Bushfire Recovery Program 2020–2021: Priority actions for threatened species in Oakview and Nangur National Parks

South East Queensland

2023

Queensland Government

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

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Front cover: Vine forest under hoop pine in Oakview National Park (Photo: T.B. Churchill)

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Executive summary

The bushfires of late 2019 to early 2020 had extensive ecological impacts across 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 emergency response projects across strategic locations, including Oakview and Nangur National Parks. At these parks, two threatened reptile species were prioritised for recovery actions: the Oakview leaf-tailed gecko *Phyllurus kabikabi* and the Nangur spiny skink *Nangura spinosa*. Both species are restricted to the semi-evergreen vine forest and listed as Critically Endangered under the Queensland *Nature Conservation Act 1992* (NCA).

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

- **Post-fire assessment**—detailed spatial evaluation of fire extent and severity, and the associated ecological impacts, to guide the survey of priority species and on-ground efforts to reduce threats to their recovery.
- **Survey 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 recovery**—implementation of actions to reduce the risk to priority species and their habitats from future unplanned fires, invasive weeds, pest animals and population decline.
- **Recommendations and guidance**—assessment of the information and insights gained from the above actions to guide the priorities for ongoing ecological monitoring, research and reducing threats to species' recovery.

The post-fire assessment identified that 1,438 hectares (ha) burned within Oakview National Park (NP) during a bushfire in late 2019. Fire severity was predominantly low to moderate, covering 97% of the total area burnt. Approximately 100ha of geographically restricted and fire-sensitive vine forest were impacted, which represented 4.7% of this vegetation type in Oakview NP. For a given level of fire severity, the ecological impacts can vary across different vegetation types based on their fire-tolerance. Fire severity was therefore incorporated with the fire-sensitivity of vegetation to spatially quantify the 'potential ecological impact' (PEI) (Laidlaw *et al*. 2022), which revealed a moderate to catastrophic level of impact for the vine forest (Meiklejohn *et al.* 2021).

The Oakview leaf-tailed gecko was surveyed in Oakview NP, where approximately 8% of its modelled habitat was impacted by the 2019 bushfire (Meiklejohn *et al.* 2021). Burnt and adjacent unburnt areas of suitable rocky habitat were surveyed using camera trapping and passive nocturnal searches. Direct fire impacts on the gecko were difficult to quantify due to the lack of baseline information. The most significant areas of core habitat with the largest known population of Oakview leaf-tailed gecko were successfully defended during the 2019 bushfire, although the creation of a fireline impacted suitable habitat. Surveys in habitat adjacent to this fireline found a decline in gecko detection rates compared to previous years. This highlighted a need for improved communication of important habitat during bushfire events to avoid additional threats to the habitat, including the creation of new pathways for weed and pest animal incursions.

The Nangur spiny skink surveys for individuals and their burrows within and adjacent to burnt habitat in Oakview NP, where approximately 2% of the species' modelled potential habitat was fire impacted (Meiklejohn *et al.* 2021), indicated that direct fire impacts to the population were limited. The most significant areas of habitat were successfully defended from the 2019 bushfire. Survey results indicate that the Nangur spiny skink populations within core areas of Oakview NP and Oakview State Forest are stable but declining at the margins of their extent.

Nangur NP was not impacted by the 2019 bushfire. However, populations of the Nangur spiny skink there are limited and genetically distinct, with their ongoing viability critical to the conservation of the species. In Nangur NP, monitoring continues to show a slow decline in mature individuals, although an observed increased in the recruitment of juveniles is encouraging.

The endangered plant species *Coleus omissus* was identified as a conservation significant species in the post-fire assessment report (Meiklejohn *et al*. 2021). Potential habitat that burned during the 2019 bushfire in Oakview NP was searched, with the post-fire recovery of identified individuals and populations monitored. One population of *C. omissus* was significantly impacted, with plants growing amongst other vegetation mostly consumed by the fire. However, this population recovered well and regenerated to mature, flowering plants.

Key threats to the recovery of the priority species included the risk of future unplanned fire, pest animals, invasive plants, illegal interference with the reptiles and reduced genetic viability of the threatened reptile populations. Planning and implementation of identified on-ground actions to reduce these threats were undertaken by Queensland Parks and Wildlife Service in addition to normal work programs. This included:

- improved planning and provision of a 6.9km critical fireline to enhance capacity for an emergency fire response and protect priority species' habitats
- establishment of monitoring programs for pest animals and unauthorised access; deployment of traps to control cats, foxes and deer
- predator exclusion cages to protect the small and genetically unique Nangur spiny skink population
- control of cat's claw and coral berry to prevent incursion into core habitat areas
- control of lantana and high-biomass grasses to mitigate future fire risk and severity
- road closures and gate installation to restrict unauthorised access to core habitat areas, and
- enhanced capacity for a successful captive-breeding program of Nangur spiny skink through the design and construction of a customised enclosure.

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 following the next natural disaster. Ongoing investment is necessary to sustain best-practice methodologies and embrace more cost-effective technologies to support ecological monitoring.

1 Context

1.1 2019–2020 bushfires

The Australian bushfire season of 2019–2020 was extraordinary in terms of its extent, duration and intensity. The year of 2019 was the hottest and driest on Australian records and the Forest Fire Danger Index exceeded all previous values (Bureau of Meteorology 2020). Over 24 million ha burned, impacting at least 37 ecological communities and 330 species listed as nationally threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (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).

In Queensland, over 7.7 million ha burned (Queensland Reconstruction Authority 2020), which included more than 1.6 million ha of protected areas and 12,000ha of Ramsar wetlands (Threatened Species Operations 2020). At least 648 threatened species were impacted, including 631 listed as threatened under the state *Nature Conservation Act 1992* (NCA) and 266 listed under the EPBC, of which 21 were Critically Endangered (Threatened Species Operations 2020). In southern Queensland, the preceding extensive drought (Bureau of Meteorology 2020) had already reduced habitat condition and availability of water and food resources, exacerbating fire impacts on wildlife. Normal refugia of gullies, rocky outcrops and rainforests were unpredictably burnt (e.g. Hines *et al*. 2020), which would have significant consequences for wildlife during the fire, as well as for their 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 modelled habitat for species listed as threatened under the NCA, potential fire impacts and key threats to their recovery. The outcomes were compared to a broader scale study by the Commonwealth 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 qualified for funding from the first 'Emergency Response' phase of the Australian Government's $200 million 'Bushfire Recovery for Wildlife and their Habitats package'. In March 2020, the Australian Government provided $1.5 million to DES to support delivery of recovery actions for the priority species 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 and Partnerships (QPWS). The first phase of the program included four projects representing strategic locations of fire-impacted threatened species: Gondwana Rainforests of Australia World Heritage Area; Coastal wallum-heath of the Cooloola area; Oakview and Nangur National Parks; and Bulburin National Park. This report summarises the actions delivered through the third project across Oakview National Park (Oakview NP) and Nangur National Park (Nangur NP).

1.3 Prioritised species

The process to prioritise threatened species for recovery efforts identified two reptile species that had more than 10% of their state-wide habitat impacted by the 2019 bushfire: Nangur spiny skink *Nangura spinosa* and Oakview leaf-tailed gecko *Phyllurus kabikabi* (Threatened Species Operations 2020; Table 1). Whilst Nangur NP was not impacted by the 2019 fire, it is the location of a second, small and genetically distinct population of the Nangur spiny skink, hence, on-ground actions were important to sustain the ongoing viability of the species.

Table 1. Reptile species prioritised for recovery actions, with the area of their modelled habitat burnt in the 2019–2020 fires, their conservation status under state (NCA) and Commonwealth (EPBC) legislation (E – Endangered; CE – Critically Endangered) (Threatened Species Operations 2020).

Common name	Species	Impacted Habitat (ha)	% Habitat Impacted	NCA	EPBC
Oakview leaf-tailed gecko	*Phyllurus kabikabi*	4,517	18	E	-
Nangur spiny skink	*Nangura spinosa*	15,594	16	E	CE

The Queensland Herbarium subsequently recognised that the plant *Coleus omissus,* which is classified as Endangered under the NCA and EPBC, was at risk from fire impacts and was also surveyed, with those results also included in this report.

1.4 Priority recovery actions

The project aimed to deliver actions that aligned to expert advice to protect and support the ongoing recovery of the priority threatened species, as follows:

- **Post-fire assessment**—detailed spatial evaluation of fire extent and severity, and the associated ecological impacts, to guide the survey of priority species and on-ground efforts to reduce threats to their recovery.
- **Survey priority threatened species**—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 recovery**—implementation of actions to reduce the risk to priority species and their habitats from future fires, invasive weeds, pest animals and population decline.
- **Recommendations and guidance**—assessment of the information and insights gained from the above actions to guide the priorities for ongoing ecological monitoring, research and reducing threats to species' recovery.

This report documents the implementation of these actions across Oakview and Nangur NPs between April 2020 and June 2021 for Phase I of the Queensland Bushfire Recovery Program.

2 Post-fire assessment

A post-fire assessment was undertaken by DES to document the 2019 bushfire event, mapping the extent, severity and potential ecological impacts (Meiklejohn *et al*. 2021). The bushfire started on 7 November 2019, presumably by lightning, and burnt across Oakview NP until it was contained on 22 November 2019. To protect the Critically Endangered Oakview leaf-tailed gecko and Nangur spiny skink, an existing fireline line was re-opened, aerial water bombing by numerous aircraft and back-burning undertaken, which successfully limited the area of vine forest habitat impacted. Maps of fire severity and potential ecological impacts from the post-fire assessment report are reproduced below, and the data utilised to provide background context for this report (refer to Meiklejohn *et al*. 2021 for the full analysis and details, and caveats of the remote sensing methodology).

