SEARCHING FOR THE ARNHEM ROCK SKINK

Bellatorias obiri

2022 – 2023 Final Report

Prepared by E. P. Hoffmann

Territory Natural Resource Management
Australian Government
Northern Territory Government
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Curtin University
Kakadu National Park

Project

NHT-MU03-P1 Conserving the Arnhem Land Gorges Skink in Kakadu National Park

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All research was conducted in accordance with Charles Darwin University Animal Ethics Approval number A22024 and National Parks Permit number RK 962 to carry out Scientific Research in Kakadu National Park.

PROJECT SUMMARY

Photo: Jordan Mulder

Background

The Arnhem rock skink (*Bellatorias obiri*) is one of Australia's most threatened species. The species is listed as endangered, and without intervention is at high risk of becoming extinct in the next 20 years. There are only a small number of historical records but they indicate an extensive decline of the species' occurrence. But with so few records and little-known about the species, it is difficult to determine the species' trajectory or accurately identify threats and their impacts.

Project and aims

This project was conducted in 2022–2023 to try and address crucial knowledge gaps for Arnhem rock skinks in order to better inform the species' status and conservation management. The key objectives of this project were to:

- develop effective survey methods for detecting Arnhem rock skinks;
- determine whether Arnhem rock skinks persist at historical sites; and,
- characterise the species' fine-scale habitat requirements.

This project was led and managed by Emily Hoffmann and Kelly Dixon (Territory Natural Resource Management), in collaboration with Billy Ross and Luke Einoder (Kakadu National Park, Parks Australia), Tony Griffiths and Peter McDonald (Northern Territory Government), Brett Murphy (Charles Darwin University), Chris Jolly (Macquarie University), and Brenton von Takach (Curtin University), and supported through funding from the Australian Government.

The project team worked closely with Traditional Owners and their families to survey historically occupied areas in Kakadu National Park and to identify other potential skink locations or sightings. Surveys targeting the Arnhem rock skink were conducted over the 2022–2023 wet-season using two recently available, non-invasive survey methods:

- **Camera traps** – deploying remote cameras to target rock crevices in areas of suitable habitat
- **Environmental DNA (eDNA)** – collecting soil and water samples from rock crevices and nearby waterbodies to analyse for eDNA

Findings

The main project findings in relation to each aim include:

1. Develop effective survey methods for detecting Arnhem rock skinks

- Standard searching and trapping are ineffective and inefficient survey methods.
- Recent trials using remote camera traps indicate the method can be highly effective for detecting Arnhem rock skinks. Individuals were captured using both time-lapse and motion triggers. A preliminary guide has been developed for targeted camera trapping for Arnhem rock skinks and is attached to this report.
- Environmental DNA methods were trialled to determine whether Arnhem rock skinks could be detected through the presence of their DNA in soil and/or water samples. Soil and water samples were collected from areas at the only confirmed location where the species was known to occur. However, no skink DNA was able to be amplified in any of the soil or water samples and as such, the trialled method was unsuccessful for detecting Arnhem rock skinks.

2. Determine whether Arnhem rock skinks persist at historical sites

- Camera trapping detected Arnhem rock skinks at five of the seven historical locations surveyed, increasing the number of locations where the species is confirmed to persist five-fold.
- Whilst recent camera trapping surveys have detected the species at several historical locations, the skinks appear to persist in small numbers.
- Through consultation with parks staff, rangers and Traditional Owners, three additional new locations were obtained from confident recent sightings (since 2021).

Photo: James Morgan

3. Characterise the species' fine-scale habitat requirements

- Recent camera trapping and habitat surveys have provided new insights into the species' ecology and habitat requirements.
- Preliminary data suggest that crevices with higher Arnhem rock skink activity (based on the number of detections) may be those that are narrow in height (less than 10 cm), with a horizontal base (flatter in slope), and a higher number of surrounding crevices.
- Crevices where Arnhem rock skinks were detected also had lower amounts of leaf litter and more soil cover compared to crevices with no activity.

- Preliminary data indicate that crevices that had higher activity had lower average temperature and higher humidity than crevices with low activity.

Implications and recommendations

During camera trapping in 2022–2023, two feral cats were detected using crevice habitats at one survey plot. These observations provide evidence that the two species co-occur in rocky habitats and highlight the valid threat that feral cats pose to Arnhem rock skinks. Targeted surveys in 2022–2023 also detected cane toads at four of the seven locations sampled, confirming that cane toads occur in similar crevice habitats used by Arnhem rock skinks.

With new monitoring tools and the ability to more successfully detect skinks, it should now be possible to determine the current species distribution with much higher confidence and monitor population trends, and subsequently, to assess the relative impacts of different threats and responses to management. A priority should be to establish an ongoing monitoring program at occupied skink sites, as well as additional and more widespread surveys throughout the species' historical range, and other areas with suitable habitat.

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1 ABOUT THE PROJECT

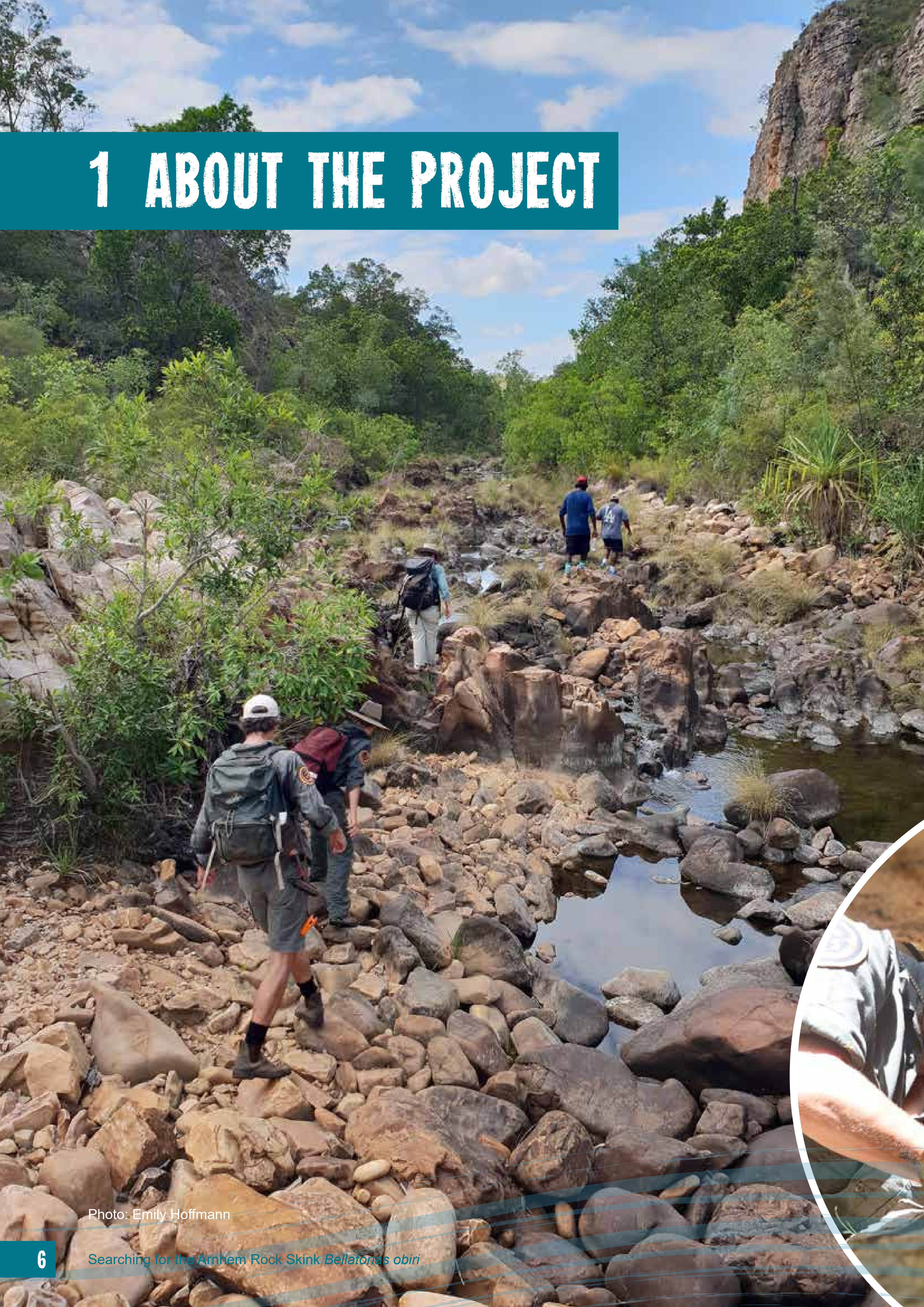


Photo: Emily Hoffmann

The Top End's most at-risk reptile

The Arnhem rock skink (*Bellatorias obiri*), also known as the Arnhem Land gorges skink, is one of Australia's most threatened species. The species is listed federally as Endangered (EPBC Act 1999) and was listed in 2021 as one of the Australian Government's 110 priority species as part of the Threatened Species Action Plan 2022–2032. The Arnhem rock skink was recently ranked as the 6th most likely Australian vertebrate and the most likely Australian reptile to go extinct in the next 20 years without intervention (Garnett et al., 2022).

Arnhem rock skinks are large, stocky, smooth-scaled lizards, growing up to ~20 cm from snout-vent (~40–50 cm total length) (Sadlier, 1990). They are generally light to dark brown in colour with variable dark patches and barring on the sides of their heads, lips and chin. The species is one of the least known reptiles in Australia, with almost nothing known about their biology, ecology, behaviour, or population trends. Despite substantial targeted searching for the species, only a small number of historical records exist (Gillespie et al., 2018; Gillespie & Fisher, 2013; Woinarski, 2004).

Photo: James Morgan

The skinks are endemic to rugged, sandstone outcrops along the western edge of the Arnhem Plateau in the Northern Territory and almost all historical records are from Kakadu National Park (Armstrong & Dudley, 2004). In 2021, the species was confirmed to persist at only one location within Kakadu National Park.

