.

Strategic alignment

Learning from the lessons of this project and adopting the suggested improvements will support the State Government's Queensland Strategy for Disaster Resilience 2022 (Queensland Reconstruction Authority 2022) which includes enhanced cooperation across all levels of government, non-government organisations, the private sector and academics to strengthen resilience. The strategy also encourages continuous improvement of processes and arrangements to ensure they remain effective and flexible.

12 References

Alexandra, J. & Finlayson, C.M. (2020) Floods after bushfires: rapid responses for reducing impacts of sediment, ash, and nutrient slugs. *Australasian Journal of Water Resources*, 19(1): 1-3.

Amos, P.J. (1982) The potoroo in Queensland. *Queensland Agricultural Journal* 108: 5-6.

Anstis, M. (2013) Tadpoles and Frogs of Australia. New Holland, Chatswood.

Atlas of Living Australia (ALA) (2022) Atlas of Living Australia occurrence download *Coeranoscinus reticulatus.* https://biocache.ala.org.au/occurrences/search?q=lsid%3Aurn%3Alsid%3Abiodiversity.org.au%3Aafd.taxon%3Af1fd00b8-a848-44eb-9cb2-73bbce6a5d14&qualityProfile=ALA. Accessed 6 January 2022.

Bain, D., Clarke R.H., Oliver, D., Bramwell, M.D., MacGregor, C., Lindenmayer, D.B., Maple, D., Dexter, N., Ehmke, G., Burbidge, A.H., Menkhorst, P.W. & Garnett, S.T. (2021) Southern Eastern Bristlebird *Dasyornis brachypterus brachypterus*. In 'Action Plan for Australian Birds 2020' (Eds ST Garnett & GB Baker) pp. 584-587. CSIRO Publishing: Melbourne.

Barung Landcare (2008) *Barung Landcare News,*11.

Bennett, A.F. (1987) Conservation of mammals within a fragmented forest environment: the contributions of insular biogeography and autecology. In 'Nature conservation: the role of remnants of native vegetation' (Eds D.A. Saunders, G.W. Arnold, A.A. Burbridge & A.J.M. Hopkins) pp. 41-52. Surrey Beatty & Sons: Chipping Norton.

Bennett, A.F. (1993) Microhabitat use by the Long-nosed Potoroo, *Potorous tridactylus*, and other small mammals in remnant forest vegetation of south-western Victoria. *Wildlife Research* 20: 267-285.

Berger, L., Roberts, A.A., Voyles, J., Longcore, J.E., Murray, K.A. & Skerratt, L.F. (2016) History and recent progress on chytridiomycosis in amphibians. *Fungal Ecology* 19 (2016): 89–99.

Beruldsen, G.R. (1973) Notes on the Albert Lyrebird. *Australian Bird Watcher* 5: 44-48.

Binskin, M., Bennett, A. & Macintosh, A. (2020) Royal Commission into National Natural Disaster Arrangements Report 28 October 2020. Canberra: Commonwealth of Australia.

Blakers, M., Davies, S.J.J.F. & Reilly, P.N. (1984) The Atlas of Australian Birds. RAOU & Melbourne University Press: Melbourne.

Bolitho, L.J., Rowley, J.J.L., Hines, H.B. & Newell, D. (2021) Occupancy modelling reveals a highly restricted and fragmented distribution in a threatened montane frog (*Philoria kundagungan*) in subtropical Australian rainforests. *Australian Journal of Zoology,* 67: 231–240.

Borsboom, A. (1996) *Dasyurus maculatus maculatus* spotted-tailed quoll. Draft Species Management Profile, Species Management Manual Vol. 1. Department of Natural Resources: Brisbane.

Borsboom, A. (2009) *Coeranoscincus reticulatus* - Species Information Sheet. Provided to the Department of the Environment, Water, Heritage and the Arts. Department of Environment and Resource Management.

Brewer, K. C., Winne, J. C., Redmond, R. L., Opitz, D. W. & Mangrich, M. V. (2005) Classifying and mapping wildfire severity: a comparison of methods. *Photogrammetric Engineering and Remote Sensing*, 71: 1311-1320.

Burckhardt, D. (2009) Taxonomy and phylogeny of the Gondwana Rainforests of Australia World Heritage Area moss bugs of Peloridiidae (Hemiptera, Coleorryhncha). *Deutsche Entomologische Zeitschrift*, 56: 173-235.

Bureau of Meteorology (2019) Special Climate Statement - severe fire weather conditions in southeast Queensland and northeast New South Wales in September 2019. Commonwealth of Australia: 24 September 2019.

Cameron, M. (2006) Distribution and cone production in *Allocasuarina diminuta* and *A. gymnanthera* (Casuarinaceae) in central New South Wales. *Rangeland Journal*, 28(2): 153-161.

Cameron, M. (2009) The influence of climate on Glossy Black-cockatoo reproduction. *Pacific Conservation Biology,* 15(1): 65-71.

Carter, K. & Goldizen, A.W. (2003) Habitat choice and vigilance behaviour of brush-tailed rock-wallabies (*Petrogale penicillata*) within their nocturnal foraging ranges. *Wildlife Research*, 30: 355-364.

Catling, P.C. & Burt, R.J. (1997) Studies of the ground-dwelling mammals of eucalypt forests in north-eastern NSW: the species, their abundance and distribution. *Wildlife Research*, 24: 1-19.

Catling, P.C., Burt, R.J. & Kooyman, R. (1997) A comparison of techniques used in survey of the ground-dwelling and arboreal mammals in forests in north-eastern New South Wales. *Wildlife Research*, 24: 417-432.

Catullo, R. & Moritz, C. (2021) Genetic assessment of bushfire-impacted vertebrate species. NESP Threatened Species Recovery Hub Project 8.3.3 Final report. Brisbane.

Certini, G., Moya, D., Lucas-Borja, M. E. & Mastrolonardo, G. (2021) The impact of fire on soil-dwelling biota: A review. *Forest Ecology and Management*, 488: 118989.

Charley, D., Stewart, D., Stone, Z.L., Roche, K., Tasker, L., Molyneux, A., Gillman, S., Baker, L., Watson, P., Maron, M., Thomas, J. & Garnett, S.T. (2021). Northern Eastern Bristlebird *Dasyornis brachypterus monoides*. In 'Action Plan for Australian Birds 2020' (Eds ST Garnett and GB Baker) pp. 588–591. CSIRO Publishing: Melbourne.

Claridge, A.W. (2002) Ecological role of hypogeous ectomycorrhizal fungi in Australian forests and woodlands. *Plant and Soil* 244: 291-305.

Claridge, A.W., Tanton, M.T., Seebeck, J.H., Cork, S.J. & Cunningham, R.B. (1992) Establishment of ectomycorrhizae on the roots of two species of Eucalyptus from fungal spores contained in the faeces of the long-nosed potoroo *(Potorous tridactylus*). *Australian Journal of Ecology*, 17: 207-217.

Claridge, A.W., Tanton, M.T. & Cunningham, R.B. (1993) Hypogeal fungi in the diet of the long-nosed potoroo (*Potorous tridactylus*) in mixed-species and regrowth eucalypt forest stands in south-eastern Australia. *Wildlife Research*, 20: 321-338.

Claridge, A.W. & Mills, D.J. (2007) Aerial baiting for wild dogs has no observable impact on spotted-tailed quolls (*Dasyurus maculatus*) in rainshadow woodland. *Wildlife Research*, 34: 116-124.

Cogger, H. (2014) *Reptiles and amphibians of Australia*. 7th ed. CSIRO: Melbourne.

Covacevich, J. & Archer, M. (1975) The distribution of the cane toad, *Bufo marinus*, in Australia and its effects on indigenous vertebrates. *Memoirs of the Queensland Museum*, 17: 395-310.

Coxen's Fig-Parrot Recovery Team (2001) Coxen's fig-parrot *Cyclopsitta diophthalma coxeni* recovery plan 2001-2005. Report to Environment Australia, Canberra. Queensland Parks and Wildlife Service: Brisbane.

DeBano, L. F. (2000) The role of fire and soil heating on water repellency in wildland environments: A review. *Journal of Hydrology*, 231-232: 195-206.