2.1 Fire extent and severity

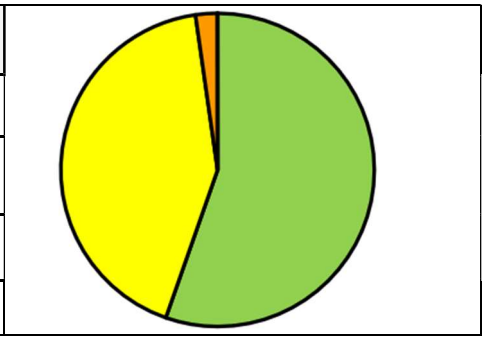
The 2019 bushfire extent was 1,438ha within Oakview NP. Fire severity was analysed by comparing satellite imagery before and after the fire event to create a Normalised Burn Ratio difference product that was classified into fire severity categories from low to extreme, aided by field verification. These classes reflect the level of observed change to vegetation, which were then summarised (Table 2) and mapped (Figure 1) for the 2019 bushfire in Oakview NP (Meiklejohn *et al.* 2021).

Oakview NP protects a range of vegetation types, including ironbark woodlands, mixed eucalypt woodlands and open forests, and araucarian notophyll and microphyll vine forests. The national park also includes localised patches of wet sclerophyll/tall open forest and two Of Concern woodlands (Meiklejohn *et al*. 2021). The habitat for the Oakview leaf-tailed gecko and the Nangur spiny skink is restricted to the semi-evergreen vine forests. Of the 1,438ha burnt within Oakview NP, the majority was dry and moist eucalypt open forests to woodlands (93%).

Fire severity was predominantly low to moderate across Oakview NP, representing 97% of the total area burnt, with limited impact on canopy. About 32ha burnt at high severity (full canopy scorch to partial canopy consumption), with a very small area (0.2ha) assessed as burning at extreme severity (full consumption of vegetation) (Table 2; Figure 1).

Table 2. The area burnt in Oakview NP across the four classes of fire severity, and the relative proportion of each class of the total area burnt (colour coded by fire severity class). Data derived from Meiklejohn *et al*. (2021).

Fire severity class	Description of effect on vegetation	Area (ha)
Low	Canopy and subcanopy unscorched, shrubs may be scorched, fire sensitive low shrubs may be killed.	796.3
Moderate	Partial canopy scorch, subcanopy partially or completely scorched, and/or fire sensitive tall shrub or small tree layer mostly killed.	609.6
High	Full canopy scorch to partial canopy consumption, subcanopy fully scorched or consumed.	32.3
Extreme	Full canopy, subcanopy and understorey consumption.	0.2



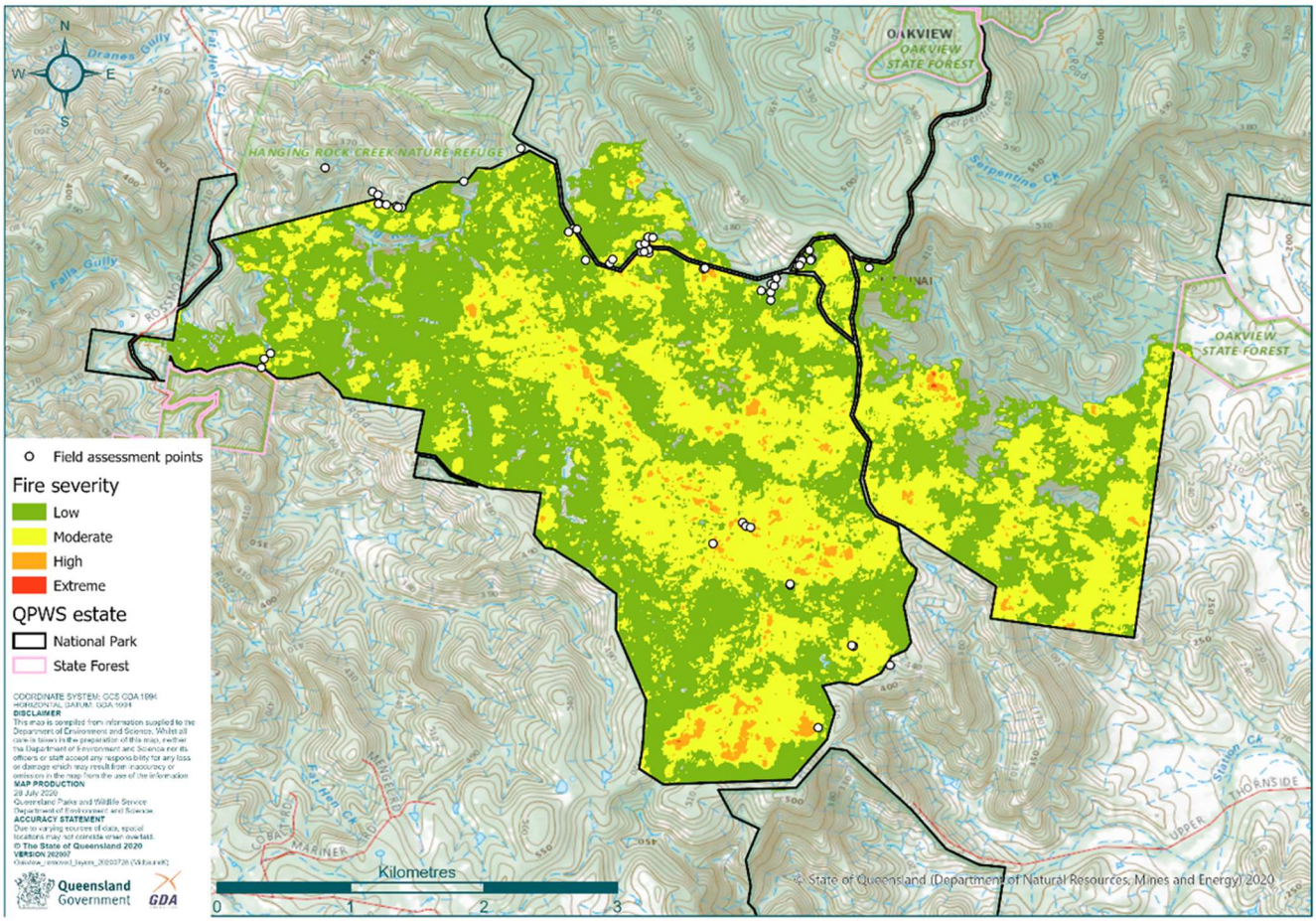


Figure 1: Distribution of the 2019 bushfire in Oakview NP, and across four classes of fire severity (low to extreme). Reproduced from Meiklejohn *et al*. (2021).

2.2 Potential ecological impacts

The ecological consequences of fire at a given level of severity varies with the type of vegetation, according to its sensitivity to fire. Flora and fauna associated with different vegetation communities have typically evolved a comparable level of fire tolerance, with those species 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' 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.

Due to the fire-adapted canopy and understorey of most of the burnt area within Oakview NP, potential ecological impacts were mostly limited. Within the fire-adapted woodlands and open forests only 31ha was assessed as burning with moderate to high potential ecological impact (Table 3; Meiklejohn *et al*. 2021). These areas of higher fire severity typically coincided with moist gullies where the density and flammability of *Lantana camara* undergrowth elevated impacts (Meiklejohn *et al*. 2021).

The geographically restricted and fire-sensitive vine forests were significantly affected by the 2019 bushfire. The Broad Vegetation Group (2M) is complex to simple, semi-deciduous microphyll to notophyll vine forest, sometimes with *Araucaria cunninghamii* (hoop pine) emergents. Approximately 100ha was burnt, representing almost 5% of the 2,110ha of vine forest within Oakview NP, with 68.7 ha burnt with moderate potential ecological impact (Table 3; Figure 2; Meiklejohn *et al.* 2021). Vine forests are highly fire-sensitive, and even at low severity, fire has a moderate potential ecological impact, with 31ha assessed as having high to catastrophic potential ecological impact (Table 3). In addition, fire can enhance the risk of incursions of ecosystem-changing weeds and pest animals into these communities, leading to further adverse ecological outcomes.

Table 3. Potential Ecological Impact to burnt remnant vegetation (ha) based on fire tolerance and relative fire severity class. Note that the concept of Potential Ecological Impact also takes into account the susceptibility of the ecosystem (given the fire severity to which it has been subjected) to threats post-fire that could significantly impede recovery. Data from Meiklejohn *et al*. (2021).

	Vine forests	**Dry-moist eucalypt woodlands and open forests**
Potential Ecological Impact	Fire-sensitive canopy & understorey	Fire-adapted canopy & understorey
Limited or none		1,307.6
Moderate	68.7	30.8
High	29.5	0.2
Catastrophic	1.5	