Missing and in decline or rare and cryptic?

The small number and restricted distribution of records from the past two decades suggests an extensive decline of the species' occurrence. Repeated surveys in 2002 at one of the locations where Arnhem rock skinks were repeatedly trapped as 'by catch' in the 1970s failed to capture any skinks (Ibbett et al., 2018; Watson & Woinarski, 2004). The species is thought to have a total population size of fewer than 50–100 individuals (Gillespie et al., 2018). However, these lizards are cryptic and occupy rock crevices in areas that are often difficult to access. As such, they may not be easily detected by traditional survey methods, such as visual searches or trapping. Consequently, Arnhem rock skinks might still occur at some historical locations but have gone undetected.

The species has a highly restricted range and likely a small population size, putting them at higher risk of extinction. Other probable threats include frequent high-severity fire, predation by feral cats, and poisoning by cane toads (Armstrong & Dudley, 2004; Woinarski et al., 2007). But with so few records and little-known about the species, it is difficult to determine the species' trajectory or accurately identify threats and their impacts. Consequently, we urgently require more information on the Arnhem rock sink to provide adequate guidance for management (Einoder et al., 2021).

Project objectives

This project was led and managed by Emily Hoffmann and Kelly Dixon (Territory Natural Resource Management), in collaboration with Billy Ross and Luke Einoder (Kakadu National Park, Parks Australia), Tony Griffiths and Peter McDonald (Northern Territory Government), Brett Murphy (Charles Darwin University), Chris Jolly (Macquarie University), and Brenton von Takach (CurtinUniversity), and supported through funding from the Australian Government.

The project was carried out from August 2022 to June 2023 and involved conducting targeted surveys to try and address crucial knowledge gaps for Arnhem rock skinks to better inform the species' status and conservation management. The key objectives of this project were to:

- develop effective survey methods for detecting Arnhem rock skinks;
- determine whether Arnhem rock skinks persist at historical sites; and,
- characterise the species' fine-scale habitat requirements.


Photo: James Morgan

Targeted surveys in 2022–2023

To address the project objectives, we undertook targeted surveys for the Arnhem rock skink between October 2022 and April 2023 at historical locations in Kakadu National Park using two recently available and non-invasive survey methods:

- **Camera traps** – deploying remote cameras to target rock crevices in areas of suitable habitat
- **Environmental DNA (eDNA)** – collecting soil and water samples from rock crevices and nearby waterbodies to analyse for eDNA

We worked closely with Traditional Owners and their families to survey historically occupied areas and identify other potential skink locations or sightings.

This report summarises existing knowledge as well as the findings from the project's targeted surveys in 2022–23. It provides updated knowledge of the species' current distribution, effective survey methods, and new information on the species' ecology, habitat requirements, and potential threats. These findings can be used by land managers to implement an ongoing monitoring program for the Arnhem rock skink and targeted management into the future.


Photo: James Morgan

2 WHERE DO ARNHEM ROCK SKINKS OCCUR?

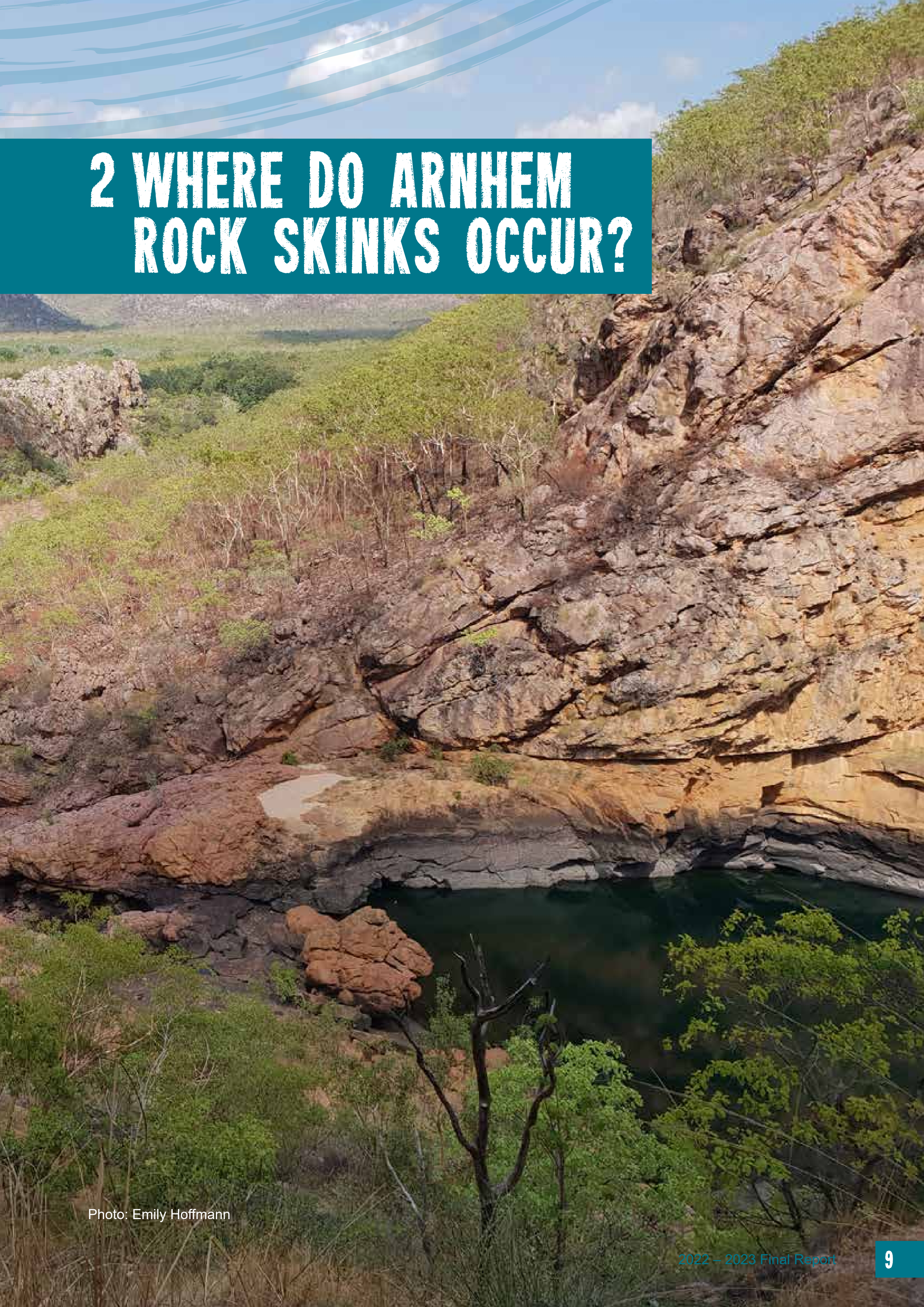


Photo: Emily Hoffmann

Historical distribution (1975–2021)

Arnhem rock skinks have been recorded from the western edge of the Arnhem Plateau, Northern Territory with most records occurring within Kakadu National Park (Figure 1). Most early records of the species were by-catch from mammal surveys in late 1970s, indicating they were locally common at the trapping sites (Armstrong & Dudley, 2004; Begg et al., 1981).

However, since those initial records, there have been relatively few observations of the species, with less than ten records between 1980 and 2003. Targeted surveys were conducted in 2004 across Kakadu National Park, including at ten historical locations, but only one sighting, one capture, and the remains of one individual were recorded (Armstrong & Dudley, 2004). In the following 17 years, ten sightings have been recorded from four sites, with the locations suggesting a potential southward contraction of the species' range (Figure 1). As of 2021, Arnhem rock skinks were only confirmed to persist at one location near the southern boundary of Kakadu National Park.

Based on all reliable historical records between 1975 and 2021, the species' maximum extent of occurrence (EOO) is estimated to be 3,637 km^2, with a maximum area of occupancy (AOO) of 60 km^2.