Delzoppo, N.A., Berris, K., Teixeira, D. & Van Rensburg, B. (2021) The impact of fire on the quality of drooping sheoak (*Allocasuarina verticillata*) cones for the endangered Kangaroo Island glossy black-cockatoo (*Calyptorhynchus lathami halmaturinus*). *Global Ecology and Conservation*, 28: e10645.

Department of Agriculture and Fisheries (2019) Queensland Invasive Plants and Animals Strategy 2019–2024. Department of Environment and Science: Brisbane.

Department of Agriculture, Water and the Environment. (2008) Approved Conservation Advice for *Sarcochilus hartmannii* (Waxy Sarcochilus. Department of Agriculture, Water and the Environment: Canberra.

Department of Agriculture, Water and the Environment (2020) Conservation advice for *Petrogale penicillata* (Brush-tailed rock-wallaby). Department of Agriculture, Water and the Environment: Canberra.

Department of the Environment (2021) *Dasyurus maculatus maculatus* (SE mainland population) in Species Profile and Threats Database. Department of the Environment: Canberra. https://www.environment.gov.au/sprat Accessed 21 Jul 2021.

Department of Environment and Energy (2008a) Approved Conservation Advice for *Coopernookia scabridiuscula* (Coopernookia). Department of Environment and Energy: Canberra.

Department of Environment and Energy (2008b) Approved Conservation Advice for *Euphrasia bella* (Lamington Eyebright). Department of Environment and Energy: Canberra.

Department of Environment and Energy (2010) Listing Advice - *Clematis fawcettii* (stream Clematis). Department of Environment and Energy: Canberra.

Department of Environment and Energy (2011) Listing Advice - *Bertya ernestiana*. Department of Environment and Energy: Canberra.

Department of Environment and Energy (2014) Approved Conservation Advice for *Sarcochilus weinthalii* (Blotched Sarcochilus, Weinthals Sarcanth). Department of Agriculture, Water and the Environment: Canberra.

Department of Environment and Energy (2019) Directory of Important Wetlands in Australia. http://www.environment.gov.au/water/wetlands/australian-wetlands-database/directory-important-wetlands Accessed 27 Nov 2019.

Department of Environment and Heritage Protection (2009a) Nomination to classify *Gonocarpus hirtus* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2009b) Nomination to classify *Huperzia varia* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2009c) Nomination to classify *Pultenaea whiteana* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2009d) Nomination to classify *Tetramolopium vagans* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2011a) Nomination to classify *Brachyscome ascendens* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2011b) Nomination to classify *Leptospermum barneyense* as Vulnerable under the NCA 1992. Department of Environment and Heritage Protection: Brisbane.

Department of Environment and Heritage Protection (2015) An Aquatic Conservation Assessment for the riverine and non-riverine wetlands of Southeast Queensland catchments. Department of Environment and Heritage Protection: Brisbane.

Department of Environment, Land, Water and Planning (2016) National Recovery Plan for the Spotted-tailed Quoll *Dasyurus maculatus*. Australian Government: Canberra.

Department of Environment and Science (2019) Nomination to classify *Zieria montana* as Critically endangered under the NCA 1992. Department of Environment and Science: Brisbane.

Department of Environment and Science (2020) Values Based Park Management Framework available at https://parks.des.qld.gov.au/managing/framework. Accessed 03 Apr 2020.

Department of Environment and Science (2021) Modelled potential habitat for selected threatened species - Queensland. https://www.data.qld.gov.au/dataset/potential-habitat-models-2022-queensland-series

Department of National Parks, Recreation, Sport and Racing (2012) Planned burn guidelines, Southeast Queensland Bioregion of Queensland. Department of National Parks, Recreation, Sport and Racing: Brisbane.

Department of Natural Resources (1995) *Muellerina myrtifolia* Species Management Profile. Department of Natural Resources: Brisbane.

Department of Natural Resources (1997) *Sarcochilus weinthalii* Species Management Profile. Forest ecosystem research and assessment: Brisbane.

Department of Natural Resources (1999) *Sarcochilus hartmannii* Species Management Profile. Forest ecosystem research and assessment: Brisbane.

Dixon, K. (2014) Habitat use and the effects of fire and grazing on the Hastings River mouse, brown antechinus, bush rat and swamp rat. B.App.Sc. Honours thesis. The University of Queensland: Gatton.

Edgar, R. & Belcher, C. (1995) Spotted-tailed quoll *Dasyurus maculatus* (Kerr, 1792) In 'The Mammals of Australia' (Ed. R. Strahan) pp. 67-68. Reed Books: Chatswood, NSW.

Ehmann, H. (1987) The habitat, microhabitat and feeding behaviour of the rainforest skink *Coeranoscincus reticulatus*. *Herpetofauna*, 17(2): 14-15.

Ekert, P.A. (2002) Monitoring of Rufous Scrub-bird (*Atrichornis rufescens*) in North-East NSW. Report by Ekerlogic Consulting Services for NSW National Parks & Wildlife Service. Ekerlogic Consulting Services: NSW.

Eyre, T.J., Kelly, A.L, Neldner, V.J., Wilson, B.A., Ferguson, D.J., Laidlaw, M.J. & Franks, A.J. (2015) BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2. Queensland Herbarium. Department of Science, Information Technology, Innovation and Arts: Brisbane.

Eyre, T.J., Kelly, A.L. & Neldner, V.J. (2017) Method for the Establishment and Survey of Reference Sites for BioCondition. Version 3. Queensland Herbarium. Department of Science, Information Technology and Innovation: Brisbane.

Eyre, T., Krieger, G., Venz, M., Haseler, M., Hines, B., Hannah, D. & Schulz, M. (1998) Systematic Vertebrate Fauna Survey Project. Stage I - Vertebrate Fauna Survey in the South East Queensland Bioregion. A Report to the Queensland CRA/RFA Steering Committee. Department of Environment: Brisbane.

Eyre, T.J., Ferguson, D.J., Smith, G.C., Mathieson, M.T., Venz, M.F., Hogan, L.D., Hourigan, C.L., Kelly, A.L. & Rowland, J. (2022) Terrestrial Vertebrate Fauna Survey Assessment Guidelines for Queensland, Version 4.0. Queensland Herbarium. Department of Environment and Science: Brisbane.

Fenner, A. L. & Bull, C. M. (2007) Short-term impact of grassland fire on the endangered pygmy bluetongue lizard. *Journal of Zoology*, 272: 444-450.

Ferrier, S. (1984) The status of the Rufous Scrub-bird *Atrichornis rufescens*: habitat, geographical variation and abundance. Doctor of Philosophy thesis. University of New England: Armidale.

Garnett, S. & Crowley, G.M. (2000) The Action Plan for Australian birds 2000. Environment Australia: Melbourne.

Garnett, S.T. & Franklin, D.C. (2014) Climate Change Adaptation Plan for Australian Birds. CSIRO: Melbourne.

Garnett, S.T., Szabo, J.K. & Dutson, G. (2011) The Action Plan for Australian Birds 2010. CSIRO: Melbourne.

Gilmore, A. & Parnaby, H. (1994) Vertebrate fauna of conservation concern in north-east NSW forests. North East Forests Biodiversity Study Report No. 3e (unpublished report). NSW National Parks & Wildlife Service.

Glossy Black Conservancy. (2022) Glossy Black-Cockatoo Conservation Guidelines for South-Eastern Queensland and Far North-Eastern New South Wales. Glossy Black Conservancy.

Greenlees, M., Hobson, R., Shea, G., Vanderduys, E., Venz, M. & Wilson, S. (2018) *Coeranoscincus reticulatus*. The IUCN Red List of Threatened Species 2018:e.T5106A101742801. https://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T5106A101742801.en. Accessed 20 February 2022.

Gynther, I., Dutson, G. & Garnett, S.T. (2021) Coxen's Fig-Parrot *Cyclopsitta coxeni*. In 'The Action Plan for Australian Birds 2020' (Eds S.T. Garnett and G.B. Baker) pp. 454–457. CSIRO: Melbourne.

Hartley, S.L. & Kikkawa, J. (1994) The population management of the Eastern Bristlebird (*Dasyornis brachypterus*). Department of Environment and Heritage: Brisbane.