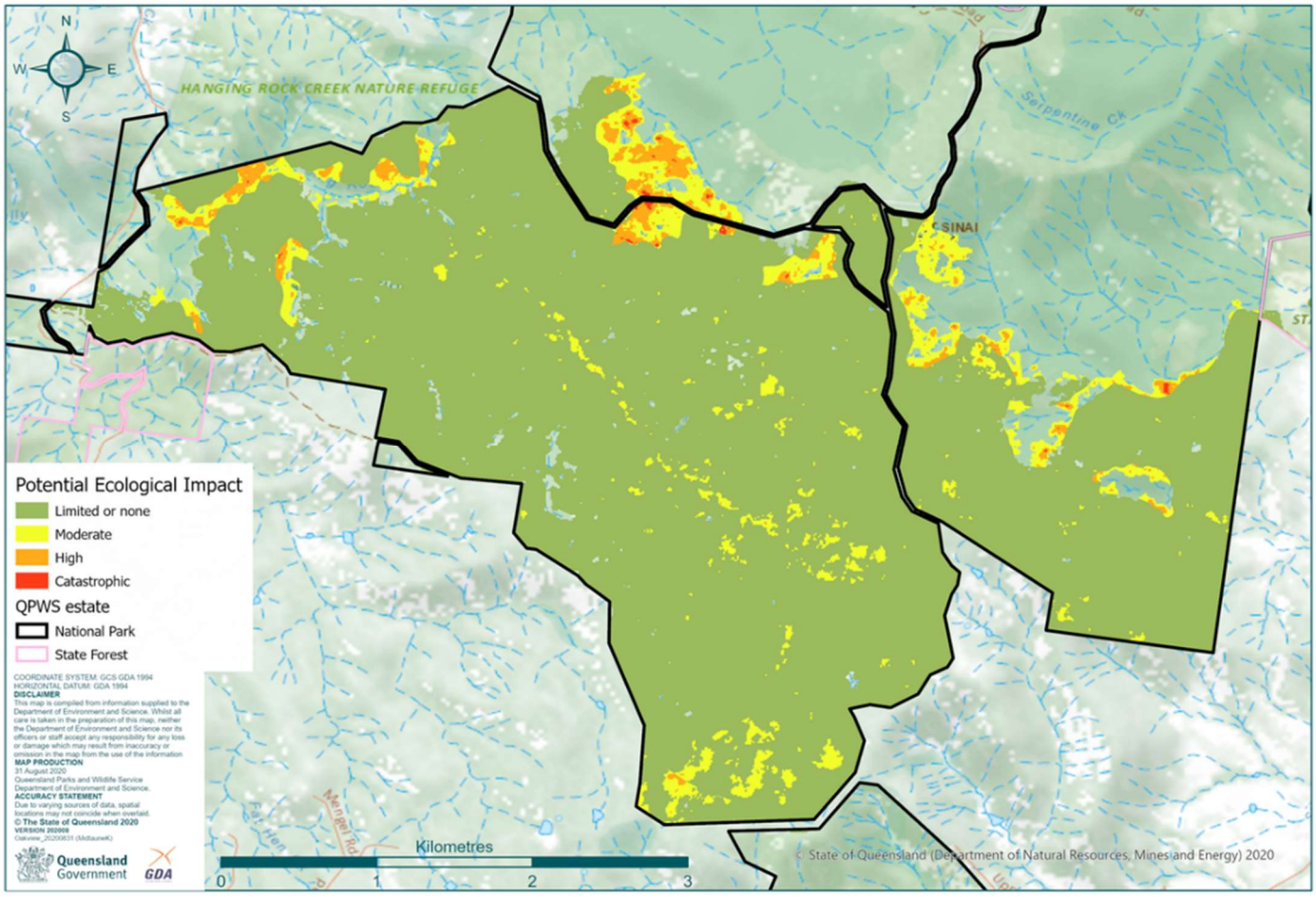


Figure 2: Distribution of potential ecological impacts from the 2019 bushfire in Oakview NP, across the four categories (limited or none to catastrophic). Reproduced from Meiklejohn *et al*. (2021).

3 Priority threatened species

3.1 Oakview leaf-tailed gecko

3.1.1 Conservation status

The Oakview leaf-tailed gecko *Phyllurus kabikabi* was formally described as a new species by Couper *et al*. (2008). No populations are known to exist outside Oakview NP or Oakview State Forest. The conservation status of the Oakview leaf-tailed gecko is Critically Endangered under the NCA. Whilst not currently listed under the EPBC, a nomination has been submitted under the Common Assessment Method (CAM) recommending that *Phyllurus kabikabi* is listed as Critically Endangered.

The Oakview leaf-tailed gecko is a small gecko up to 15cm (8cm snout–vent length) with large tubercles (conical or wart-like projections) covering its body and tail. It is grey-brown in colour with fine dark mottling or blotches, pale spots and 5–6 pale bands on the narrow cylindrical tail (Figure 3). Regenerated tails lack the pale bands and tubercles of original tails. The species is nocturnal and arboreal, sheltering by day among boulders and in hollows, and actively forages over rocks and low vegetation above the rock throughout the night. Like other members of the genus, this species likely feeds on small invertebrates such as arthropods (Wilson & Knowles 1988; Couper *et al*. 1993).

The Oakview leaf-tailed gecko is only found in Araucarian vine forest (Regional Ecosystems 12.12.13 and 12.12.16) growing over a deep layer of broken igneous rock (Couper *et al*. 2008; D. Ferguson, unpublished data 2019). The species does not utilise the rock substrates outside of vine forest, even where it is adjacent to occupied habitat, and rarely moves far into vine forest without a rocky ground layer (D. Ferguson, unpublished data 2019). This strong association with rocky rainforest sites is seen across most *Phyllurus* species (Couper *et al*.1993, Couper *et al*. 2000, Hoskin *et al*. 2003). The extent of vine forest in the Oakview area (NP, State Forest and surrounding tenures) totals approximately 1,800ha. However, the distribution of Oakview leaf-tailed gecko is limited by the presence of layered rock underneath the vine forest, which is extremely patchy. Preliminary data indicate a rocky outcrop must be in excess of 0.8 ha in size to support the species, with currently known sites ranging in size from approximately 0.8ha to 6.1ha (D. Ferguson, unpublished data 2019). The extent of suitable habitat in Oakview NP is very limited and highly isolated, but any estimates of available suitable habitat remain unknown due to the rugged inaccessible nature of the terrain and the highly cryptic behaviour of the gecko.

A total of 1,252ha of modelled potential habitat for the Oakview leaf-tailed gecko occurs in Oakview NP, with 7.9% impacted by the 2019 fire (Meiklejohn *et al*. 2021; see Laidlaw & Butler 2021 for modelled habitat methodology). Ground surveys were undertaken to evaluate the likely impact on the population after the fires, and to monitor and manage the threats posed post-fire, including from weeds, pest animals and the increased accessibility to the protected area.

Figure 3: Oakview leaf-tailed gecko in Oakview NP. (Photos, left to right: M. Mathieson; D. Ferguson).

3.1.2 Survey sites and methods

To survey the Oakview leaf-tailed gecko, two techniques were applied across burnt and unburnt sites of suitable rocky habitat. The location of survey sites remains confidential in order to protect the species.

Sites

Four sites with suitable habitat for Oakview leaf-tailed geckos within vine forest were selected: two with known occupation by geckos (K#), based on previous surveys, and two with unknown levels of gecko occupation (U#).

Site K1

At approximately 6.1ha in size, this site has the largest known sub-population of Oakview leaf-tailed geckos (D. Ferguson, unpublished data 2021). The vegetation was impacted by reopening an old forestry road during the emergency fire response to the 2019 bushfire in order to create a firebreak and protect this critically important gecko habitat.

Site K2

This site has approximately 0.8ha of suitable habitat known to be occupied by the Oakview leaf-tailed gecko, although the aggressive cat's claw creeper (refer to section 4.3) has been encroaching onto the rocky areas since at least January 2019, when it was first discovered (D. Ferguson, unpublished data 2019). As of April 2021, approximately 40–50% of the suitable rocky ground layer has been at least partially covered by cat's claw (Figure 4).

Site U1

Despite having approximately 1.8ha of suitable habitat, this site had not been previously surveyed to establish the presence of Oakview leaf-tailed gecko. The 2019 bushfire burned the adjacent open forest and margins of the vine forest to within 50m of this site. This site is located less than 140m from the burnt site (U2), but there is a lack of continuity of a rocky ground layer under the vine forest to provide a suitable habitat connection.

Site U2

This site was considered to be potential habitat for the Oakview leaf-tailed gecko, due to a rocky ground layer within suitable vine forest, although it had not previously been surveyed to confirm its presence. The 2019 bushfire burned through the adjacent open forest and penetrated the vine forest by 200–300m at low severity over the rocky substrate, with fire scars indicating a flame height of approximately 10–15cm. Under the prevailing dry conditions, the fire killed many of the rainforest tree species found across the site and significantly altered the ground layer.

Methods

Camera trapping

Nine cameras were deployed at each site (total of 36 cameras) between 9 September 2020 and 20 March 2021. The cameras had modified focal lengths of 75cm and were a mix of Reconyx PC850 Hyperfire Professional White Flash and Scoutguard SG562-C. The cameras were set to take an image of an appropriate rocky area every five minutes during the night between 1830 and 0530 when the Oakview leaf-tailed gecko is active. A low-sensitivity motion trigger was also set on these same cameras to detect pest animals present at the sites.

Passive nocturnal searches

Passive nocturnal searches for the Oakview leaf-tailed gecko were carried out within suitable areas of rocky habitat by highly experienced observers at eight sites on three occasions between 20 September 2020 and 21 April 2021. Search area and the time spent searching was determined by the available area of suitable habitat and approximately equated to one person-hour per hectare. Head torches were used with a red filter to detect eye-shine and without a filter (white) to visually detect movement of the Oakview leaf-tailed gecko, as per the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (Eyre *et al*. 2022).

3.1.3 Survey results

A total of 643GB of data, approximately 650,000 images, were recorded on the camera traps during the survey period. A manual analysis of the images was undertaken to detect geckos (e.g. Figure 5) across each of the four survey sites to calculate the number of detections (Table 4).

Table 4. The number of detections of the Oakview leaf-tailed gecko from camera trapping (with number of trap-nights) and nocturnal searches across the four survey sites.

		Camera trapping		Nocturnal search
Site	**Description**	#detections	#trap-nights	
K1	Known occupancy; largest sub-population; fireline impact	47	1067	9
K2	Known occupancy; cat's claw-impacted	2	433	-
U1	Unknown occupancy; suitable habitat; unburnt	84	941	7
U2	Unknown occupancy; suitable habitat; burnt	0	901	0

At K1, there were a significant number of detections of the Oakview leaf-tailed gecko using camera trapping and nocturnal searches (Table 3), supporting ongoing site occupancy despite the disturbance from reopening an old fireline within the vine forest. The southern spotted velvet gecko *Oedura tryoni*, listed as Least Concern under the NCA, was readily detected in the area that was not impacted by cat's claw creeper.

At Site K2, which was being invaded by cat's claw vine, there was a much lower rate of gecko detections per unit of survey effort for both camera traps and nocturnal searches.

The highest number of detections of Oakview leaf-tailed geckos was at Site U1, which confirms site occupation and suitability of the habitat.