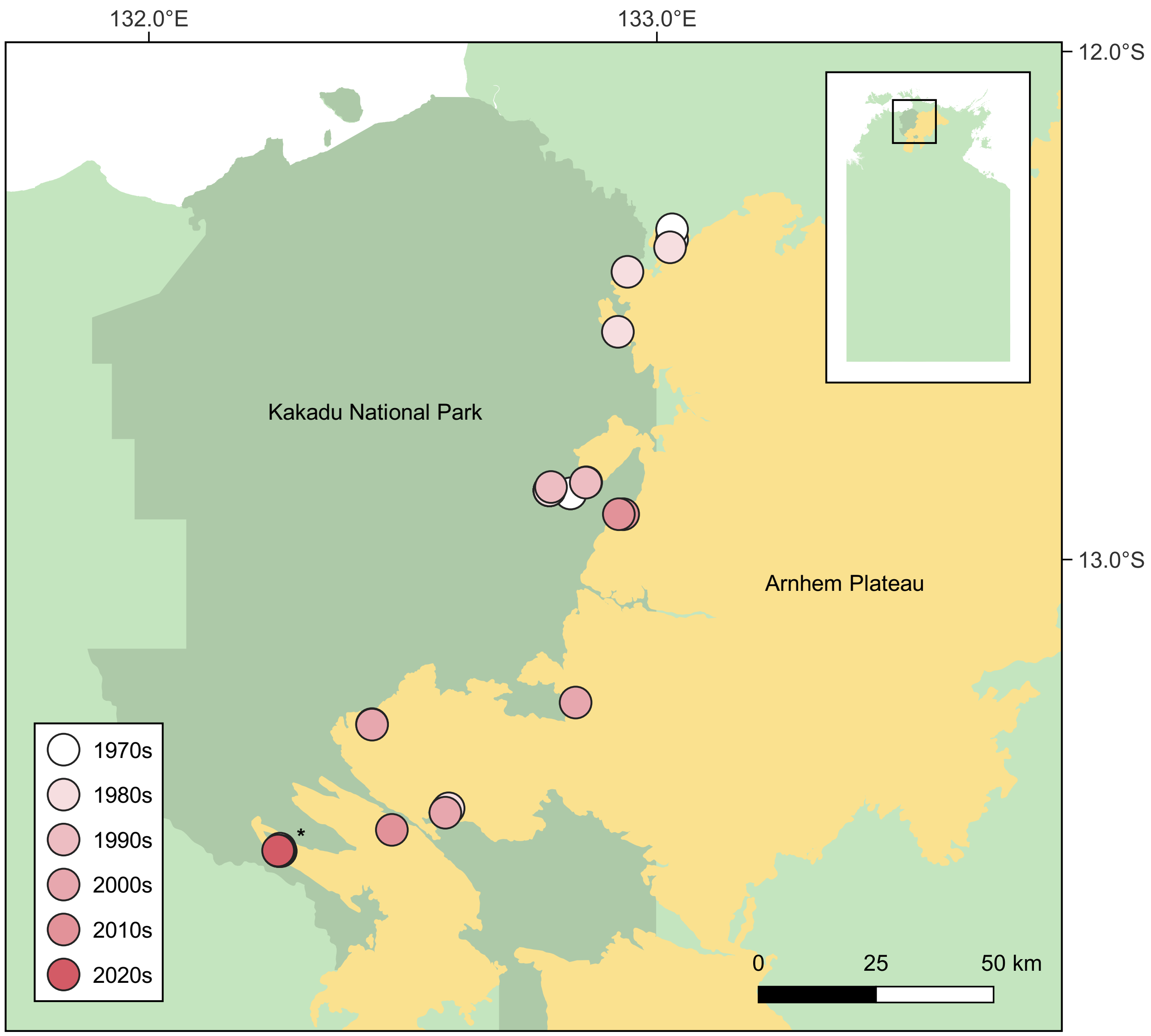


Figure 1. The distribution of Arnhem rock skinks based on reliable records between 1975 and 2021. Asterisk indicates the only location where the species was confirmed to persist as of 2021. Insert shows the location within the Northern Territory.

Current distribution from targeted surveys in 2022–2023

In 2022–2023, targeted surveys were carried out by the project team in collaboration with Kakadu National Park staff and Traditional Owners. Six locations with historical records of Arnhem rock skinks—including the one location where the species was known to persist—were surveyed for ~4–5 months over the wet season using camera traps. An additional location was also surveyed for approximately one month at the end of the wet season.

Camera trapping confirmed the presence of Arnhem rock skinks at five of the seven locations surveyed (Figure 2), increasing the number of locations where the species is confirmed to persist five-fold. Furthermore, through consultation with parks staff, rangers, and Traditional Owners, three additional new locations were obtained from confident recent sightings (since 2021) (Figure 3). This increase in the number of confirmed locations may not necessarily suggest a change in occurrence, instead it is likely to reflect the increased sampling effort and use of different survey methods.

The number of detections of Arnhem rock skinks varied considerably by location, with the most camera trap images collected at the southern sites (Figure 2). The most northern site where the species was detected captured only a few images of the species on a single camera. Preliminary analysis suggests that there were a small number of individuals at most locations, and estimates the minimum number known alive to be 21 individuals. Therefore, whilst recent camera trapping surveys have detected the species at several historical locations, the skinks appear to persist in small numbers.

More widespread surveys at other historical locations, as well as new additional locations, are required to obtain a more complete picture of the species' current distribution. As proposed by Armstrong and Dudley (2004), the species' distribution may extend further along the Arnhem Plateau to the north-east and south, into west Arnhem Land or Nitmiluk National Park.

From the recent camera trapping surveys, the species' current minimum extent of occurrence (EOO) is 1194 km^2, with a minimum area of occupancy (AOO) of 24 km^2.

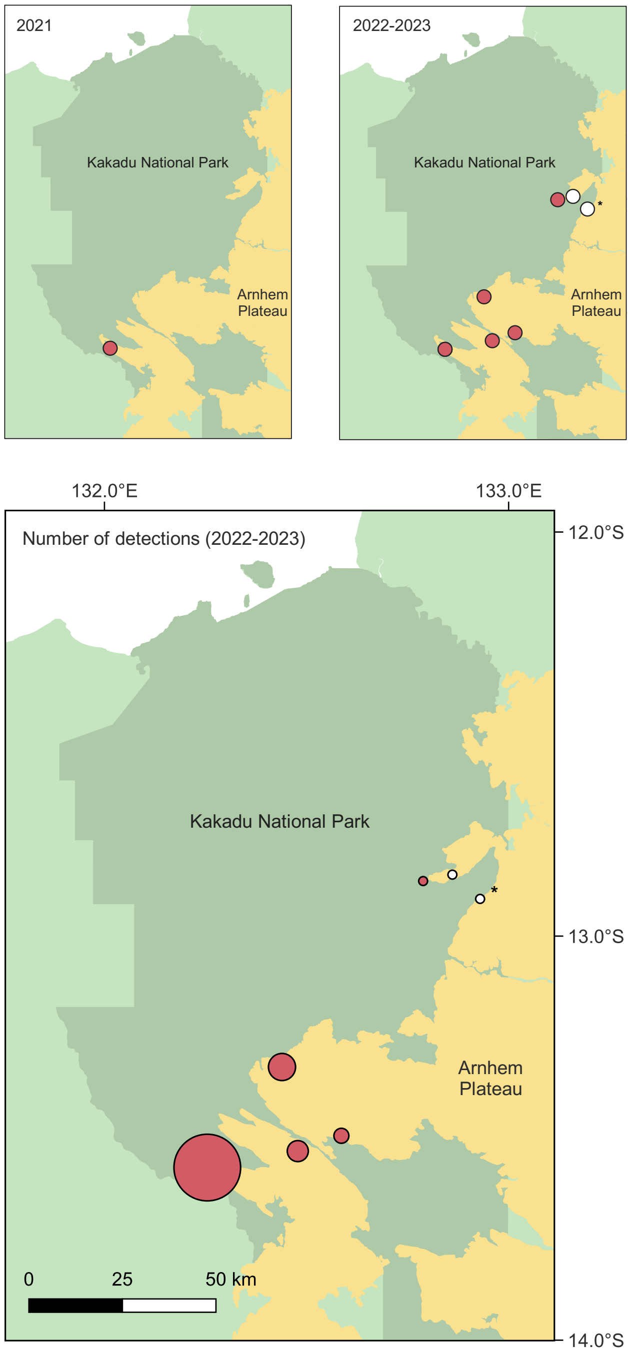


Figure 2. Confirmed presence of Arnhem rock skinks (filled symbols) in 2021 (top left) and in 2023 (top right) after targeted camera trapping surveys at a number of sites (circles), and average number of camera trap detections (per plot) recorded across sites indicated by the size of circle (bottom). Asterisk indicates site that was sampled for a shorter duration.

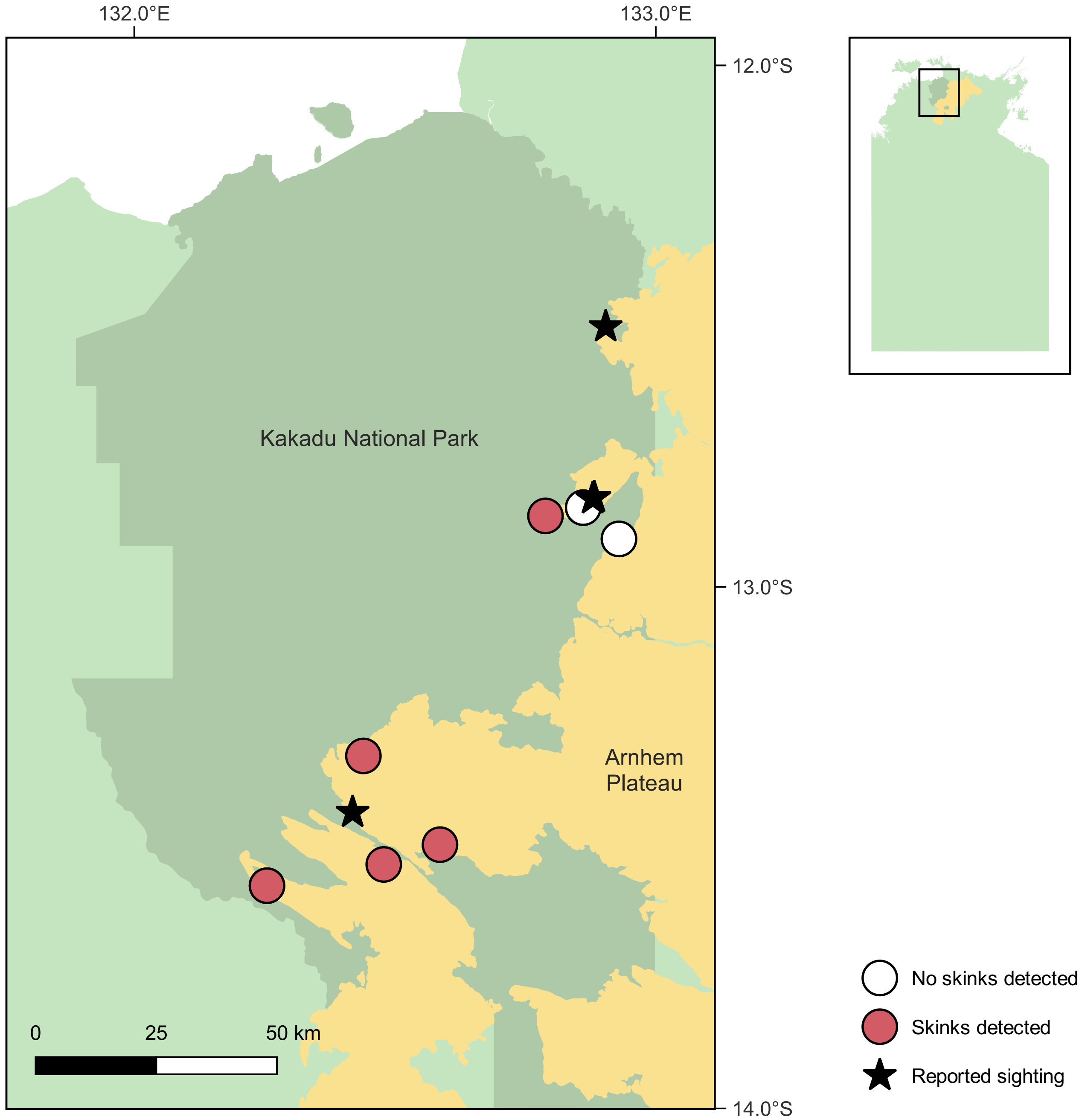


Figure 3. Location of additional incidental skink sightings gathered through consultation in 2022–2023 (stars) relative to sites surveyed in 2022–2023 (circles). Filled circles = species detected. Open circles = species not detected.