Heard, G., Bolitho, L., Newell, D., Hines, H., McCall, H., Smith, J. & Scheele, B. (2021) Post-fire impact assessment for priority frogs: northern *Philoria*. NESP Threatened Species Recovery Hub Project 8.1.3 report: Brisbane.

Hendry, H. & Mann, C. (2018) Camelot – intuitive software for camera trap data management. *Oryx,* 52(1): 15.

Henry, S., Kirkpatrick J.B. & McQuillan P.B. (2022) The half century impact of fire on invertebrates in fire-sensitive vegetation. *Austral Ecology*, 47(3). Doi:10.1111/aec.13141.

Hero, J. & Morrison, C. (2004) Frog declines in Australia: global implications. *Herpetological Journal,* 14: 175-186.

Herold, N., Ekstrom, M., Kala, J., Goldie, J. & Evans, J.P. (2018) Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture. *Weather and Climate Extremes,* 20: 54-68.

Hines, H.B. (2012) Fleay's Barred Frog *Mixophyes fleayi*. In 'Queensland's Threatened Animals' (Eds L.K. Curtis, A.J. Dennis, K.R. McDonald, P.M. Kyne, & S. Debus) pp. 327-330. CSIRO: Melbourne.

Hines, H.B. & South-east Queensland Threatened Frogs Recovery Team (2002) Recovery plan for stream frogs of south-east Queensland 2001-2005. Environmental Protection Agency: Brisbane.

Hines, H.B., Laidlaw, M.J., Buch, W., Olyott, L., Levy, S., Melzer, R. and Meiklejohn, A. (2020) Post-fire Assessment Report – Natural Values: 2019 bushfire, Lamington National Park, South East Queensland Region. Department of Environment and Science: Brisbane. https://parks.des.qld.gov.au/__data/assets/pdf_file/0027/256545/qpws-post-fire-evaluation-lamington-np.pdf Accessed December 2022

Hines, H.B., Levy, S., Laidlaw, M.J., Midtaune, K., Finlayson, S. and Meiklejohn, A. (2021) Post-fire Assessment Report – Natural Values: 2019 bushfire complex, Main Range National Park and adjacent QPWS estate, South West Queensland Region. Department of Environment and Science: Brisbane. https://parks.des.qld.gov.au/__data/assets/pdf_file/0028/256546/qpws-post-fire-evaluation-main-range-np.pdf Accessed December 2022

Hines, H.B., Laidlaw, M.J., Midtaune, K., O'Connell, J. and Hughes, D. (2022) Post-fire Assessment Report – Natural Values: 2019 bushfire, Mt Barney National Park, South East Queensland Region. Department of Environment and Science: Brisbane. https://parks.des.qld.gov.au/__data/assets/pdf_file/0034/266299/qpws-post-fire-evaluation-mount-barney-np-natural-values.pdf Accessed December 2022

Hines, H.B., Mahony, M. & McDonald, K. (1999) An assessment of frog declines in wet subtropical Australia. In 'Declines and disappearances of Australian frogs' (Ed A. Campbell) pp. 44–63. Environment Australia: Canberra.

Hobbs, M. T. & Brehme, C. S. (2017) An improved camera trap for amphibians, reptiles, small mammals and large invertebrates. *PloS one*, 12(10): e0185026.

Holmes, G. (1989) Eastern Bristlebird: species management plan for northern populations. Draft unpublished report for the Queensland Parks and Wildlife Service and NSW National Parks and Wildlife Service.

Holmes, G. (1998) Eastern Bristlebird Recovery Plan 1998-2003. Draft report prepared for the Eastern Bristlebird Recovery Team. Queensland Department of Environment, Brisbane.

Hutchinson, M. N., Couper, P., Amey, A. & Wilmer, J. W. (2021) Diversity and Systematics of Limbless Skinks (*Anomalopus*) from Eastern Australia and the Skeletal Changes that Accompany the Substrate Swimming Body Form. *Journal of Herpetology*, 55(4): 361-384. Doi.org/10.1670/20-137.

Ingram, G.J. & McDonald, K.R. (1993) An update on the decline of Queensland's frogs. In 'Herpetology in Australia: a diverse discipline' (Eds D. Lunney and D. Ayers) pp. 297-303. Royal Zoological Society of New South Wales: Mosman.

Jarman, P.J., Johnson, C.N., Southwell, C.J. & Stuart-Dick, R. (1987) Macropod studies at Wallaby Creek. The area and animals. *Australian Wildlife Research,* 14: 1-14.

Jarman, P.J., Taylor, D., Duncan, C. & Paisley, G. (1997) A ground survey of Sundown National Park for the Brush-tailed Rock-wallaby (*Petrogale penicillata*). Report to Queensland Department of Environment.

Johnston, P.G. (2008) Long-nosed potoroo. In 'The Mammals of Australia' (Eds S. van Dyck & R. J. Strahan) pp. 302-304. Reed New Holland: Sydney.

King, G.C. (1984) Habitat utilized by *Pseudomys oralis* Thomas (Rodentia: Muridae). *Australian Mammalogy*, 7: 139–147.

Kinnaird, M. F. & O'Brien, T. G. (1998) Ecological effects of wildfire on lowland rainforest in Sumatra. *Conservation Biology*, 12(5): 954-956.

Kirkpatrick, T.H. & Martin, J.H.D. (1971) Uncommon native fauna. *Queensland Agricultural Journal* 97: 114–115.

Kitching, R.L., Putland, D., Ashton, L.A., Laidlaw, M.J., Boulter, S.L., Christensen, H. & Lambkin, C.L. (2011) Detecting biodiversity changes along climatic gradients: the IBISCA-Queensland Project. *Memoirs of the Queensland Museum – Nature*, 55(2): 235-250.

Knowles, R., Mahony, M., Armstrong, J. & Donnellan, S. (2004) Systematics of sphagnum frogs of the genus *Philoria* (Anura: Myobatrachidae) in eastern Australia, with the description of two new species. *Records of the Australian Museum*, 56: 57–74.

Körtner, G., Gresser, S. & Harden, R. (2003) Does fox baiting threaten the spotted-tailed quoll, *Dasyurus maculatus*? *Wildlife Research,* 30: 111-118.

Krieger, G. (2010) Habitat assessment and monitoring of the brush-tailed rock-wallaby (*Petrogale penicillata*) in south-east Queensland., Queensland Parks and Wildlife Service - internal report.

Krieger, G. & Caparraro, S. (1999) An assessment of the brush-tailed rock-wallaby population in the Mt Machar and Cooks Tableland areas of Glen Rock. Queensland Parks and Wildlife Service - internal report.

Laidlaw, M.J. & Butler, D.W. (2021) Potential habitat modelling methodology for Queensland. Version 2.0 Updated November 2021. Queensland Herbarium. Department of Environment and Science: Brisbane.

Laidlaw, M.J., Hines, H.B., Melzer, R.I. & Churchill, T.B. (2022) Beyond bushfire severity: mapping the ecological impact of bushfires on the Gondwana Rainforests of Australia World Heritage Area. *Australian Zoologist.* 42(2): 502-513.

Laidlaw, M. J., McDonald, W. J. F., Hunter, J., Kitching, R. L. & Putland, D. (2011) Potential impacts of climate change on Australian subtropical rainforest. *Australian Journal of Botany*, 59: 440-449.

Lamb, D. Turnbull, M.H. & Meyers, N. (1993) Eastern Bristlebird habitat assessment in southern Queensland and northern New South Wales. Report to Australian National Parks and Wildlife Service. University of Queensland: Brisbane.

Laurance, W.F., McDonald, K. & Speare, R. (1996) Epidemic disease and the catastrophic decline of Australian rain forest frogs. *Conservation Biology*, 10: 406–413.

Laws, R. J. and Goldizen, A. W. (2003) Nocturnal home ranges & social interactions of the brush-tailed rock-wallaby *Petrogale penicillata* at Hurdle Creek, Queensland. *Australian Mammalogy*, 25(2): 169–176. Doi: 10.1071/am03169.