For the burnt Site U2, there were no detections of Oakview leaf-tailed geckos by either camera trapping or nocturnal searches. However, other reptile species known to occur at this site were detected, including diamond-shielded sunskink *Lamproholis adonis* and *Oedura tryoni* (D. Ferguson, unpublished data). A comparison of habitat variables measured before and after the 2019 bushfire showed a decline in habitat suitability for the Oakview leaf-tailed gecko, with a decrease in litter cover and tree canopy cover, and a significant increase in ground and shrub cover comprised primarily of the weed species inkweed *Phytolacca octandra* and Brazilian nightshade *Solanum seaforthianum* (D. Ferguson, unpublished data).

3.1.4 Discussion

Previous research has demonstrated that timelapse camera trapping is a useful innovative technique for long-term monitoring of Oakview leaf-tailed gecko population size and trends in response to threatening processes (D. Ferguson, unpublished data). Using Random Encounter Occupancy Modelling, detection probability and abundance can be estimated within each of the sub-populations found in Oakview NP. Detection probability is the chance of a single camera detecting a gecko in that sampling area after a specified number of trapping nights. From previous survey work, it has been determined that after 30 nights there is 98% confidence that a gecko would be detected if the species were present in the sampling area (Figure 6).

Abundance estimates for the entire Oakview population indicate there are approximately 14 individuals per hectare of suitable habitat (D. Ferguson, unpublished data). Extrapolating this figure to include the new site found during the bushfire recovery project (U1) gives a population estimate of 196 individuals (95% CI 112.7 to 336.98) across the approximately 14ha (eight sub-populations) of known suitable habitat. This is likely to be an underestimate, with further unsurveyed suitable habitat scattered throughout the protected area. However, given the isolated nature of the suitable habitat, the population remains very small and highly disjunct with little to no gene flow between sub-populations.

Data collected during this project will allow future analysis of population trends for both the largest known population (Site K1) of Oakview leaf-tailed gecko and a small population of geckos for which the habitat is being invaded by cat's claw creeper (Site K2). The project has also established a baseline for the ongoing monitoring of trends in the new gecko population detected at Site U1.

Figure 4: Cat's claw creeper encroaching on suitable rocky habitat in an area occupied by the Oakview leaf-tailed gecko, an example of a sparse covering in Oakview NP.

Figure 5: Oakview leaf-tailed gecko captured on camera trap in Oakview NP.

Given that only two individuals were detected at Site K2, Oakview leaf-tailed geckos are now considered to be at very low abundance at this site, which may be due to the encroachment of cat's claw creeper and worthy of further investigation.

Impacts from the 2019 bushfire on the Oakview leaf-tailed gecko were generally limited, although they were difficult to quantify due to the lack of baseline information on sites directly affected by the fire, such as Site U2. Given the close proximity of the burnt Site U2, where no geckos were detected, to Site U1 with the newly discovered population of Oakview leaf-tailed gecko, it is possible that geckos were present at Site U2 prior to the 2019 bushfire. The fire may have then made them locally extinct, reduced their abundance or influenced their behaviour making detection less likely. It is possible that additional, inaccessible habitat areas near the vine forest margins were also fire impacted.

Detection rates appear to be slightly lower in the habitat immediately adjacent to the firebreak (Site K1) compared to rates from surveys in previous years (D. Ferguson, unpublished data). It is unknown whether this is due to the reduced canopy density or the increase in deer and/or feral predators (e.g. cats), or a combination of these. It should be noted that the firebreak was an existing forestry track that was reopened to protect this largest known population of Oakview leaf-tailed gecko from the 2019 bushfire. Planned burns in the 18 months prior to this fire also contributed significantly to firefighting efforts and the protection of this significant population. The Bushfire Recovery Program has supported on-ground action to reduce threats to, and promote the recovery of, critical habitat which will be continued beyond the completion of this project and improve conservation outcomes for the Oakview leaf-tailed gecko.

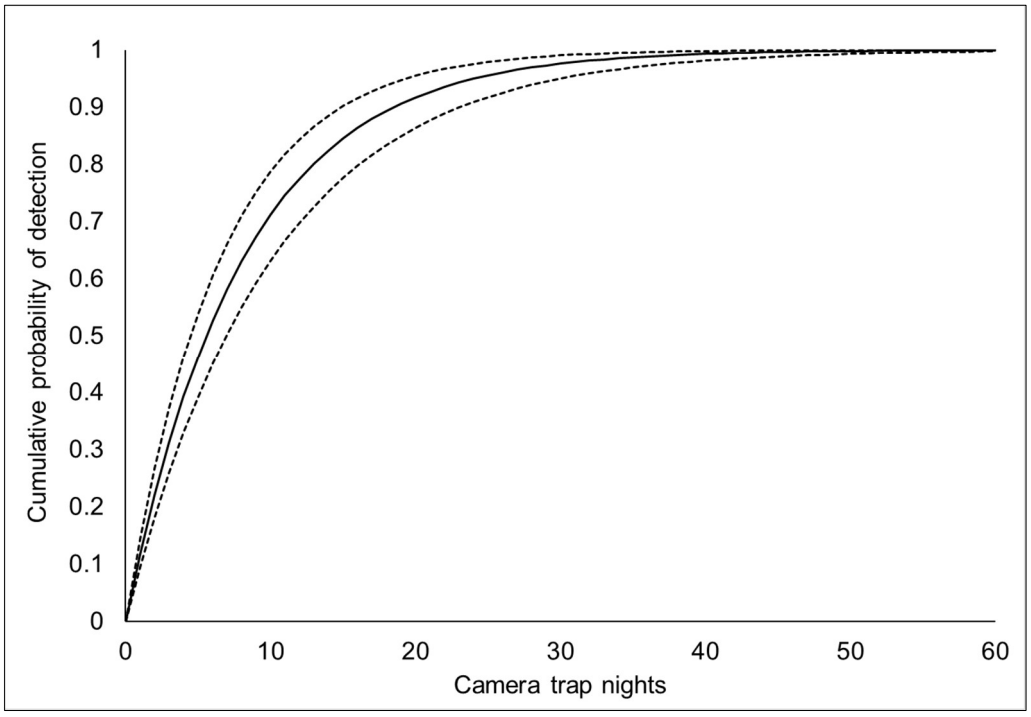


Figure 6: The probability of detecting Oakview leaf-tailed gecko in relation to a specified number of camera trap-nights using Random Encounter Occupancy Modelling based on previous survey work within Oakview NP.

3.1.5 Recommendations

Reducing key threats

Fire

- Protect from fire

  Future fires are a significant threat to the geckos and their fire-sensitive vine forest habitats. They also enhance the risk of weed incursions that degrade habitat quality. Ongoing improvements in collaborative fire management with adjacent landholders will achieve better landscape-scale protection for the vine forest habitats.

Pest animals

- Reduce impacts of cats and foxes

  Cats and foxes can develop learned foraging behaviours which could decimate remnant gecko populations. Maintain monitoring and the use of Felixer traps or other controls to reduce local cat and fox populations.

- Reduce impacts of feral deer

  The increasing populations of feral deer present a significant threat to vine thicket habitats and gecko microhabitats. The established trapping program should be maintained at optimal times for deer capture.

- Reduce impact of pigs

  Pigs can damage habitat and rocky shelters, as well as predate upon geckos and their prey. Ongoing controls, based on camera detections or other evidence of pig presence in Oakview NP, is therefore important.

Invasive plants

- Monitor the threat of invasive plants

  The ongoing threat of existing and new ecosystem-transforming weed species, including lantana and high-biomass grasses, needs to be monitored across occupied and suitable gecko habitats, and adjacent areas (including firebreaks) in Oakview NP, to inform control efforts to prevent weed populations becoming established.

- Reduce impacts of cat's claw creeper

  The significant threat to suitable vine forest habitat from the aggressive cat's claw vine should be mitigated with ongoing herbicide control and release of jewel beetles as a biocontrol agent in Oakview NP.

- Reduce impacts from coral berry within vine forest

  The significant threat of coral berry *Rivina humilis* spreading into vine forest in Oakview NP needs to be monitored and suitable controls used to limit the spread and impact on Oakview leaf-tailed gecko habitat.

Human impacts

- Reduce the risk of wildlife interference

  Sustain the monitoring, inspection and/or maintenance of the established gates and associated infrastructure in Oakview NP to reduce the risk of illegal take of the Oakview leaf-tailed gecko, as well as of interference stress and introduction of disease.

Ecological monitoring

- Continue to monitor Oakview leaf-tailed geckos using remote timelapse (or improved active trigger) camera trapping protocols to establish population trends and extent in response to known and emerging threats.

Ecological research

- Identify the extent and occupancy rates of suitable rocky habitat in Oakview NP. Improve the use of remote sensing (e.g. Landsat) technology to identify rocky areas under the dense canopy of the vine forest.
- Refine population estimates and trends using genetic sequencing techniques and expanding camera trap random encounter occupancy models. This can also provide information to support management of the species with respect to weeds, pest animals and climate change.
- Continue to measure the genetic diversity of populations in Oakview NP, guided by the outcomes of a collaborative genetic analysis underway with James Cook University, to inform ongoing conservation actions.

3.2 Nangur spiny skink

3.2.1 Conservation context

The Nangur spiny skink *Nangura spinosa* is a robust lizard growing to around 19cm in length and with a snout–vent length (SVL) to 9.5cm (Covacevich *et al*. 1993) (Figure 7). The species is listed as Critically Endangered under the EPBC and the NCA, with key threats and recovery objectives outlined in the recovery plan (DERM 2010).

Since the species was described in 1992 (Covacevich *et al.* 1993), the Nangur spiny skink is still only known from two locations approximately 30km apart in South East Queensland, despite significant survey effort (Horsup *et al*. 1993; Hannah *et. al*. 1997; Borsboom *et al*. 2005; Borsboom *et al*. 2010; Borsboom & Ferguson 2012; Borsboom 2014; Borsboom & Ferguson 2015). One location is Oakview NP, extending into sections of Oakview State Forest, with an extent of occurrence of approximately 870ha. The second location is a small section of Nangur NP, with an extent of occurrence of less than 50ha, where there are less than 50 mature individuals remaining. An analysis by Borsboom *et al*. (2010) revealed that the Oakview and Nangur lineages are genetically distinct, having separated over 1 million years ago. The two populations therefore have high biogeographical significance and are not a consequence of a recently fragmented landscape.