3 WHAT IS THE BEST SURVEY METHOD TO DETECT ARNHEM ROCK SKINKS?

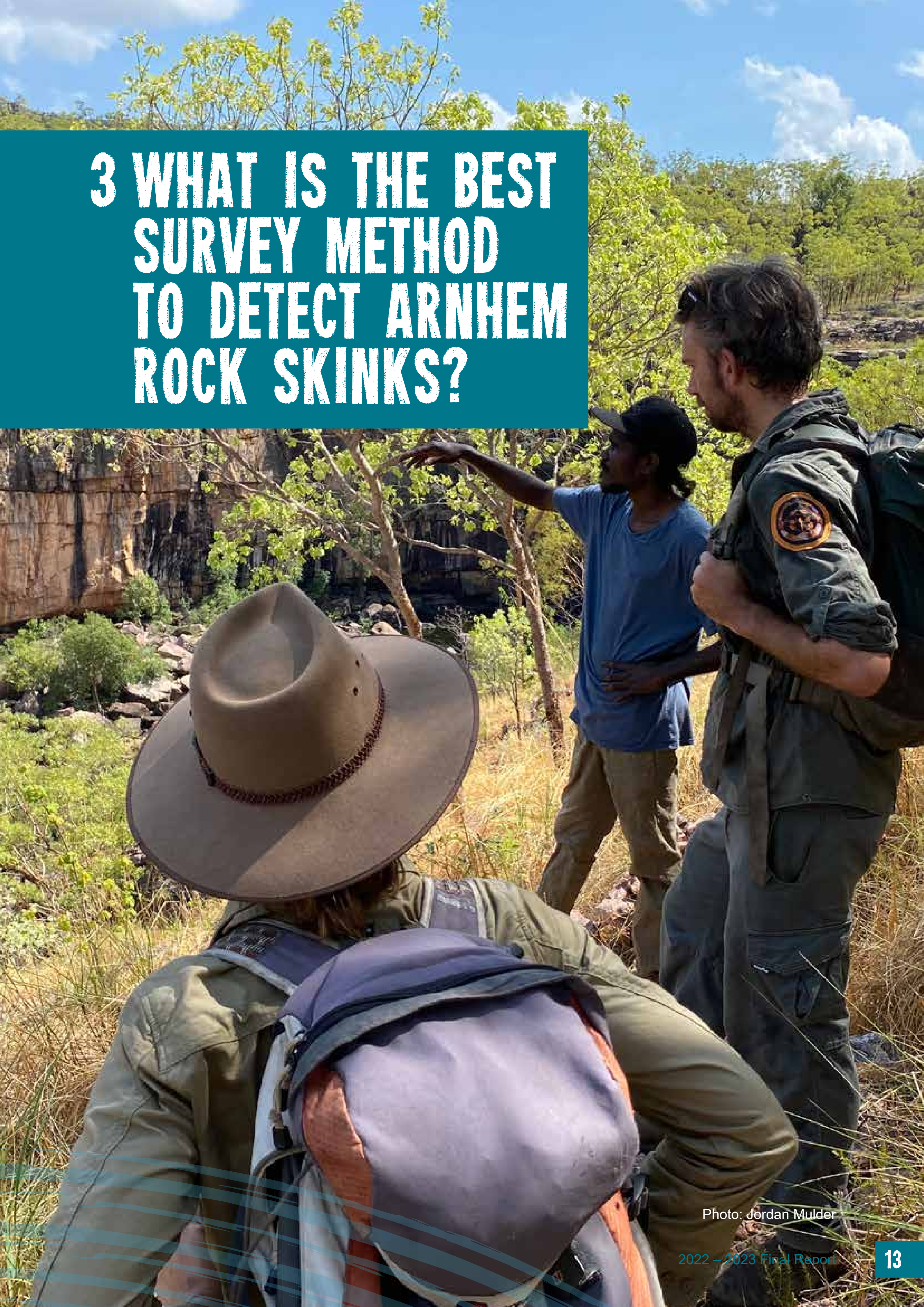


Photo: Jordan Mulder

Survey methods can vary in their ability to detect different species, and some traditional methods may not be appropriate for rare or cryptic species. For example, visual surveys may not detect species that are small or well-camouflaged, while acoustic surveys may miss species with low or no vocalisations. Detection of species can also be difficult for those that occur in remote and challenging environments (e.g., tropical northern Australia).

Arnhem rock skinks are shy and occur in rugged, remote habitats. There are relatively few observations of the species and most records have been from incidental sightings (e.g., accidental flushing of individuals). This is despite targeted survey efforts and the large size of the skinks (> 40 cm total length), which suggests that the species is challenging to detect (Armstrong & Dudley, 2004). The difficulty in the detection of the species has meant that there is no established ongoing monitoring program.

Here, we summarise the survey methods used to date, including recent camera trapping and environmental DNA trials, and their effectiveness for detecting Arnhem rock skinks.

1. Visual searches

Visual searching is a common method for surveying reptiles and is the main method that has been used to survey Arnhem rock skinks to date. However, targeted active search surveys (including those using hand torches) have obtained very few records of Arnhem rock skinks. For example, intensive targeted surveys in 2004 mainly consisted of searches on foot, by searching rocky areas, crevices and caves, and scanning scree slopes for sightings or any signs of skinks. However, this method only recorded the remains of one individual. Furthermore, in the current project, extensive areas of habitat and crevices were searched as part of the camera trapping deployment, including areas where Arnhem rock skinks were later confirmed to occur, and only one individual was sighted during this time. Given the low success rate, traditional visual search methods are not effective for reliable detection and monitoring of the species.

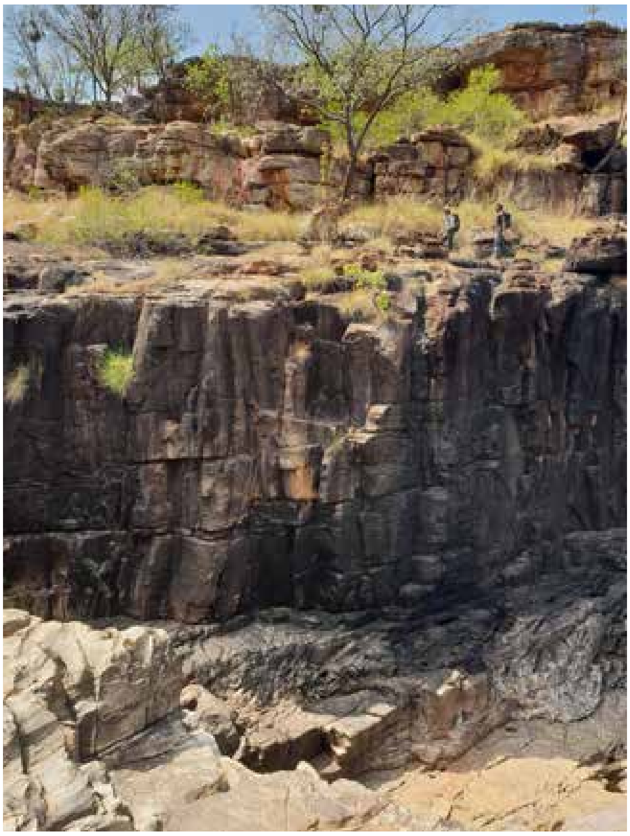


Figure 4. Active searches and surveying crevices with hand torches has proved be an ineffective search method for Arnhem rock skinks. (Photos: James Morgan (left), Emily Hoffmann (right)).

2. Trapping

Many of the initial observations of Arnhem rock skinks were as occasional by-catch from mammal surveys (1977–80) where they were caught in Elliott (small aluminium box) traps (Armstrong & Dudley, 2004; Begg et al., 1981). The traps were baited with peanut butter, oats, fruit, and sardines and set in the late evening. However, the species was not captured during subsequent surveys using similar methods (Ibbett et al., 2018; Woinarski et al., 2015).

Closely related species on the east coast, the major skink (*Bellatorias frerei*) and land mullet (*Bellatorias major*), are also noted as shy and flighty and notoriously difficult to capture (Osterwalder et al. 2004) but have been trapped successfully using Elliott traps baited with peanut butter, rolled oats and honey (Fuller et al., 2005).

Elliott traps baited with peanut butter, oats, honey, and tuna were used in 2004 to successfully trap one individual after an incidental sighting was made in the area. However, the significant effort used (50–100 traps per night, for 3–6 days in 2004), and low success rate (one individual), suggests this method is not an efficient searching or monitoring method. The individual was captured when trapping was extended to keep traps open during the day, suggesting that Elliott trapping may be more successful if traps are opened both day and night.

One individual was reportedly captured using a funnel trap along a drift fence, a common method used for trapping medium-sized reptiles.

In summary, trapping via cage, Elliott or funnel traps has detected the species, or their close relatives, but requires extensive sampling effort and capture rates are very low.