Legge, S., Woinarski, J. C. Z., Scheele, B. C., Garnett, S. T., Lintermans, M., Nimmo, D. G., Whiterod, N. S., Southwell, D. M., Ehmke, G., Buchan, A., Gray, J., Metcalfe, D. J., Page, M., Rumpff, L., Leeuwen, S., Williams, D., Ahyong, S. T., Chapple, D. G., Cowan, M., Hossain, M.A., Kennard, M., Macdonald, S., Moore, H., Marsh, J., McCormack, R.B, Michael, D., Mitchell N., Newell, D., Raadik, T.A. and Tingley, R. (2022) Rapid assessment of the biodiversity impacts of the 2019–2020 Australian megafires to guide urgent management intervention and recovery and lessons for other regions. *Diversity and Distributions*, 28(3): 571– 591. Doi.org/10.1111/ddi.13428.

Lewis, B. D. (2016) Additional crossing of the Clarence River at Grafton: Three-toed Snake-toothed Skink (*Saiphos reticulatus*) – Construction Management Plan. Report to NSW Roads and Maritime Services.

Lindenmayer, D.B. & Viggers, K.L. (1994) Northern range limits of the Long-nosed Potoroo, *Potorous tridactylus*. *Memoirs of the Queensland Museum*, 35: 180.

Lyon, J.P. & O'Connor, J.P. (2008) Smoke on the water: Can riverine fish populations recover following a catastrophic fire-related sediment slug? *Austral Ecology*, 33: 794–806.

Marsh, J., Bal, P., Fraser, H., Umbers, K., Greenville, A., Rumpff, L. & Woinarski, J.C.Z. (2021) Assessment of the impacts of the 2019–2020 bushfires of southern and eastern Australia on invertebrate species. Final report. NESP Threatened Species Recovery Hub Project 8.3.1. Brisbane.

Marsh, J.R., Payal Bal, Fraser, H., Umbers, K., Latty, T., Greenville, A., Rumpff, L. & Woinarski, J.C.Z. (2022) Accounting for the neglected: Invertebrate species and the 2019–2020 Australian megafires. *Global Ecology and Biogeography.* 31: 2120–2130. Doi.org/10.1111/geb.13550.

Matthews, E.G. (1974) A revision of the Scarabaeine dung beetles of Australia. II. Tribe Scarabaeini. *Australian Journal of Zoology* Supplementary Series, 24: 1-211.

Maxwell, S., Burbidge, A.A. & Morris, K. (1996) The 1996 Action Plan for Australian Marsupials and Monotremes. 234 pp. Wildlife Australia: Canberra.

Melzer, R., Ezzy, L. & Hines, H.B. (2019) Health Checks: A simple tool for assessing the condition of values and effectiveness of reserve management. *PARKS* 25(2), Nov. 2019

McDonald, K.R. & Davies, M. (1990) Morphology and biology of the Australian tree frog *Litoria pearsoniana* (Copland) (Anura, Hylidae). *Transactions of the Royal Society of South Australia* 114: 145-156.

McGregor, M. & Burnett, S. (2014) Proximity to coarse woody debris increases reptile presence in an Australian subtropical rainforest remnant. *Australian Zoologist*, 37(2): 267-274.

McGregor, H. W., Legge, S., Jones, M. E. & Johnson, C. N. (2014) Landscape management of fire and grazing regimes alters the fine-scale habitat utilisation by feral cats. *PloS one,* 9(10): e109097.

McGregor, H. W., Cliff, H. B. & Kanowski, J. (2017) Habitat preference for fire scars by feral cats in Cape York Peninsula, Australia. *Wildlife Research*, 43(8): 623-633.

McHugh, D. & Robyns, L. (2020) *Coeranoscincus reticulatus* (Three-toed Snake-tooth Skink). Predation. *Herpetological Review* 51(2): 229-230.

McLeod, R. F. & Gates, J. E. (1998) Response of herpetofaunal communities to forest cutting and burning at Chesapeake Farms, Maryland. *The American Midland Naturalist* 139: 164-177.

Miller, J.D. & Thode, A.E. (2007) Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). *Remote Sensing of Environment,* 109: 66-80.

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Addicott, E.P. & Appelman, C.N. (2019a) Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 5.0. Updated March 2019. Queensland Herbarium. Department of Environment and Science: Brisbane.

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F., Ford, A.J. & Accad, A. (2019b) The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 4.0. Queensland Herbarium. Department of Environment and Science: Brisbane.

New South Wales National Parks and Wildlife Service (1994) Fauna of north-east NSW forests. NEFBS Report No 3, unpublished report., NSW National Parks and Wildlife Service.

New South Wales Office of Environment and Heritage (2013) Three-toed Snake-tooth Skink - profile. Available from http://www.environment.nsw.gov.au/threatenedspecies. Accessed September 2022.

Newell, D.A., Goldingay, R.L. & Brooks, L.O. (2013) Population recovery following decline in an endangered stream-breeding frog (*Mixophyes fleayi*) from subtropical Australia. *Public Library of Science*, 8(3): 1-8.

North, H., Lamont, R.W., Ogbourne, S.M. & Conroy, G.C. (2020) Feeding profitability is associated with Glossy Black-Cockatoo (*Calyptorhynchus lathami* ssp. *lathami*) feed tree selection. *Emu*, 120(1) 1-9.

Norton, M. (2012) Long-nosed Potoroo (south-east mainland subspecies) *Potorous tridactylus tridactylus*. In 'Queensland's threatened animals' (Eds L.K. Curtis, A.J. Dennis, K.R. McDonald, P.M Kyne and S.J.S. Debus) pp. 368-369. CSIRO: Melbourne.

Norton, M., Prentice, A., Dingle, J. French, K. & Claridge, A. (2015) Population characteristics and management of the long-nosed potoroo (*Potorous tridactylus*) in high-quality habitat in the Southern Highlands of New South Wales. *Australian Mammalogy,* 37: 67-74.

Nugent, D.T., Leonard, S.W.J. & Clarke, M.F. (2014) Interactions between the superb lyrebird (*Menura novaehollandiae*) and fire in south-eastern Australia. *Wildlife Research*, 41(3): 203–211.

Office of Environment and Heritage (2012) National Recovery Plan for Eastern Bristlebird *Dasyornis brachypterus*. Office of Environment and Heritage. Department of Premier and Cabinet: Sydney.

Pedersen, T. (2021) Coxen's Fig-Parrot acoustic remote sensing results, Gondwana Rainforests Bushfire Recovery Project. Department of Environment and Science – internal report. September 2021.

Penman, T. D., Lemckert, F. L. & Mahony, M. J. (2006) A preliminary investigation into the potential impacts of fire on a forest dependent burrowing frog species. *Pacific Conservation Biology*, 12(1): 78-83.

Pepper, J.W. (1997) A survey of the South Australian glossy black-cockatoo (*Calyptorhynchus lathami halmaturinus*) and its habitat. *Wildlife Research*, 24(2): 209-223.

Pizzey, G. & Knight, F. (1997) The Field Guide to the Birds of Australia. Angus & Robertson: Sydney.

PlantNET (NSW Plant Information Network System). Royal Botanic Gardens and Domain Trust: Sydney. https://plantnet.rbgsyd.nsw.gov.au. Accessed 30 June 2021.

Poole, M.A. (1994) The Hastings River mouse, *Pseudomys oralis*, from Gambubal State Forest, southeast Queensland. *Memoirs of the Queensland Museum*, 37: 280.

Queensland Herbarium (2021) Regional Ecosystem Fire Guidelines (March 2021). Department of Environment and Science: Brisbane.

Quick, G., Goldingay, R.L., Parkyn, J. & Newell, D.A. (2015) Population stability in the endangered Fleay's barred frog (*Mixophyes fleayi*) and a program for long-term monitoring. *Australian Journal of Zoology*, 63: 214−219.

Risch, D. R., Ringma, J. & Price, M. R. (2021) The global impact of wild pigs (*Sus scrofa*) on terrestrial biodiversity. *Scientific Reports*, 11(1): 1-10.

Rix, M.G. & Harvey, M.S. (2011) Australian Assassins, Part I: a review of the Assassin Spiders (Araneae, Archaeidae) of mid-eastern Australia. *ZooKeys*, 123: 1-100.