The Nangur spiny skink inhabits semi-evergreen vine thicket and vine forest (Regional Ecosystems 12.12.13, 12.12.16 and 12.12.17), living in short single-entrance burrows usually associated with a structure, such as a rock, exposed tree root or tree base. Although these skinks tend to feed around dusk and dawn, typically no more than a few metres from their burrows, nothing detailed is known of their movement patterns or home range around the burrow. Scat analysis indicates their diet includes arthropods.

A total of 1,469ha of modelled potential habitat for the Nangur spiny skink occurs in Oakview NP, with 2.2% of habitat impacted by the 2019 bushfire (Meiklejohn *et al*. 2021; see Laidlaw & Butler 2021 for modelled habitat methodology). Ground surveys were undertaken to evaluate the likely impact of the fire on the population and to monitor and manage the threats posed post-fire, including weeds, pest animals and increased accessibility to the protected area.

Figure 7: Nangur spiny skink at the entrance to its burrow (Photo: D. Ferguson).

3.2.2 Survey sites and methods

To determine the direct impacts from the 2019 bushfire in Oakview NP, searches for Nangur spiny skink and their burrows or remnants of burrows were conducted within and adjacent to accessible burnt potential habitat between January and June 2020. Potential habitat was identified using a combination of suitable regional ecosystem mapping (Queensland Herbarium 2018), on-ground knowledge, and draft potential habitat modelling (Laidlaw & Butler 2021).

To assess the potential indirect impacts on Nangur spiny skink populations in adjacent unburnt suitable habitat, three historic monitoring transects of 500–600m were repeated and a further 10 one-hectare gridded area searches established to sample the entire population more effectively in Oakview NP. These monitoring surveys were conducted between September 2020 and April 2021.

To provide a species-wide assessment, annual monitoring of the population in Nangur NP was also conducted in March 2020 and again in March 2021 as part of an ongoing project funded by DES. Survey methods, detailed in Borsboom (2020), involved teams thoroughly searching areas of suitable habitat within Nangur NP for individuals and their burrows. This provided information about the abundance and population trends of mature and immature animals in the remaining sub-populations.

3.2.3 Survey results

Surveys in accessible burnt areas of potential habitat of unknown occupancy detected no Nangur spiny skinks or remains of their burrows, supporting desktop analysis that very little (2.2%), if any, of the population was directly impacted by the fire.

Repeated monitoring transects all indicated that the Nangur spiny skink population within core areas in Oakview NP and Oakview State Forest is stable. However, the newly established, one-hectare monitoring grids suggested the species is probably slowly declining at the margins of its extent within Oakview. Further monitoring and more detailed analysis are required to confirm this trend and determine the threatening processes driving the decline. The monitoring grids have provided a good baseline measure of the variability in density of the Nangur spiny skink across Oakview NP and State Forest, which ranged from one to 83 animals per hectare.

In Nangur NP, monitoring continues to show a slow decline from 48 mature animals in 2020 to 44 in 2021. Recruitment into the population is promising, with immature animals increasing in the population from nine in 2020 to 25 in 2021.

3.2.4 Discussion

The limited impact of the 2019 bushfire on the Oakview NP and State Forest Nangur spiny skink population was primarily due to the fire suppression activities implemented by QPWS, in conjunction with prior fire management planning and knowledge regarding the importance of protecting the species' important habitat. Another bushfire in 2020–2021 may have also impacted the margins of Nangur spiny skink habitat; however, the extent and severity of this impact has not been fully assessed due to lack of access into the burnt area. This later fire is also expected to have had either no or minor impacts on the Nangur spiny skink population due to fire suppression activities implemented to specifically protect the vine forest habitat.

Monitoring of Nangur spiny skink has been expanded in Oakview NP and State Forest to incorporate additional information on the vegetation structure and composition across the species' entire extent of occurrence. This will provide greater insights into the population trend, the impacts of the threatening processes, including future fire impacts, and the outcomes of management intervention. Likewise, annual monitoring in Nangur NP will continue to inform recovery of the species in situ and maximise the outcomes for captive breeding of this genetically distinct population.

The future management of Nangur spiny skink populations across the species' range and ongoing priorities for the captive-breeding program will be informed by the outcomes of a genetic analysis project currently underway in collaboration with James Cook University. The results of sequencing will provide information on the genetic diversity within and between the remaining populations, possible inbreeding depression, effective population sizes, population structure and connectivity, kinship and demographic history. This will then guide any requirements for more specific genetic rescue actions to ensure that viable populations of Nangur spiny skinks persist in Nangur NP.

3.2.5 Recommendations

Reducing key threats

Fire

- Protect from fire

  Future fires are a significant threat to Nangur spiny skinks and their fire-sensitive vine forest habitats. They also enhance the risk of weed incursions that degrade habitat quality. Ongoing improvements in collaborative fire management with adjacent landholders will achieve better landscape-scale protection for the vine forest habitats.

- Prevent impacts from an emergency fire response

  Improve emergency fire response planning to avoid unintentional impacts to Nangur spiny skinks and their habitats, such as re-opening or enhancing firelines, which also provide new pathways for pest incursions. QPWS park staff should have confidential access to maps of known populations and suitable habitat to guide actions.

Pest animals

- Prevent predation by cats and foxes

  Cats and foxes can develop learned foraging behaviours that would rapidly deplete remnant populations, especially of burrowing species. Sustain pest animal monitoring and use Felixer traps or other controls to protect Nangur spiny skinks from predation.

- Reduce impacts of deer

  The increasing numbers of deer present a significant threat to vine thicket habitats, microhabitats and burrows for the Nangur spiny skink. The established trapping program should be maintained in the optimal seasons for deer capture.

- Reduce impact from pigs

  Pigs can damage habitat and burrows, as well as predate upon small reptiles and skink food resources. Sustain pest animal monitoring and implement controls when required in Oakview and Nangur NPs.

Invasive plants

- Monitor the threat of invasive plants

  The threat of existing and new ecosystem-transforming weed species, including lantana and high-biomass grasses, needs to be monitored across occupied and suitable habitats and adjacent areas (including firebreaks) in Oakview and Nangur NPs to prioritise control efforts to prevent weed populations becoming established.

- Reduce impacts of cat's claw creeper

  The significant threat to suitable vine forest habitat for the Nangur spiny skink from the aggressive cat's claw creeper needs to be mitigated with ongoing herbicide control and release of jewel beetles as a biocontrol agent.

- Prevent incursion of cat's claw creeper into core habitat

  Cat's claw creeper can smother habitat and burrow entrances of Nangur spiny skinks. It must be actively prevented from invading occupied habitat areas in Oakview NP through manual control and use of herbicides.

- Eradicate cat's claw creeper from Nangur NP

  Cat's claw creeper presents a significant threat to the habitat of the critical population in Nangur NP, and its early incursion makes the goal of eradication an achievable and important goal. It is advised to focus initial control efforts closest to the remnant skink population and move outward from the core habitat.

- Reduce impacts of coral berry

  The spread of coral berry within the vine forest needs to be controlled to avoid impacts on suitable habitat in Oakview NP and to prevent incursion into core habitat with active burrows in Nangur NP.

Human impacts

- Reduce the risk from wildlife interference

  Sustain the monitoring, inspection and/or maintenance of the established gates and associated infrastructure in Oakview NP to reduce the risk of illegal take of Nangur spiny skinks, as well as the introduction of disease and interference stress. Seek funding for the purchase and installation of similar infrastructure in Nangur NP to restrict access to the critical remnant population.

Genetic viability

- Augment wild populations

  Sustain the current captive-breeding program to achieve the goal of releasing skinks into the wild in order to augment the small remnant population in Nangur NP and sustain their genetic viability.

Ecological monitoring

- Continue to monitor skink populations using the established methodology in Oakview NP, at least triennially, and assess threats such as fire, weeds and pest animals. Include the established habitat assessment methodology to track change in suitable habitat structure, composition and quality.
- Continue to monitor skink populations using the established methodology in Nangur NP to track population size and recruitment rates to inform ongoing conservation actions.

Ecological research

- Determine the Oakview population trend and quantify threats, including fire, weeds and pest animals.
- Determine the contribution of threatening processes to the decline of the Nangur NP population and monitor the effectiveness of conservation measures.
- Continue to measure the genetic diversity of populations in Oakview and Nangur NPs, guided by the outcomes of a collaborative genetic analysis underway with James Cook University, to inform ongoing conservation actions.

3.3 *Coleus omissus*

3.3.1 Conservation context

Coleus omissus is listed as Endangered under the NCA and the EPBC. It is a softwood/succulent herb in the mint bush family (Lamiaceae) and occurs sporadically along the subcoastal ranges from north-west of Gympie to Mapleton, including a few sites in Oakview NP. The species occurs primarily in shallow soil pockets on rock outcrops, ledges, rock piles and occasionally skeletal stony soils within sclerophyll forests, woodlands and vine forests.

The main threat to *C. omissus* has been identified as competition from invasive plants such as lantana *Lantana camara* and billy goat weed *Ageratum houstonianum* (Forster 1992; Halford 1998), with a potential threat of inappropriate fire regimes (Halford 1998).

3.3.2 Survey sites and methods

Potential *C. omissus* habitat that was burnt during the 2019 bushfires in Oakview NP was opportunistically searched to determine the presence of the species. Identified individuals and populations present were then monitored to assess how *C. omissus* recovered post fire.

3.3.3 Survey results

One population of *C. omissus* was affected by fire in Oakview NP. Those plants growing amongst other vegetation were primarily scorched to the ground. Plants that were growing in small, isolated patches on rock, away from other shrubs and herbs, were substantially less fire impacted. Rainfall recorded at the nearby Kilkivan Post Office during 2020 was 750mm, the average being 623mm. A further 324mm was recorded during January to April 2021. In subsequent months after the fire, regeneration of the species was noted both by seedling germination and, more prominently, by reshooting from succulent stems and root systems under the soil (Figure 8). Reshooting from above-ground stems less affected or unaffected by the bushfire also occurred. By the end of April 2021, the fire-affected population had largely regenerated to mature, flowering plants (Figure 9).