Figure 5. Small aluminium box (Elliott) traps (top), cage traps (middle), and funnel traps (bottom) have been used with some success to trap Arnhem rock skinks and their relatives. (Photos (top to bottom): Pilkarra Traps, Julie-Anne Ellis, and Dylan Westaway).

3. Environmental DNA

Environmental DNA (eDNA)—genetic material that can be extracted from an environmental sample, such as soil or water—is an increasingly employed tool that has proven to be useful for detecting rare or cryptic species. In late 2022, a trial was conducted to determine whether Arnhem rock skinks could be detected through the presence of their DNA in soil and/or water samples. Soil and water samples were collected from areas at the only confirmed location where the species was known to persist at the time. No skink DNA was able to be amplified in any of the soil or water samples and, as such, the trialled methods were unsuccessful for detecting Arnhem rock skinks. One scat was collected incidentally from a rock crevice at the same location (where skinks are known to occur) and was also sent for analysis. The scat was positively identified as from an Arnhem rock skink.

Given that the soil and water samples were taken from an area with relatively high activity of Arnhem rock skinks, eDNA does not appear feasible for detecting the species using our trialled methods (target DNA fragment and choice of substrate). This could be in part because terrestrial reptiles may shed lower amounts of DNA compared to other species (Nordstrom et al., 2022) and/or the high levels of microbial activity in tropical environments (Zulkefli et al., 2019).

Furthermore, unlike some closely related skink species (e.g., *Egernia stokesii, Egernia striolata*), Arnhem rock skinks do not appear to use or have accessible latrines (scat piles) outside their refuges. No further scats were sighted in the field, despite hundreds of crevices being inspected. Therefore, scat collection also does not appear to be a practical method for detecting and monitoring Arnhem rock skinks.

Figure 6. TNRM Project Officer, Dr. Emily Hoffmann, collecting soil samples from crevices occupied by Arnhem rock skinks for environmental DNA analysis. (Photos: Georgia Kielbaska).

4. Remote cameras

Remote cameras can be an effective non-invasive survey method and for some species can require less effort and be more cost-effective than manual trapping (Welbourne et al., 2020). Camera traps can also capture behaviours of rare species or those that are otherwise difficult to observe, as well as provide insights into their ecology. Whilst increasing in use, camera trapping has been less frequently applied to surveying reptiles. To trigger a camera sensor, a temperature differential is often needed in addition to movement. Ectotherms (including reptiles) are often similar in temperature to their surrounding environment, making detection less reliable (Meek et al., 2015). However, camera trapping is a promising survey technique and has been effective for detecting many reptile species (Moore et al., 2020; Welbourne et al., 2017).

Recent trials using remote camera traps indicate the method can be highly effective for detecting Arnhem rock skinks. Northern Territory Government (NTG) and Kakadu National Park (KNP) staff conducted a 12-month pilot study in 2021–2022, where camera traps were set at 30 crevices around a site with numerous confirmed visual sightings of Arnhem rock skinks. Cameras with custom short-range focus (90 cm) were set facing inside rock crevices and were highly successful at detecting the species.

Following the success of this pilot study, camera trapping was trialled in the current project to conduct targeted surveys at historical locations. The survey design utilised the NTG and KNP pilot study data to estimate the number of cameras and sampling duration required. During the 2022–2023 wet season, over 100 cameras were deployed across seven locations with historical records of Arnhem rock skinks, and successfully detected skinks at five of those locations. Different camera models, settings, and the use of baited lures were trialled to refine and optimise a standard camera trap methodology for the species.

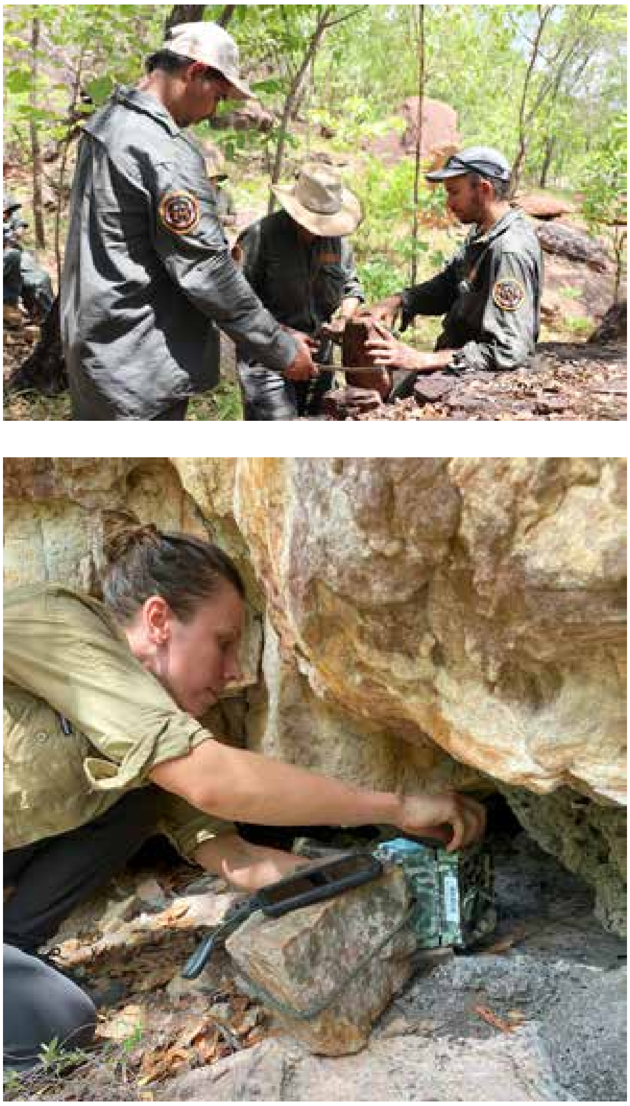


Figure 7. Setting up camera traps in crevice habitats to search for Arnhem rock skinks (Photos: James Morgan, Georgia Kielbaska).

Figure 8. Photo of an Arnhem rock skink (*Bellatorias obiri*) from a camera trap in 2023.

Recommended survey methods

Camera trapping is by far the most effective method for detecting Arnhem rock skinks that has been trialled to date. Using the information gained from recent studies, a preliminary guide has been developed for targeted camera trapping for Arnhem rock skinks (Appendix B), which provides a robust starting point for conducting ongoing monitoring at key sites and more widespread surveys. More broadly, camera trapping focused on rock crevices has also proven effective for detecting numerous other threatened or rarely seen rock-dwelling species (Appendix C).

Elliott, cage or funnel traps may still prove useful for collecting fine-scale individual data (e.g., genetic samples), but would be most efficient if used to target areas where the species is confirmed to occur via more efficient methods, such as camera trapping.


Photo: Csenta Roberts

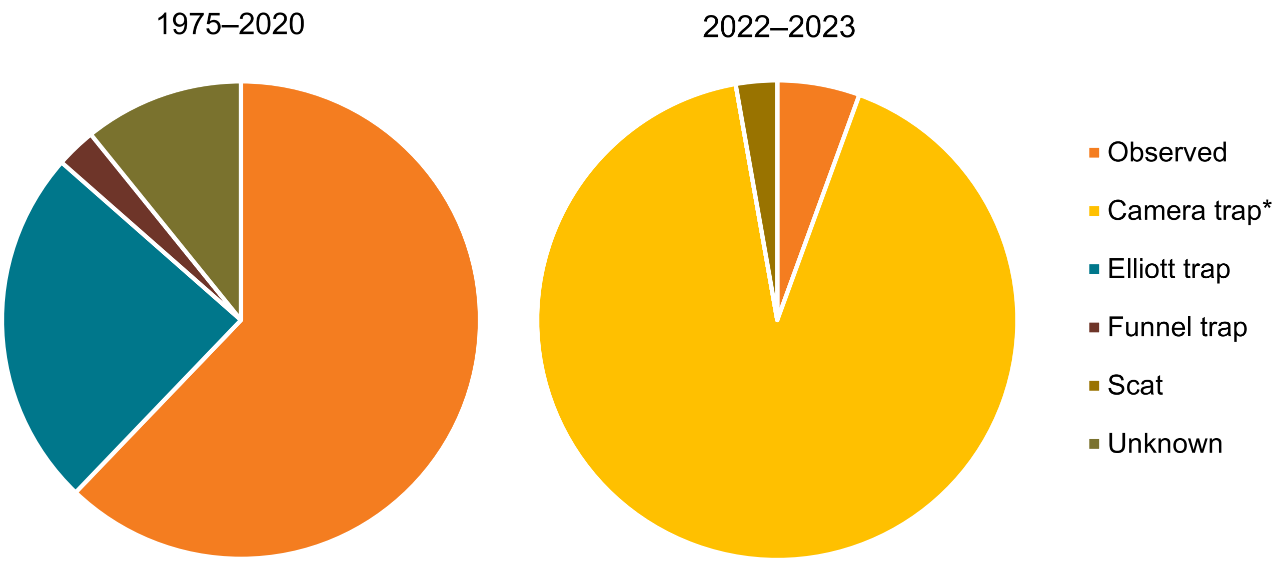


Figure 9. Comparison of the proportion of detections of Arnhem rock skinks by different methods from 1975–2020 (37 records) and during this most recent targeted study in 2022–2023 (36 records). **Camera detections represent individual camera traps that had at least one detection of the species.*