Rix, M.G. & Harvey, M.S. (2012) Phylogeny and historical biogeography of ancient assassin spiders (Araneae: Archaeidae) in the Australian mesic zone: evidence for Miocene speciation within Tertiary refugia. *Molecular Phylogenetics and Evolution*, 62: 375-396.

Rix, M.G., Worthington Wilmer, J. & Harvey, M.S. (2022) Rainforest pelican spiders (Archaeidae: *Austrarchaea*) of south-eastern Queensland, Australia: two new species and a distributional reassessment of regional endemic clades. *Journal of Arachnology* 50: 231-249.

Rounsevell, D., Drury, W. & Smyth, A.K. (1998) Towards reserve options for forest taxa in South-East Queensland: Taxa at risk, threats, conservation requirements, and recovery planning. Draft report to the SEQ CRA Environment & Heritage Technical Committee.

Sadlier, R. & Shea, G. (2011) Survey Guidelines for Australia's Threatened Reptiles: guidelines for detecting reptiles listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999*. Department of Sustainability, Environment, Water, Population and Communities: Canberra.

Sands, D. (2018) Important issues facing insect conservation in Australia: now and into the future. *Austral Entomology*, 57(2): 150–172.

Seebeck, J.H., Bennett, A.F. & Scotts, D.J. (1989) Ecology of the Potoroidae - a review. In 'Kangaroos, Wallabies and Rat-kangaroos.' (Eds G. Grigg, P. Jarman, and I. Hume) pp. 67-88. Surrey Beatty: Chipping Norton.

Shields, J. & Rowland, P.R. (1994) Albert's Lyrebird *Menura alberti*. In 'Cuckoos, Nightbirds & Kingfishers of Australia.' (Ed R. Strahan) pp. 186-188. Angus & Robertson: Sydney.

Smith, G.C. (2013) Vertebrate Survey Effort across Queensland. Queensland Herbarium. Department of Science, Information Technology, Innovation and the Arts: Brisbane.

Smith, A.P., Hines, H.B. and Webber, P. (1989a) Mammals, reptiles and amphibians of the rainforests of the Mount Warning Caldera region. Unpublished report to NSW National Parks and Wildlife Service.

Sparks, D. (2022) Understanding the Variation and Ecology of *Coeranoscincus reticulatus* in Queensland, Australia. Unpublished report to Queensland Museum. Griffith University: Nathan.

Spencer, P.B.S. (1991) Evidence of predation by a feral cat, *Felis catus* (Carnivora: Felidae) on an isolated rock-wallaby colony in tropical Queensland. *Australian Mammalogy*, 14: 143-144.

Stewart, D. (2021) April 2021 meeting minutes of the Eastern Bristlebird Recovery Team Northern Working Group.

Stewart, D. (2006) Rufous scrub-bird surveys in the Queensland CERRA; November 2006. Unpublished report to the Queensland Parks and Wildlife Service.

Stewart, D. (2007) Rufous scrub-bird surveys in the Queensland GWHA Rainforest Reserves of Australia (CERRA); November 2007. Unpublished report to the Queensland Parks and Wildlife.

Stewart, D. (2017) A summary of recovery efforts and future directions for the rufous scrub-bird *Atrichornis rufescens*, January 2018. Department of Environment and Science: Brisbane.

Stewart, D., Hill, F., Newman, O.M.G., Ehmke, G. & Garnett, S.T. (2021) Northern Rufous Scrub-bird *Atrichornis rufescens rufescens.* In 'Action Plan for Australian Birds 2020' (Eds ST Garnett, GB Baker) pp. 477-480. CSIRO: Melbourne.

Stuart, A. & O'Leary, M. (2019). A method for investigating Rufous Scrub-birds using automated recording and rapid, semi-automated data analysis*. Corella* 43: 57-64*.*

Stuart, A., Newman, O.M.G., Ehmke, G. & Garnett, S.T. (2021) Southern Rufous Scrub-bird *Atrichornis rufescens ferrieri*. In 'Action Plan for Australian Birds 2020' (Eds ST Garnett, GB Baker) pp. 474-477. CSIRO: Melbourne.

Teixeira, D., Hill, R., Barth, M., Maron, M. & Van Rensburg, B.J. (2020) Nest-associated vocal behaviours of the south-eastern red-tailed black cockatoo, and the Kangaroo Island glossy black cockatoo. *Austral Ecology,* 45(7): 990-1006.

Threatened Species Operations (2020) Initial analysis of 2019–2020 bushfire impacts on threatened species in southern Queensland. Department of Environment and Science: Brisbane.

Threatened Species Scientific Committee (2001) Commonwealth Listing Advice on Land clearance. Threatened Species Scientific Committee. Department of the Environment, Water, Heritage and the Arts: Canberra. www.environment.gov.au/biodiversity/threatened/ktp/clearing.html

Threatened Species Scientific Committee (2017) Conservation Advice *Mixophyes fleayi* (Fleay's frog). Department of the Environment and Energy: Canberra.

Threatened Species Scientific Committee (2019) Conservation Advice *Potorous tridactylus tridactylus* Long-nosed Potoroo (SE Mainland). Department of the Environment and Energy: Canberra.

Threatened Species Scientific Committee (2020) Conservation Advice *Dasyurus maculatus maculatus* (southeastern mainland population) Spotted-tailed Quoll, south eastern mainland. Department of Agriculture, Water and the Environment: Canberra.

Tingley, R., Meiri, S. & Chapple, D. G. (2016) Addressing knowledge gaps in reptile conservation. *Biological Conservation*, 204: 1–5.

Townley, S.J. (2000) The ecology of the Hastings River mouse *Pseudomys oralis* (Rodentia: Muridae) in northeastern New South Wales and southeastern Queensland. Bachelor Applied Science thesis. Southern Cross University: Lismore.

Valette, J. C., Gomendy, V., Maréchal, J., Houssard, C. & Gillon, D. (1994) Heat-transfer in the soil during very low-intensity experimental fires-the role of duff and soil-moisture content. *International Journal of Wildland Fire*, 4(4): 225-237.

Ward, M., Tulloch, A.I.T., Radford, J.Q. Williams, B.A., Reside, A.E., Macdonald, S.L., Mayfield, H.J., Maron, M., Possingham, H.P., Vine, S.J., O'Connor, J.L., Massingham, E.J., Greenville, A.C., Woinarski, J.C.Z., Garnett, S.T., Lintermans, M., Scheele, B.C., Carwardine, J., Nimmo, D.G., Lindenmayer, D.B., Kooyman, R.M., Simmonds, J.S., Sonter, L.J. & Watson, J.E. (2020) Impact of 2019–2020 mega-fires on Australian fauna habitat. *Nature Ecology and Evolution*, 4: 1321–1326. Doi.org/10.1038/s41559-020-1251-1.

Watt, A. (1993) Conservation Status & Draft Management Plan for *Dasyurus maculatus* and *D. hallucatus* in Southern Queensland. Final report to the Queensland Department of Environment and Heritage and the Department of the Environment, Sport & Territories: Brisbane.

Welsh, H.H. & Ollivier, L.M. (1998) Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. *Ecological Applications, 8*(4): 1118-1132.

WildNet (2022) Biodiversity database. Department of Environment and Science, Queensland Government. Accessed 20 February 2022.

Wilson, S. (2005) A field guide to reptiles of Queensland. Reed New Holland: Sydney.

Wilson, S. & Swan, G. (2003) A Complete Guide to Reptiles of Australia. Page(s) 480. Sydney: Reed New Holland.

Wintle, B.A., Legge, S. & Woinarski, J.C.Z. (2020) After the megafires: What next for Australian wildlife? *Trends in Ecology & Evolution,* 35(9): 753–757. Doi.org/10.1016/j.tree.2020.06.009.

Wishart, J., Lapidge, S. Braysher, M., Sarre, S. S. & Hone, J. (2015) Observations on effects of feral pig (*Sus scrofa*) age and sex on diet. *Wildlife Research 42* (6): 470-474.

Woinarski, J.C.Z., Burbidge, A.A. & Harrison, P.L. (2014) The Action Plan for Australian Mammals 2012*.* CSIRO: Melbourne.