3.3.4 Discussion

Coleus omissus is recovering well post fire in Oakview NP. The threats to *C. omissus* include competition from invasive plants, such as lantana and billy goat weed (Forster 1992; Halford 1998), inappropriate fire regimes (Halford 1998), and trampling by the public, pigs or the increasing populations of feral deer. Priority actions to support the recovery of *C. omissus* are outlined by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC 2022) in the approved conservation advice for this species as *Plectranthus omissus* (DEWHA 2008).

Figure 8: Regeneration of *Coleus omissus* by reshooting from succulent stems and root systems in Oakview NP.

Figure 9: Regenerated plants of the *Coleus omissus* population in the fire-affected site, showing flowering (left) and mature plants (right) in Oakview NP.

3.3.5 Recommendations

Reducing key threats

Fire

- Protect *C. omissus* from fire

  This species needs to be incorporated into the fire strategy alongside the provision of maps of key populations.

- Prevent impacts of an emergency fire response

  Improve emergency fire response planning to avoid unintentional impacts to *C. omissus*, such as when re-opening or enhancing firelines, which also provide new pathways for the incursion of competitive weeds. QPWS to gain expert advice on known populations, pending further research and more detailed maps to guide actions.

Pest animals

- Reduce impacts of deer

  The increasing populations of feral deer present a significant threat to *C. omissus*. The established trapping program should be maintained at optimal times for deer capture to minimise foraging and trampling impacts.

- Reduce impacts of pigs

  Pigs can damage or kill plants when foraging and turning the soil. Ongoing controls, based on camera detections or other evidence of pig presence in Oakview NP, are therefore important.

Invasive plants

- Prevent impacts of weeds

  The threat of ecosystem-transforming and competitive weed species, such as lantana and billy goat weed, needs to be monitored in known localities and controls implemented where required to protect the species.

Human impacts

- Prevent impacts of non-target weed control

  The accidental use of herbicide during weed control activities presents a risk to this species. It is important to train staff and contractors to identify this species to ensure that it is excluded from herbicide application or drift.

- Prevent impacts of trampling by park visitors

  Improve the planning and provision of walking tracks to avoid impacts from trampling by visitors. Consider opportunities to include in public education activities or interpretative signage.

Ecological monitoring

- Design and implement a specific monitoring program for *C. omissus* or if appropriate, support and enhance existing programs to track post-fire recovery.

Ecological research

- Identify and map *C. omissus* core populations of high conservation priority to guide management
- Survey suitable and potential habitat to locate additional or remnant populations and occurrences
- More precisely assess *C. omissus* population size, distribution, ecological requirements and the relative impacts of threatening processes.

4 Reducing threats to recovery

The key threats to the post-fire recovery of the Oakview leaf-tailed gecko and the Nangur spiny skink were identified by experts (Threatened Species Operations 2020). These included the risk of future fire, pest animals, invasive plants, illegal interference with the reptiles and reduced genetic viability of populations. On-ground actions to reduce these threats were then planned and implemented based on the modelled habitat maps for the priority reptile species, expert ecological knowledge, available project budget and local understanding of threats by QPWS Rangers.

4.1 Fire

Several of the sites known to support Oakview leaf-tailed gecko populations had evidence of previous fires. While none of the vine forest currently occupied by either the Oakview leaf-tailed gecko or the Nangur spiny skink burned in the 2019 bushfires, the surrounding vine forest was burnt. It was recognised, however, that any fire in the occupied habitat of these species could be catastrophic for their persistence and that it was important to implement immediate actions to mitigate that risk, as well as those that could reduce the threat of fire over the longer term.

Critical firelines

QPWS park management worked soon after the 2019 bushfire to remove hazards along the vehicle track network and to restore safe access, which would support an emergency response to any subsequent fire. The condition of firelines was then reviewed with respect to core habitats for the priority species and local knowledge of likely fire pathways. A critical fireline of 6.9km was identified and established utilising old forestry tracks and old firelines (including ‘E Break’ and Old Sinai Road), adjacent to vine forest habitat occupied by the two reptile species (Figure 10; Figure 11). The fireline will protect Oakview leaf-tailed gecko and Nangur spiny skink habitats from future fires by enhancing access to control bushfires, conduct planned burns and support ongoing post-fire recovery processes.

Fire strategy

The fire strategy for Oakview NP had previously identified the key values based on the Values Based Management Framework (DES 2020), which included the Oakview leaf-tailed gecko and Nangur spiny skink with an approach to fire management to protect these species. The ongoing QPWS program of planned burns in fire-adapted plant communities is guided by the fire strategy to reduce fuel hazard and potential fire severity of bushfires, and to increase capacity to control bushfires and protect refugia for threatened species. This strategy led to planned burns that were implemented in the 18 months prior to the bushfire event, which reduced the intensity of the 2019 bushfire and facilitated back-burning and activities that successfully protected the largest known population of Oakview leaf-tailed gecko.

The strategy was updated after the 2019 fire to address the enhanced threat from fire. This included identifying where critical firelines can be established without impacting the two priority reptile species. Planned burns will continue to be conducted in forests adjacent to the fire-sensitive vine forest, as steered by the fire management guidelines (Department of National Parks, Recreation, Sport and Racing 2013) for the relevant regional ecosystem (Qld Herbarium 2021), using the shorter stated intervals where practical. This approach contributes to broader conservation outcomes by maintaining the health and diversity of fire-adapted vegetation types across the park.

Ongoing concerns for the long-term recovery of the priority reptile species associated with future fires include: potential habitat loss in inaccessible areas; increased risk from unauthorised access and illegal interference; degradation of suitable habitat from the incursion of weeds and feral animals; and changing microclimatic conditions.

Figure 10: The 6.9km critical fireline was created using historic forestry tracks through vine forest in Oakview NP.

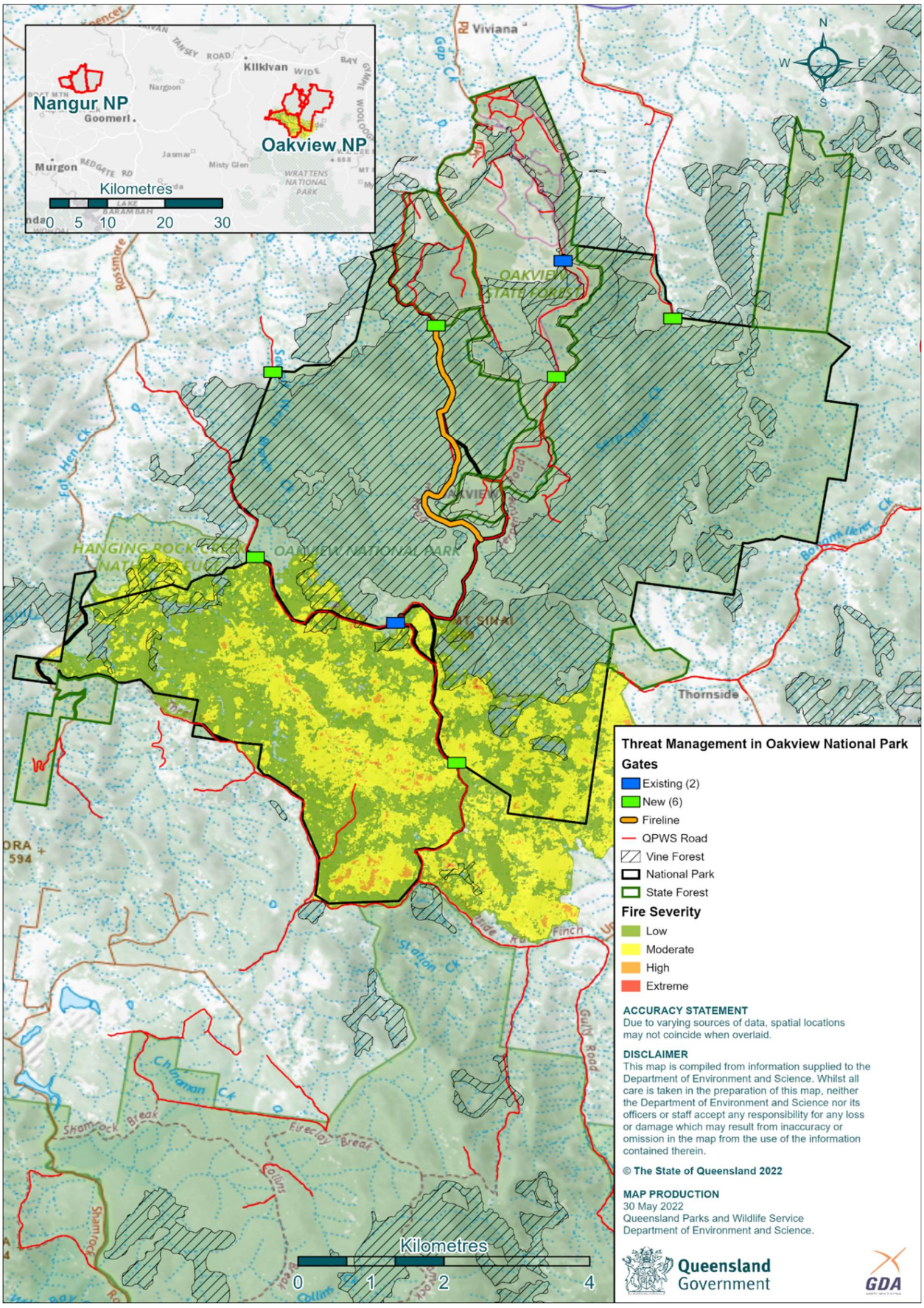


Figure 11: The location of the new fireline and gate installations in relation to vine forest and fire severity within Oakview NP and State Forest. Inset shows the location and relative distance between Oakview and Nangur NPs.