4 RECENT INSIGHTS INTO ECOLOGY AND HABITAT REQUIREMENTS

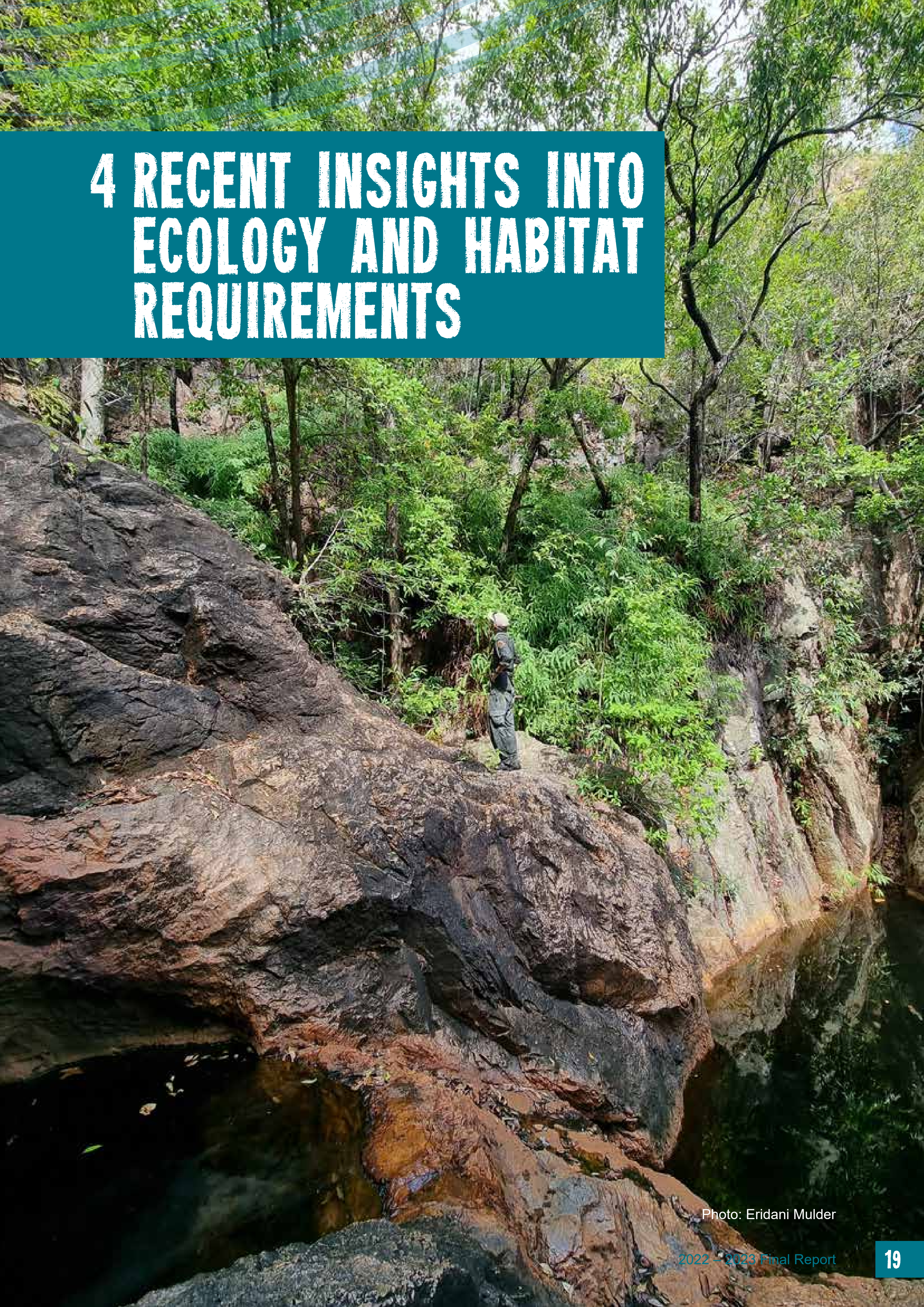


Photo: Eridani Mulder

Given the scarcity of Arnhem rock skink records, almost nothing is known about the species' biology, ecology, or diet. However, recent camera trapping and habitat surveys have provided new insights into the species' ecology and habitat requirements.

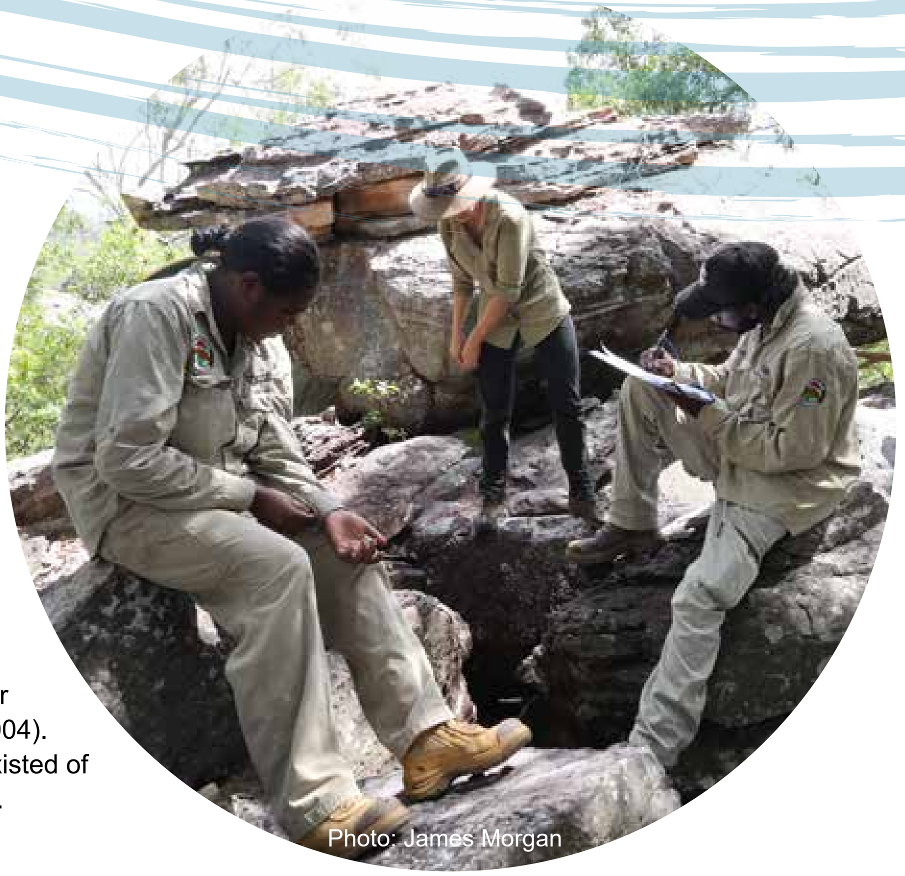


Photo: James Morgan

Habitat associations

Arnhem rock skinks were initially described from moist, thickly vegetated gorges on the western edge of the Arnhem Plateau (Sadlier, 1990). Later, they were also recorded from drier rock habitats including scree slopes with open woodland or *Allosyncarpia* forest (Armstrong & Dudley, 2004). Prior to this project no detailed knowledge existed of their finer-scale requirements or preferences.

Fine-scale habitat requirements

The pilot camera trap study in 2021–2022 found considerable variation in the level of skink activity (inferred from the number of camera detections) across different crevices. In October 2022, a pilot microhabitat study was conducted to compare characteristics of crevices of differing levels of use. These preliminary data suggest that crevices with higher Arnhem rock skink activity may be those with more southerly aspect, horizontal base (flatter in slope), narrower entrance heights (most were less than 40 cm), and a higher number of surrounding crevices.

A more widespread study was carried out as part of this project in 2023, sampling crevice and habitat characteristics across the seven historical locations sampled with camera traps. These new data corroborate that Arnhem rock skinks may be associated with crevices that are narrow in height (<10 cm for highly used crevices), relatively flat (horizontal), and that have a high number of nearby crevices (Figure 10). The crevices where Arnhem rock skinks were detected had lower amounts of leaf litter and more soil cover compared to crevices with no activity.

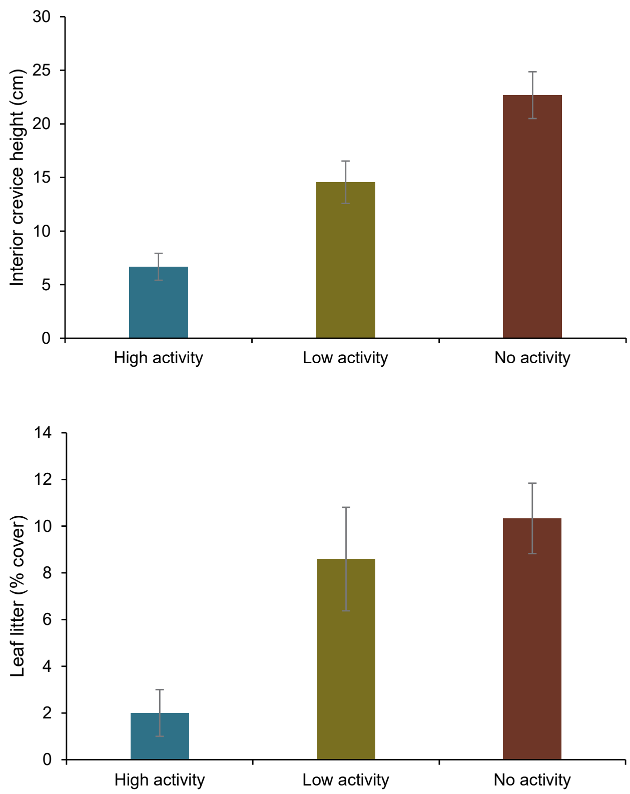
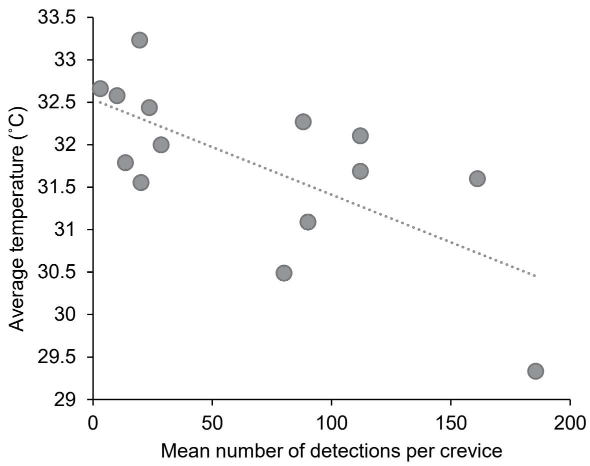


Figure 10. Crevices with high Arnhem rock skink activity were narrower in height and had less leaf litter than other crevices.