Appendix 1: Summary of camera trapping deployment

Detailed information regarding camera traps set across GWHA to survey long-nosed potoroos, spotted-tailed quoll and Albert's lyrebird.

Table A1.1: Summary of camera trapping locations and effort set

	Mount Barney NP		Main Range NP		Lamington NP		Total
	Baited	Unbaited	Baited	Unbaited	Baited	Unbaited	
Number of sites	10	23	23	23	2	7	**88**
High to Catastrophic PEI	0	0	0	0	0	0	**0**
Moderate to High PEI	1	6	0	0	1	4	**12**
Low to Moderate PEI	2	8	4	12	1	3	**30**
Limited to Low PEI	7	7	15	7	0	0	**36**
Unburnt	0	2	4	4	0	0	**10**
Number of deployments	15	35	28	25	2	7	**112**
Camera trap-days	2,335	3,396	1,679	1,667	182	388	**9,647**
Mean trap-days per deployment	156	97	60	67	91	55	**-**
Total images (blank images; % blank images)	107,081 (10,225; 9.5%)	173,287 (146,834; 84.7%)	71,783 (18,608; 25.9%)	83,453 (75,221; 90.1%)	1,830 (443; 24.2%)	5,672 (4,893; 86.3%)	**443,106 (256,223; 57.8%)**
Mean number of images per deployment	7139	4951	2564	3338	915	810	-

Table A1.2: Technical specifications for the four types of camera traps deployed during this project.

Device*	# cameras deployed	Image resolution (megapixels)	Trigger time (seconds)	Flash	Firmware
Swift ENDURO (Outdoor Cameras Australia; Toowoomba)	22	12	0.35	Infrared	3CrA5010; MCU 4.5.5
BolyGuard SG2050-D (Boly, Inc; Santa Clara, CA, USA)	19	36	Not published	Xenon white	3.05.12; MCU V30
Hyperfire 2 Covert (RECONYX, Inc.; Holmen, WI, USA)	13	3	0.20	Infrared	1.4d
PC800 Hyperfire Professional (RECONYX, Inc.; Holmen, WI, USA)	3	3.1	0.20	Infrared	
Bushnell Trophy Cam (Bushnell; Overland Park, KS, USA)	4	8	1	Infrared	2010

*All cameras used a 32GB SanDisk Ultra 90MB/s SD Card and Energizer Max Plus non-rechargeable Alkaline batteries.

Appendix 2: Calculation of Landscape PEI

Landscape PEI is an extension of the PEI concept, as per Laidlaw *et al.* (2022) and described in Hines *et al.* (2020, 2021 & 2022). It provides an index of PEI within the landscape surrounding a survey point, at a scale appropriate to the survey method. Each survey point for a particular method is buffered by a distance relevant to the method. For example, a buffer with a 250m radius was determined to be a suitable scale for camera traps. The area of each of PEI Class within the buffer was calculated as a percentage of the total area within the burn extent, within the buffer. The area of each PEI Class was then multiplied by a factor weight potential ecological impact; a lower number for less impact and a higher number for more impact (1x for limited or none PEI, 2x for moderate PEI, 3x for high PEI, and 4x for catastrophic PEI). The resultant scores were summed within to assign the survey point a single Landscape PEI Score. Six Landscape PEI classes were categorised according to Table A2.1.

Table A2.1. Landscape PEI classes

Landscape PEI Score	Landscape PEI Class
0	**None**
>0 and <100	**Limited to Low**
>=100 and <200	**Low to Moderate**
>=200 and <300	**Moderate to High**
>=300 and <400	**High to Catastrophic**
>=400	**Catastrophic**

Appendix 3: Three-toed snake-tooth skink survey details

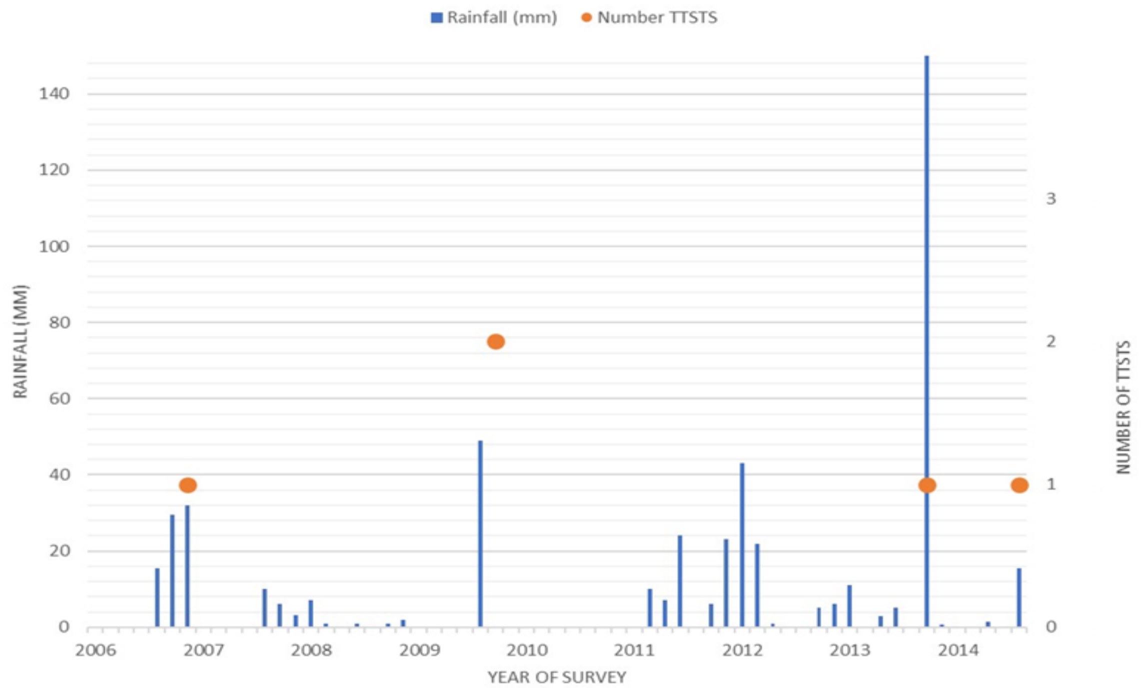

Figure A3.1. TTSTS captures during pitfall trapping previously undertaken at the same site and with the same drift fence configuration as the camera trapping array. Blue bars show rainfall on trap nights during the surveys, undertaken for 4–5 nights in late January, 2006–2014 (Ian Gynther unpubl. data). Axis bounds have been constrained; rainfall on final trap night in 2013 was 250mm.

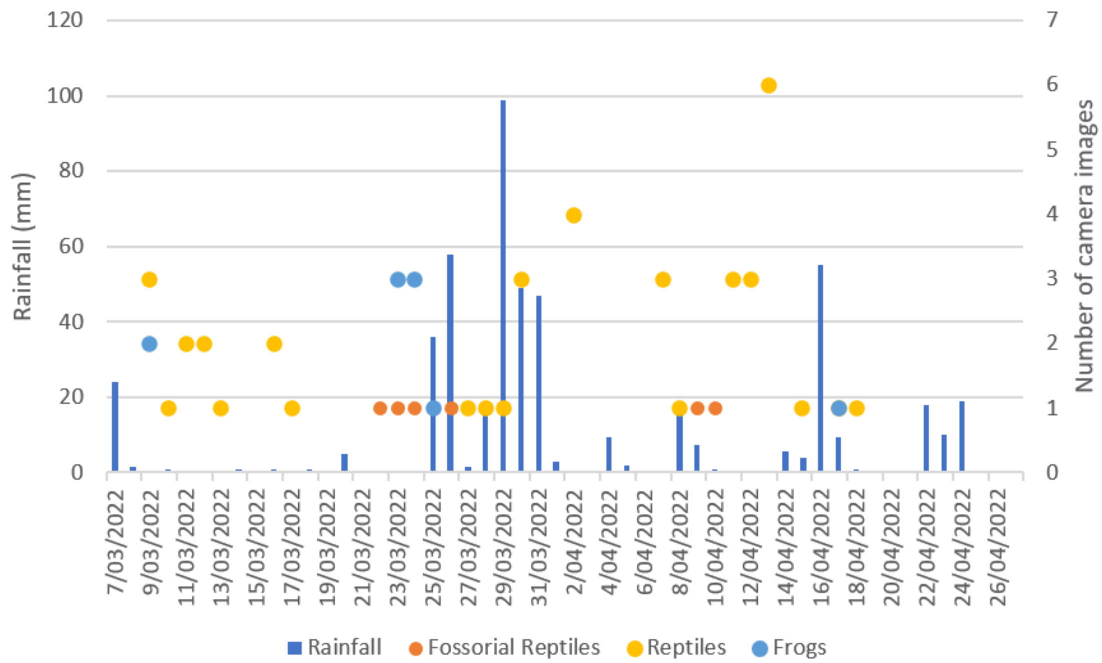

Figure A3.2. Herpetofauna images captured on camera trap array, plotted against rainfall. Fossorial reptile records on 9–10 April 2022 were positively identified as TTSTS; other fossorial reptile images could not confidently be identified to species level.