4.2 Pest animals

The management of pest animals is a continuing priority for QPWS to protect the key values of both Oakview and Nangur NPs. As land managers, QPWS complies with the general biosecurity obligation under the state *Biosecurity Act 2014* to minimise the risks presented by invasive 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 (Department of Agriculture and Fisheries 2019).

Invasive animals can impact native wildlife through a range of processes, including predation, competition for food and water, habitat degradation, soil erosion and decline of water quality. Predation by feral cats and foxes, and impacts from wild deer, were identified as significant threats to the two priority reptile species (Threatened Species Operations 2020) and targeted for control. Fifteen cameras were deployed throughout the vine forest areas of Oakview NP in early June 2020 to monitor the abundance and activity of pest animals and the outcomes of control measures. The Swift Enduro (regular infrared flash) cameras were set up on pathways and tracks to operate 24 hours a day throughout the project, with a medium sensitivity motion trigger. Given the significance of the Nangur spiny skink population in Nangur NP, efforts to control pest species are critically important. Existing Nangur spiny skink monitoring cameras in Nangur NP continue to monitor feral animal activity around their burrows. The pest animals identified as major threats were cats *Felis catus*, foxes *Vulpes vulpes*, red deer *Cervus elaphus* and pigs *Sus scrofa* (Figure 12).

Figure 12: Pest animals identified on camera traps in Oakview NP: red deer (top left); cat (top right); fox (bottom left); and pig (bottom right).

Cats and foxes

Feral cats and foxes occur throughout the range of both priority reptile species, with high numbers of cats occurring within the vine forests in Oakview NP (D. Ferguson and A. Borsboom, unpublished data; Figure 12). Whilst the level of predation is unknown, many Australian studies confirm that cats and foxes prey on small reptiles (cats: Bayly 1976; Jones & Coman 1981; Catling 1988; Tidemann *et al.* 1994; Martin *et al.* 1996; Paltridge *et al.* 1997; Molsher *et al.* 1999; Risbey *et al.* 1999; Read & Bowen 2001; Kutt 2011; Legge *et al*. 2017); (foxes: Martensz 1971; Ryan & Croft 1974; Croft & Hone 1978; Catling 1988; Read & Bowen 2001). There is a significant threat of foxes, and particularly cats, developing learned behaviours that target threatened reptiles in localised populations, especially a burrow-dependent species such as the Nangur spiny skink. The likely success rate of such learned predatory behaviour could quicky decimate critical populations of this species and other threatened reptiles.

In Oakview NP, two Felixer grooming traps were deployed in May 2021 to control feral cats and foxes (Figure 13). Felixers use rangefinder sensors to differentiate cats and foxes from non-target wildlife and spray these targets with a measured dose of toxic 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. The traps were set at sites in vine forest within or adjacent to core Oakview leaf-tailed gecko and Nangur spiny skink habitat. As the potential impact on non-target species was a primary concern, Felixers were initially operated in a non-toxic mode to assess the risk to local wildlife. The devices successfully targeted cats and a fox, whilst bandicoots, small birds, possums, wallabies and Australian brush-turkeys *Alectura lathami* were not identified as targets. The traps were then set in toxic mode by the end of the project, successfully targeted cats, and will continue to be installed at different sites across Oakview NP and Nangur NP to reduce predation pressure on the priority reptile species.

In Nangur NP, additional controls were implemented to reduce direct predation by cats and foxes and burrow disturbance by pigs or native brush-turkeys.

Figure 13: A Felixer device deployed to control feral cats in vine forest in Oakview NP.

Deer

Feral red deer occur within Oakview NP (e.g. Figure 12) and Oakview State Forest, and these have increased in abundance since surveys undertaken in 2017 (D. Ferguson, unpublished data). Deer cause significant ground disturbance within vine forest habitats, with compaction of rocky substrates and an associated loss of the interstitial spaces in which reptiles, including the Oakview leaf-tailed gecko, seek shelter (D. Ferguson, unpublished data). Deer can also trample Nangur spiny skinks and their burrows. Foraging deer browse on, and trample, the ground layer vegetation, ring-bark trees and spread environmental weeds (DAF 2019) such as coral berry, with incursions detected along the paths established by deer through the vine forest (D. Ferguson, unpublished data).

To reduce the impacts of red deer, an automatically triggered gate was purchased and installed on an already fenced permanent water point in Oakview NP. Prior work had closed all artificial water points within the vine forest areas in Oakview NP and fenced a single remaining dam to use as a trap. During dry periods, this dam represents one of the only permanent water sources found near the essential vine forest habitat of the two priority threatened species. Poor mobile network coverage (4G) initially hampered efforts to remotely trigger the gate; however, additional modifications resolved the issue. The trap successfully captured 25 deer in an eight-week period before wet weather provided deer with other drinking sources. The trap will continue to be used when conditions are suitable for deer capture.

Pigs

Feral pigs are known to occur within Oakview (e.g. Figure 12) and Nangur NPs. Pigs were recorded in low numbers in November 2020 within the vine forest reptile habitats of Oakview NP and were occasionally detected in Nangur NP during the initial surveys. As a result, the pest management resources available for the project were directed to the control of cats, foxes and deer. The frequency and number of pig observations (sightings, camera images and evidence of feeding activities) within the vine forest in Oakview NP, however, have been increasing since November 2020. Feral pigs are opportunistic, omnivorous feeders and are known to prey on small reptiles (Mitchell & Dorney 2006). Nangur spiny skinks are particularly at risk of predation when they are in short burrows away from tree bases and larger tree roots or in burrows under rocks that pigs can move. The abundance of invertebrate prey for both the Nangur spiny skink and Oakview leaf-tailed gecko may also be reduced by pigs through predation, trampling and disturbance to litter and rock microhabitats. Pigs may increase the spread of weeds and reptile diseases/pathogens. QPWS has subsequently initiated pig control actions to reduce their impacts on the priority reptile species.

4.3 Invasive plants

Invasive plants are prioritised for management by QPWS to protect the key values of Oakview and Nangur NPs and comply with the general biosecurity obligation under the *Biosecurity Act 2014*. QPWS also works collaboratively with local government and adjoining landholders where feasible, consistent with the objectives of the Queensland invasive plants and animals strategy (Department of Agriculture and Fisheries 2019).

Weeds can quickly establish and expand their range in a post-fire environment, outcompeting native species and hindering the natural regeneration processes. Without control, weeds can increase fuel hazards and the subsequent risk of high severity fires, and lead to changes in vegetation structure, species composition and ecological processes. Weed incursions can be facilitated through the disturbed ground of new firelines, as well as the introduction of infrastructure or movements of vehicles, deer and pigs that can transport seeds.

Invasive weeds that were identified as a threat to the recovery of the priority reptile species and their habitats in Oakview and Nangur NPs during this project include: cat's claw creeper *Dolichandra unguis-cati*, coral berry *Rivina humilis*, lantana *Lantana camara,* Brazilian nightshade *Solanum seaforthianum*, glycine *Neonotonia wightii*, and a variety of high-biomass grasses (Guinea grass *Megathyrsus maximus* var. *maximus*, green panic *Megathyrsus maximus* var. *pubiglumis*, Rhodes grass *Chloris gayana* and rat's tail grasses *Sporobolus* spp.).

Many weed species, including ink weed *Phytolacca octandra* and Brazilian nightshade, quickly colonised the firebreak that partially dissects the Oakview leaf-tailed gecko habitat. However, these were not deemed to be a direct threat to the Oakview leaf-tailed gecko or its habitat and will be managed as part of the established QPWS weed control program. The area will continue to be monitored for ecosystem-transforming species, such as cat's claw creeper and coral berry.

Cat's claw creeper

Cat's claw creeper is a perennial woody vine that can reach up to 30m and develops an extensive, tuberous root system. It forms dense mats that smother and outcompete native ground covers and seedlings, reduces food and shelter for wildlife, including the priority threatened species, and climbs over shrubs and trees, often with lethal results (DAF 2020). Significant infestations of cat's claw creeper are present in vine forest surrounding areas occupied by the Oakview leaf-tailed gecko and Nangur spiny skink. In Oakview NP, these outbreaks threaten the two priority reptile species by smothering the ground strata (reptile burrows and open rocky screes), altering the forest structure, changing the microclimate and reducing the availability of invertebrate prey.

Control of cat's claw creeper infestations in Oakview NP was therefore a priority and initiated using: i) a biocontrol agent; and ii) the manual application of herbicide through cut-and-swab techniques. The release of the jewel beetle *Hylaeogena jureceki* as a biocontrol agent was conducted in collaboration with Gympie Landcare on two occasions (Figure 14). Approximately 200 jewel beetles were released initially, followed by a second release of 2,000 beetles six months later. Gympie Landcare was also engaged to manually treat approximately 12ha of cat's claw creeper vines encroaching on the core Nangur spiny skink habitat, with some plants up to 8cm in diameter and smothering the tree canopy. Large vines were cut close to the ground and stumps immediately treated with herbicide (Figure 14). QPWS and Gympie Landcare will continue to treat these outbreaks within Oakview NP.

In Nangur NP, several outbreaks (<1ha in size) of cat's claw creeper in vine forest exist approximately 1.2km from the known Nangur spiny skink population and were therefore treated manually with herbicide to prevent the incursion into Nangur spiny skink habitat. Control efforts using herbicide and the cut-and-swab technique will be continued to achieve the park's weed strategy objective to eradicate cat's claw creeper from the park.

Coral berry

Coral berry is particularly invasive in rainforests and other closed forests, as seeds can germinate in low light conditions under a dense canopy. It can dominate the understorey, where natural ground cover is typically sparse, reducing native plant diversity, as well as the light levels reaching the forest floor by up to 70% (DAF 2019). This is likely to be detrimental for both threatened reptile species that occur where ground cover is minimal and which require an availability of sunlit basking areas and more open foraging substrate.

Control of coral berry in Nangur NP began in 2013 (Borsboom 2013) on a significant infestation in an area occupied by the Nangur spiny skink. Manual control was continued through this project, with plants removed by hand where they occur near known burrows of Nangur spiny skinks (Figure 14). Coral berry has also started to invade core habitat for Nangur spiny skink and Oakview leaf-tailed gecko in Oakview NP, and viable control measures are to be pursued, including hand removal in areas occupied by these priority reptile species.