Micro-climate requirements

In October 2022, temperature and humidity loggers were deployed across a range of crevices with varying Arnhem rock skink activity levels. Preliminary data indicate that crevices that had higher activity (based on the number of camera detections) had lower average temperature and higher humidity than crevices with low activity (Figure 11).

Cooler, more humid crevices might be those that are more sheltered (e.g., south facing) or narrower and deeper (based on preliminary data), but more data are needed to better understand these relationships. It is likely that microclimate patterns may be more differentiated during the late dry season when weather conditions are typically hottest and driest.



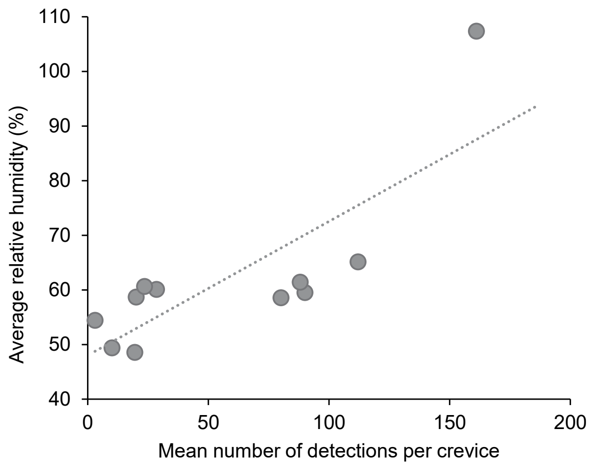


Figure 11. Crevices with higher Arnhem rock skink activity (number of detections) were cooler and more humid.

Figure 12. Retrieving and downloading micro-climate data from crevices in the field. (Photos: Emily Hoffmann, Jordan Mulder)

Seasonal and daily activity patterns

Prior to the 2021–2022 pilot study conducted by NTG and KNP and this project, Arnhem rock skinks were assumed to be active year-round, and there was speculation as to whether the species was diurnal (active during the day), crepuscular (active around dawn and dusk), or nocturnal (SEWPAC, 2011; Sadlier, 1990).

The NTG and KNP pilot camera trapping study in 2021–2022 found marked seasonality in Arnhem rock skink activity levels over a 12-month period (Figure 13). The highest skink activity (inferred by the number of camera detections) was recorded during the wet season (December–March), and very little activity occurred for several months during the dry season (May–August) (Figure 13).

Observations from camera trapping in 2022–2023 confirmed that the species is primarily diurnal, with most motion detections during daylight hours, between 8am–6pm, peaking in the middle of day (Figure 14).

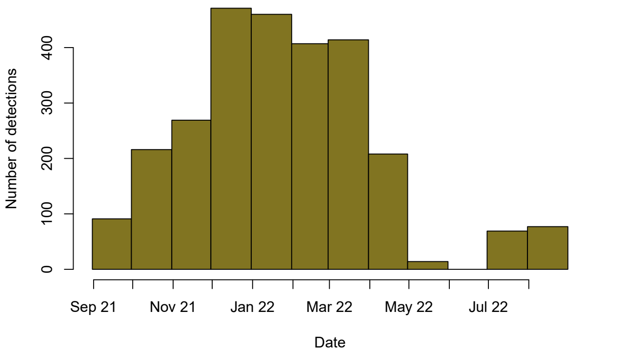


Figure 13. Detections of Arnhem rock skinks on camera traps in 2021–2022 showed activity is highly seasonal (Data source: NTG and KNP).

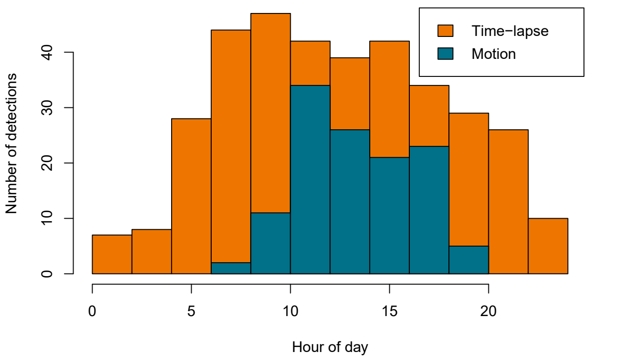


Figure 14. Frequency of Arnhem rock skink detections at different times of day (0–24 hours) of on camera traps in 2022–2023, showing the species is most active during daylight hours. Colours show different trigger mechanisms: time-lapse (orange) and motion (blue).

Sociality

The *Egernia* group of skinks, to which the Arnhem rock skink belongs, include some of the most social of all squamates (lizards and snakes) (Chapple, 2003). Camera trapping over the 2022–2023 wet season indicated Arnhem rock skinks may live in small family aggregations. Multiple individuals were observed repeatedly using a single crevice at a small number of locations. Where this was observed, it appeared to be at least one adult and a juvenile or sub-adult. Skinks were clearly distinguishable due to size and/or pattern. An adult and sub-adult were photographed co-occurring in one crevice (Figure 15).

Figure 15. An adult and subadult Arnhem rock skink detected occupying a crevice together via camera trapping in November 2022.

5 POTENTIAL THREATS AND SPECIES MANAGEMENT

Photo: James Morgan

The primary threats thought to be impacting Arnhem rock skinks include frequent high-severity fire, predation by feral cats and poisoning by cane toads (Armstrong & Dudley, 2004; Woinarski et al., 2007). This project has provided new insights into the species' current distribution and ecology; however, there is still very little direct evidence of their threats. The below section details observations from the 2022–2023 surveys in relation to the primary threats recognised for Arnhem rock skinks.

Feral cats

Feral cats (*Felis catus*) have been attributed as the main cause for severe declines of small mammals in northern Australia and are known to depredate reptiles of a similar size to the Arnhem rock skink (Doherty et al., 2015). However, cats are potentially less common and less successful in rocky areas (Hohnen et al., 2016; McGregor, Legge, Jones, et al., 2015). During camera trapping in 2022–2023, two feral cats were detected using crevice habitats at one survey plot. The detections were made on two cameras, one in November 2022 and one in March 2023 (Figure 16). Arnhem rock skinks were not detected at the plot where feral cats were detected but were detected in low numbers at a nearby plot, approximately 200 m away. Given cat home ranges in northern Australia range from an average of 10 ha to 300 ha (McGregor, Legge, Potts, et al., 2015), this provides evidence that the two species co-occur in rocky habitats and highlights the valid threat that feral cats pose to Arnhem rock skinks.

Cane toads

Introduced cane toads (*Rhinella marina*) reached Kakadu National Park in the early 2000's and have been linked to the decline of related large lizards (Jolly et al., 2015; Shine, 2010). Targeted surveys in 2022–2023 detected cane toads at four of the seven locations sampled, confirming that cane toads occur in similar crevice habitats used by Arnhem rock skinks. Cane toads were detected using two crevices that were also used by Arnhem rock skinks (Figure 16). Cane toads were detected using several crevices at one historical location where no Arnhem rock skinks were detected in 2022–2023.

Figure 16. Feral cats (top) and cane toads (bottom) were detected on camera traps using crevice habitats whilst searching for Arnhem rock skinks in 2022–2023.

Fire

Increasing frequency and severity of fires may directly impact Arnhem rock skink habitat and food availability, as well as interact with other threats, such as increasing accessibility and predation by feral cats (McGregor, Legge, Jones, et al., 2015). During 2022–2023 surveys, Arnhem rock skink sites generally appeared to be moist and lush habitats. However, it was observed that some survey areas had evidently been burnt, or had vegetation with high fuel loads (e.g., annual sorghum) encroaching or directly adjacent to some sites.

Future recommendations

With new monitoring tools and the ability to detect skinks more successfully, it should now be possible to determine the current species distribution with much higher confidence and monitor population trends. A priority should be to establish an ongoing monitoring program at occupied skink sites, as well as additional and more widespread surveys throughout the species' historical range, and other areas with suitable habitat.

Priority areas for surveys should include historical sites that were not able to be accessed in 2022–2023, as well as the areas where new sightings were documented, to confirm the presence and distribution of skinks. With the information from more widespread and ongoing monitoring, it should soon be possible to assess the relative impacts of different threats and responses to management.

Photo: James Morgan

Photo: Eridani Mulder

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APPENDIX A: PROJECT FINDINGS FACTSHEET

Photo: James Morgan

FINDINGS FACTSHEET

Searching for the Top End's most threatened reptile
THE ARNHEM ROCK SKINK

Photo: James Morgan

Photo: Chris Jolly

Background

Arnhem rock skinks are large, brown, chunky lizards—similar in size to the more common blue-tongued skink. These lizards occur in association with sandstone escarpments and have only been recorded from a few areas along the western edge of the Arnhem Plateau. Most records of Arnhem rock skinks are from Kakadu National Park.

Arnhem rock skinks are shy and hard to find, and we know very little about them. The species is one of the most threatened reptiles in Australia and is thought to be disappearing from historical areas where they used to be found. At the start of this project, the species was only confirmed to still occur in one location.

Main aim of the research

We aimed to find Arnhem rock skinks using new non-invasive survey methods. We wanted to see if the lizards still exist in areas where there are historical records of them, or if they have truly disappeared from those places.