Table A3.1. Three-toed snake-tooth skink survey efforts and results at Goomburra section of Main Range NP.

Site	Site ID	Method	Burnt	Effort description	Date and time of search	Number of TTSTs: this survey	Number of TTSTS: historic records	Rain during /or prior 24 hrs?	Notes
1	CRAS001	Diurnal active search	No	1 ha for 1 person hour	22/02/2022 13:20	0	0	No	
				1 ha for 1 person hour	23/02/2022 15:00	0		Yes	
2	CRWT001	Diurnal walking transect	No	~500 m for 1 pers. hr	22/02/2022 14:00	0	1	No	
3	CRAS002	Diurnal active search	No	1 ha for 1 person hour	22/02/2022 15:30	0	0	No	
				1 ha for 1 person hour	23/02/2022 10:45	1		Yes	
				1 ha for 1 person hour	23/02/2022 14:00	1		Yes	
4	CRWT002	Diurnal walking transect	No	~500 m for 1 pers. hr	23/02/2022 11:15	0	1		
5	CRA0545	Diurnal active search	No	1 ha for 1 person hour	22/02/2022 16:15	0	9	No	
6	CRWT003	Diurnal walking transect	No	~500 m for 1 pers. hr	22/02/2022 16:45	0	0	No	
7	CRWT005	Nocturnal walking transect	Part	900 m for 40 pers mins	22/02/2022 18:20	0	0	Yes	Burnt near lookout
					23/02/2022 21:15	0		Yes	
8	CRA0546	Diurnal active search	No	1 ha for 1 person hour	23/02/2022 8:30	0	2	Yes	
9	CRWT004	Diurnal walking transect	No	~500 m for 1 pers. hr	23/02/2022 9:00	0	0	Yes	
10	CRWT006	Diurnal walking transect	Part	900 m for 30 pers mins	23/02/2022 11:20	0	0	Yes	Burnt near lookout
11	CRA0548	Diurnal active search	No	1 ha for 1 person hour	24/02/2022 8:45	0	0	Yes	
12	CRA0549	Diurnal active search	No	1 ha for 1 person hour	24/02/2022 10:10	0	0	Yes	
13	Lookout Rd	Nocturnal driving transect	No	6 km for 40 minutes	22/02/2022 19:10	0	0	Yes	
				12 km for 1 hour	22/02/2022 21:20	0		Yes	
				12 km for 1.2 hours	23/02/2022 20:00	0		Yes	
		Diurnal driving transect	No	6 km for 30 minutes	22/02/2022 12:50	0	1	No	
			No	6 km for 30 minutes	23/02/2022 11:50	0		Yes	
Total of Active Searching									9 person hours
Total of Walking Transects									5 person hours
Total of Driving Transects									4 hours

Table A3.2. Three-toed snake-tooth skink camera trapping effort at Green Mountains, Lamington NP.

Camera Type	Camera ID	Position N-S	Ist Deployment Date	Notes on Position	Notes on Deployment	Number of Photos Downloaded				Total number of camera-trap nights	Number of Images	
						Download #1 22/03/22	Download #2 6/04/22	Download #3 27/04/22	Total		Herpetofauna	Herpetofauna images ID-ed to species
Black Flash Standard focus	EN011	6	9/03/2022	Camera facing uphill; 2m from large decomposing log	Battery failure early in 2nd deployment	17386	1220	17967	36573	24	0	0
	EN012	4	9/03/2022	Camera facing uphill; attached to tree 55 cm DBH		16645	16850	18103	51598	35	4	0
	EN013	8	9/03/2022	Facing across/down slope; 3m from large rotting log; top of clearing		15280	17254	18146	50680	26	8	7
	EN014	10	9/03/2022	Camera facing uphill; next to clearing 10 x 8 m		16694	17312	18617	52623	36	10	1
	EN015	12	9/03/2022	Camera facing uphill		16632	17385	18142	52159	36	5	1
	EN016	13	9/03/2022	Camera facing uphill	Battery failure early in 1st & 2nd deployment	6156	2203	18220	26579	19	5	4
Subtotal for Black Flash Standard Focus Cameras									270212	176	32	13
Black Flash Close Focus	ENCF01	3	9/03/2022	Camera facing uphill/ across slope		18132	10556	18511	47199	33	3	2
	ENCF02	5	9/03/2022	Camera facing uphill; dense canopy overhead		16326	16519	18540	51385	35	1	1
	ENCF03	7	9/03/2022	Camera facing uphill; next to large decomposing log		17635	16419	17896	51950	35	4	4
	ENCF04	9	9/03/2022	Facing uphill/ across slope; edge of clearing 10 x 8 m	Settings not saved in 1st deployment	17365	16832	18568	52765	26	7	0
	ENCF05	11	9/03/2022	Facing uphill to embedded boulder	Settings not saved in 1st deployment	6653	16679	17843	41175	25	3	1
	ENCF06	14	9/03/2022	Facing downhill; mossy log 25cm diameter in backdrop		18429	11088	17710	47227	33	7	1
Subtotal for Black Flash Close Focus Cameras									297701	187	25	8
White Flash Close	BirdCam	15	9/03/2022	Facing uphill; on a 17 cm DBH tree		15151	15986	15502	46639	32	1	0
	SGCF07	2	22/03/2022	Facing uphill near embedded boulder	5 min intervals	N/A	3217	3331	6548	36	0	0
	SGCF09	1	22/03/2022	Facing uphill towards horizontal root	5 min intervals	N/A	2894	3087	5981	36	0	0
	SGCF15	16	22/03/2022	Facing uphill to clearing; with small stone embedded to right side	5 min intervals	N/A	2810	3321	6131	36	1	0
Subtotal for White Flash Close Focus Cameras									65299	140	2	0
Total for all Cameras									**627212**	**503**	**59**	**21**

Appendix 4: Invertebrate survey sites and methods

A4.1 Standardised invertebrate survey sites

Table A4.1: Location of the 12 invertebrate survey sites across three levels of fire severity, and two locations at both Main Range (Figure A4.1) and Lamington (Figure A4.2) NPs. Survey timing in 2020: Cunninghams Gap area 20–25 October; Mt Cordeaux area 21–26 October; Yandooya 24–29 November; and Binna Burra 25–30 November.

Location	Descriptor	Fire severity	Latitude	Longitude	Altitude	Habitat
Cunninghams Gap	North-west of carpark	Unburnt	-28.04802222	152.3925056	810 m	complex notophyll vine forest
	Mt Mitchell Track	Moderately burnt	-28.05388889	152.3945528	850 m	
	Mt Mitchell Track	Severely burnt	-28.05196111	152.3943222	830 m	
Mt Cordeaux	South-east of Bare Rock	Unburnt	-28.02933333	152.3876194	1140 m	simple microphyll fern forest
	South of Bare Rock	Moderately burnt	-28.02687222	152.3854667	1140 m	
	Morgans Walk	Severely burnt	-28.02869167	152.3914306	1130 m	
Yandooya	IBISCA IQ-300-A	Unburnt	-28.14823889	153.1367889	270 m	notophyll vine forest
	IBISCA IQ-300-C	Moderately burnt	-28.15079722	153.1383111	280 m	
	IBISCA IQ-300-B	Severely burnt	-28.15447500	153.1387528	275 m	
Binna Burra	Bellbird Circuit	Unburnt	-28.19836944	153.1889944	785 m	complex notophyll vine forest
	Tea House area	Moderately burnt	-28.19892222	153.1866333	795 m	
	Caves Circuit	Severely burnt	-28.19756667	153.1860944	785 m	

A4.2 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 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, that was then assessed for live archaeids (Figure A4.3).