Ongoing monitoring and targeted control of coral berry in Oakview and Nangur NPs has been incorporated into the weed management strategies, with an objective to prevent new infestations establishing in critical habitat for the two priority reptile species. Sustained monitoring of the Oakview leaf-tailed gecko and Nangur spiny skink on sites with and without established coral berry will help evaluate the impact on the species and the outcomes of control efforts.

Lantana and high-biomass grasses

Lantana and the high-biomass grasses in Oakview and Nangur NPs do not typically invade undisturbed vine forest; however, they occur along the margins and on disused tracks where they increase fire intensity (Berry *et al*. 2011). During extreme weather conditions, such as the those associated with the 2019 bushfire, these weeds significantly increase the fire risk to vine forest communities and the resident Nangur spiny skink and Oakview leaf-tailed gecko populations. Lantana and the high-biomass grasses were therefore slashed and removed from important habitat areas for the threatened skink and gecko within vine forest in Oakview NP. The slashing is also reducing the spread of the high-biomass grasses from roads and tracks into the open forests adjacent to the vine forests. Ongoing slashing and planned burning will reduce the fire hazard on the rainforest margins and reduce the risk of fire to the vine forests.

Figure 14: Invasive weeds and their control: cat's claw creeper infestation (top left); biocontrol jewel beetle (top right); coral berry infestation (bottom left); and manual treatment around Nangur spiny skink burrows (bottom right).

4.4 Wildlife interference

An increase in the illegal removal of Oakview leaf-tailed gecko and Nangur spiny skink individuals for the wildlife trade was identified as a threat to the ongoing genetic viability and survival of both species (Threatened Species Operations 2020). Existing infrastructure, gates, fences and adjacent vegetation were damaged during the 2019 bushfire, enabling vehicular access into areas of Oakview NP where these reptiles occur.

The greater public access post-fire also increased the risk of reptile enthusiasts seeking to sight or photograph these species, potentially damaging habitat, injuring the animals or introducing pathogenic disease. Australian reptiles are increasingly at risk from fatal exotic diseases, with some already present in wild reptiles in South East Queensland (e.g. Rose *et al.* 2017; Peterson *et. al.* 2019). Without the use of strict hygiene protocols, these pathogens can be unknowingly introduced to a population, which could lead to the extinction of these threatened reptiles in Oakview and Nangur NPs.

To reduce these risks, this project limited public access to the core vine thicket habitats of the priority species. Recent acquisitions (Black Snake properties), along with the hand back of the HQPlantations lease, provided QPWS with the opportunity to close several gazetted roads (Serpentine Road, Range Road, and Old Sinai Road) which traverse Oakview NP. Six gates (at road entry/exit points), vehicle exclusion infrastructure and fencing were installed to restrict public access to areas adjacent to vine forest occupied by the Oakview leaf-tailed gecko and Nangur spiny skink (Figure 11; Figure 15). After fulfilling complex legal and tenure-related requirements involving state and local government agencies, which included assessments by surveyors, public consultation, road closure and de-gazettal, the gates were locked for the completion of the project.

Cameras have also been installed in both Oakview and Nangur NPs to monitor unauthorised access and provide evidence for prosecution.

Figure 15: Gates and fencing installed on de-gazetted roads to restrict public vehicle access to Oakview NP. Side barriers have since been installed on the gate in the top right.

4.5 Genetic viability

A trial captive-breeding program for the Nangur spiny skink was established in Brisbane to determine if it presented a viable option to augment the small relictual population in Nangur NP. The breeding program aims to enhance the long-term genetic viability of the species in the wild and reduce the risk of extinction due to catastrophic events, such as bushfire, or from climate change and other threats.

In January 2020, 14 mature Nangur spiny skinks were captured from the larger and more stable population in Oakview NP to establish the first captive population. This provided the opportunity to establish the husbandry procedures required to breed this species in captivity, using an eight-bay purpose-built enclosure. The breeding program has been successful, with four sets of twins born in February 2020, followed by two sets of triplets and one set of twins born in late January 2021 (Figure 16). The total number of captive individuals was 30 by February 2021. The Bushfire Recovery Program has supported the expansion of the captive-breeding facilities through the design and construction of a second 14-bay enclosure at the QPWS facility (Figure 16). Alongside the breeding success to date, this will allow the program to progress more rapidly into captive breeding of the at-risk Nangur NP population, with collection planned for early 2023. The next stage of the captive breeding program is to trial wild release of captive-bred animals into an unoccupied area of suitable habitat to establish a new wild population.

Figure 16: A new enclosure for the Nangur spiny skink captive-breeding program at a QPWS facility (left), and an adult female with triplets born in captivity in late January 2021 (right).

5 Summary recommendations and guidance

Reducing ongoing threats to recovery

Recommendations for ongoing threat reduction for the priority species are summarised (Table 5). Refer to the relevant species' section for more details and contact experts (Appendix 1) for guidance as required.

Table 5. Recommendations for reducing ongoing threats to the recovery of priority species.

	Oakview leaf-tailed gecko	**Nangur spiny skink**		***Coleus omissus***
Recommendation	Oakview NP	Oakview NP	Nangur NP	Oakview NP
Fire				
Protect from fire	✓	✓	✓	✓
Reduce impacts of an emergency fire response	✓	✓	✓	✓
Pest animals				
Monitor pest animals to target control efforts	✓	✓	✓	✓
Reduce impacts of cats and foxes	✓			
Prevent predation by cats and foxes		✓	✓	
Reduce impacts of deer	✓	✓		✓
Reduce impacts of pigs	✓	✓		✓
Invasive plants				
Monitor and control ecosystem-transforming weeds	✓	✓	✓	✓
Reduce impacts of cat's claw creeper in vine forests	✓	✓		
Prevent incursion of cat's claw creeper into core habitat		✓	✓	
Eradicate cat's claw creeper from the park			✓	
Reduce impacts of coral berry	✓	✓	✓	
Prevent impacts of non-target weed control				✓
Wildlife interference				
Limit public access using road-based infrastructure	✓	✓	✓	
Prevent impacts of trampling by visitors				✓
Genetic viability				
Augment wild populations through captive breeding		✓	✓	

Ecological monitoring and research

Recommendations for future ecological monitoring and research for the priority species are summarised (Table 6). Refer to relevant species' section for more details and contact experts for guidance as required (Appendix 1).

Table 6. Recommendations for ecological monitoring and research for priority species.

	Oakview leaf-tailed gecko	**Nangur spiny skink**		***Coleus omissus***
Recommendation	Oakview NP	Oakview NP	Nangur NP	Oakview NP
Ecological monitoring				
Continue monitoring populations with the established protocols	✓	✓	✓	
Design and implement a specific monitoring program				✓
Ecological research				
Identify the location and size of core and remnant populations				✓
Assess ecological requirements				✓
Identify the extent and occupancy rates of suitable habitat	✓			
Refine population estimates and trends	✓			
Understand the genetic diversity and viability of populations	✓	✓	✓	
Improve current understanding of threatening processes	✓	✓	✓	✓

6 Lessons learnt and forward guidance

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

6.1 Risk management

Risks to wildlife

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

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

6.2 Ecological data and expert services

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

Post-fire ecological assessment

To map fire severity and summarise the ecological impacts to key natural values, a new process needed to be established to provide guidance in the context of QPWS-managed protected areas (Meiklejohn *et al*. 2021). 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. 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

The survey methodology for the priority species had been established though previous research projects. The adoption of camera traps to survey the Oakview leaf-tailed gecko provided an effective technique for ongoing monitoring. However, the captured images had to be analysed manually to identify this species, which was labour intensive and delayed the provision of results. Artificial intelligence software is rapidly evolving to enable cost-effective image analysis and species identification. 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 fires, this project was one of four to survey 56 threatened species, in addition to invertebrates, across six protected areas. The expertise available to provide ecological guidance, lead field work, oversee projects and ensure consistency in survey methodology and data capture was limited. To improve capacity for wildlife recovery efforts, it is therefore vital to:

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

Potential habitat mapping

To inform and guide recovery actions for the priority species, a potential habitat map was generated when a minimal set of locality data was available for a spatial modelling process (Laidlaw & Butler 2021). Potential habitat maps were invaluable to help design surveys for priority species and to guide QPWS Rangers in their on-ground efforts to reduce threats from pest animals, invasive plants or future fires. It is therefore recommended that:

- potential habitat maps for threatened species are maintained with updates when new data are available.

6.3 Partnerships and networks

This project was delivered in collaboration with the Queensland Herbarium (Appendix 1), which facilitated field surveys of the priority taxa, data capture, analysis and interpretation, and provision of report content with forward recommendations. The ability to secure this expertise was due to established relationships that shared common conservation concerns for the priority taxa. Amidst other work programs and an increasing chance of natural disasters, the availability of such expertise at short notice may become limited. It is therefore recommended that:

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

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Appendix 1: Authors and contributors

Report context	Authors and key contributors	Department or institution
Executive Summary Sections 1, 2, 4, 5 & 6.	Dr Tracey Churchill (Program Manager)	Threatened Species Operations, QPWS, DES
Project lead	Dr Teresa Eyre	Queensland Herbarium, DES
2. Post-fire assessment	Andrew Meiklejohn	Ecological Assessment Unit, QPWS, DES
3.3 Oakview leaf-tailed gecko 3.4 Nangur spiny skink	Daniel Ferguson, Michael Mathieson, Melanie Venz, Adrian Borsboom & Dr Teresa Eyre Patrick Couper & Andrew Amey	Queensland Herbarium, DES Queensland Museum
3.5 *Coleus omissus*	Michael Mathieson	Queensland Herbarium, DES
4. Reducing threats	Jo Zadkovich, Matt Tucker Gympie Management Unit	QPWS Technical Support, South-East Region QPWS, South-East Region
Editorial	Dr Tracey Churchill Dr Clare Hourigan	Threatened Species Operations, QPWS, DES