Litter extraction: leaf litter was collected (Figure A4.3) and sifted to provide two $1m^2$ samples per site to be 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) were sprayed with 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 past an obstruction, e.g. Diptera (flies) and Hymenoptera (bees, wasps). The trap base 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 A4.4).

Unbaited pitfall traps: ten 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 and a square plastic cover suspended 3–4cm above the trap (Figure A4.5).

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 A4.5).

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

Ant collecting: one sample was collected between 09:05–16:50hrs 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 (Figure A4.5).

Figure A4.1. The six invertebrate survey sites across three levels of fire severity at both Cunninghams Gap and Mt Cordeaux, Main Range NP. (Photos: M. Rix)

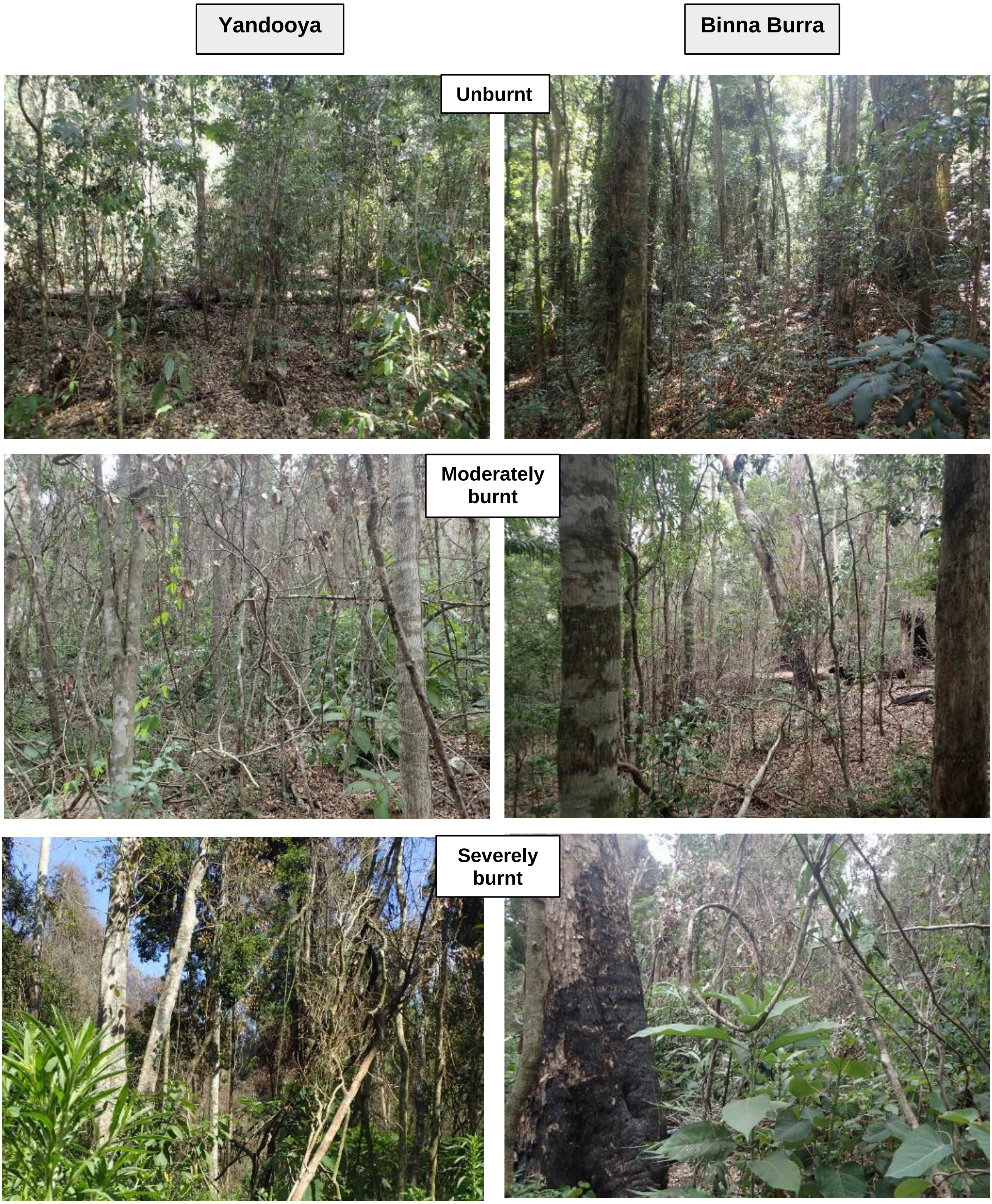

Figure A4.2. The six invertebrate survey sites across three levels of fire severity at both Yandooya and Binna Burra, Lamington NP. (Photos: M. Rix)

Figure A4.3: Sifting suspended leaf litter for spiders in the family Archaeidae (left) and collecting leaf litter for Tullgren funnel extraction (right). (Photos, left to right: C. Lambkin; M. Laidlaw)

Figure A4.4: Malaise trap set up at Lamington NP, Yandooya moderately burnt plot (left) and insects in the collecting jar at the unburnt site at Binna Burra (right). (Photos: C. Lambkin)

Figure A4.5: Invertebrate survey techniques: unbaited pitfall trap (left); baited pitfall trap—mushroom (centre left); baited pitfall trap—dung (centre right); and ant collecting (right). (Photos: M. Laidlaw (left and centre left); T. Churchill (centre right); and C. Lambkin (right))

Appendix 5: Authors and contributors

Report section	Authors and key contributors	Department or institution
Executive Summary; 1, 2, 9, 10 & 11	Dr Tracey Churchill (Program Manager & Project Lead)	Threatened Species Operations, QPWS, DES
2. Post-fire assessments	Harry Hines (lead)	Ecological Assessment Unit, QPWS, DES
3.1 Brush-tailed rock-wallaby	Dr Jennifer Molyneux & Dr Alan Horsup George Krieger	Threatened Species Operations, QPWS, DES Coastal & Island Region, QPWS, DES
3.2 Long-nosed potoroo 3.3 Spotted-tailed quoll 3.4 Hastings River mouse & New Holland mouse 4.1 Albert's lyrebird 4.2 Coxen's fig-parrot	Dr Ian Gynther & Hunter McCall	Threatened Species Operations, QPWS, DES
4.3 Glossy black-cockatoo	Dr Daniella Teixeira	Queensland University of Technology
4.4 Eastern bristlebird 4.5 Rufous scrub-bird	Dr David Stewart & Luke Geelen	Threatened Species Operations, QPWS, DES
5.1 Stream frogs 5.2 Mountainfrogs	Harry Hines & Hunter McCall	Ecological Assessment Unit, QPWS, DES Threatened Species Operations, QPWS, DES
5.3 Three-toed snake-tooth skink	Melanie Venz, Daniel Ferguson & Dan Sparks Dr Paul Oliver	Queensland Herbarium, DES Queensland Museum
6. Priority invertebrates	Dr Michael Rix, Dr Chris Burwell and Dr Christine Lambkin Dr Tracey Churchill Dr Melinda Laidlaw	Queensland Museum Threatened Species Operations, QPWS, DES Queensland Herbarium, DES
7. Priority flora 8. Priority ecosystems	Dr Melinda Laidlaw	Queensland Herbarium, DES
9. Reducing threats	Jo Zadkovich Wil Buch, Mykel Holmes, Todd Brown Justin O'Connell, Diana Hughes Tim Wood, Adrian Gurra, Chris Job & Steve Finlayson Sophie Cooper	Technical Services, South East Region, QPWS Lamington NP, South East Region, QPWS Mt Barney NP, South East Region, QPWS Main Range NP, South West Region, QPWS State Fire & Pest Management, QPWS, DES
Editorial	Dr Tracey Churchill Dr Clare Hourigan & Emily Snell Dr Ian Gynther	Threatened Species Operations, QPWS, DES