What we did

We looked for Arnhem rock skinks using two methods:

- **Camera trapping** – setting remote cameras facing rock crevices in areas with historical records
- **Environmental DNA** – collecting small amounts of soil and water from rock crevices and nearby waterbodies to see if we can detect the species' DNA (genetic material) in the environment

What we found

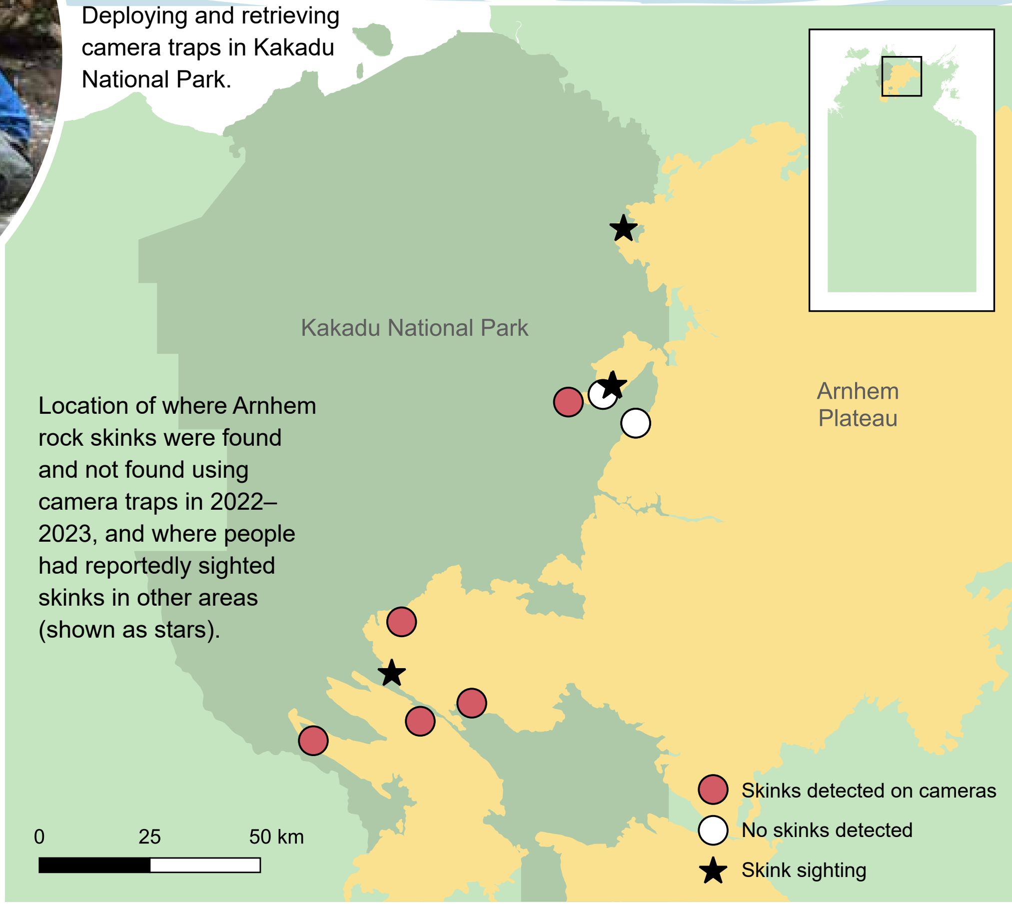
Camera trapping successfully detected Arnhem rock skinks. We found the species at five of the seven historical locations we surveyed. This is exciting as the species had not been recorded at many of these areas for 20 or 30 years.

However, in the areas where we did find Arnhem rock skinks, we commonly only found one or two lizards. So, the skinks seem to occur in low numbers in many of the areas we found them.

Looking at the crevices where we found skinks has helped us understand what habitat they might prefer. We found Arnhem rock skinks used flat, deep, wide crevices that were narrow in height. These crevices may provide cooler and more humid habitats and and protect them from predators.

The environmental DNA methods trialled in this project were not successful for finding skinks. No Arnhem rock skink DNA was detected in any soil or water sample, despite being collected from an area with relatively high activity of rock skinks.

Deploying and retrieving camera traps in Kakadu National Park.



Location of where Arnhem rock skinks were found and not found using camera traps in 2022–2023, and where people had reportedly sighted skinks in other areas (shown as stars).

Implications

The camera trapping survey methods trialled in this project can be used to learn more about Arnhem rock skinks and their threats.

- Annual surveys during the wet-season using camera traps could help to monitor population numbers, to see if they are stable or decreasing.
- Additional camera trapping could be used to look for them at other historical sites as well as in new areas.
- Camera trapping could be a useful way to check the health of rocky-escarpment country.

The camera traps also captured images of other threatened or lesser-seen species, including water and rock goannas, an Oenpelli python, Arnhem rock-rats, giant cave geckos, and rakali (water rats). Additionally, the camera traps recorded images of feral animals such as cats and cane toads in some rocky areas which can help us know where to manage threats on country.

Acknowledgements

We thank the Traditional Owners and their families of areas we worked within Kakadu National Park for their consent and assistance with accessing areas of historical sightings.

This project was a collaboration between Territory Natural Resource Management, Parks Australia (Kakadu National Park), Charles Darwin University, Northern Territory Government, Macquarie University, and Curtin University, and was supported through funding from the Australian Government's National Landcare Program.

Photos of Arnhem rock skinks (*Bellatorias obiri*) from camera trapping in 2023.

Photo: James Morgan

APPENDIX B: CAMERA TRAPPING GUIDE

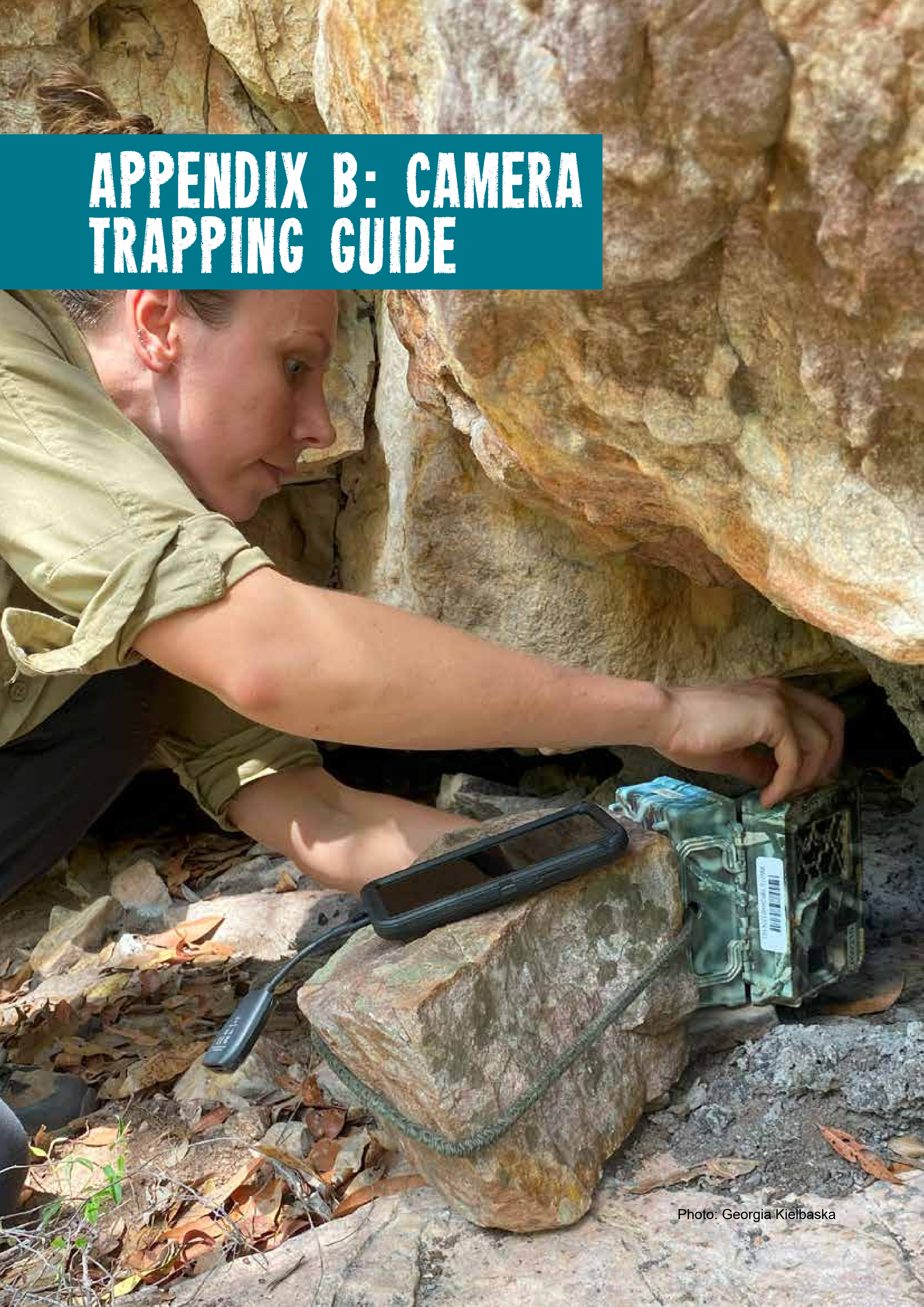


Photo: Georgia Kielbaska

CAMERA TRAPPING GUIDE

DETECTING ARNHEM ROCK SKINKS

Djurrubu Ranger, Clayton Nadjamerrek, deploying a camera and bait station. Photo: Joel Smith

Photo: Csenta Roberts

Photo: Chris Jolly

Purpose of this guide

This guide aims to aid land managers and researchers in the site selection, deployment design, and camera set up for conducting targeted surveys for Arnhem rock skinks. We detail the camera trapping methods that were used in 2022–2023 which were highly successful at detecting the species at a range of different locations. The methodology was developed based on the pilot study conducted by NTG and KNP in 2021–2022 and has been further refined based on the results from this project. By using consistent camera trapping methods, the findings from surveys will be comparable across different areas and over time.

Survey design

Site selection and design

Arnhem rock skinks have been recorded from the western edge of the Arnhem Plateau from near Gunbalanya to near the southern KNP boundary. The species' distribution may extend further along the Arnhem Plateau to the north-east and south, into west Arnhem Land or Nitmiluk National Park.

The species has been recorded from moist, thickly vegetated gorges on the western edge of the Arnhem Plateau, as well as some drier rock habitats including scree slopes with open woodland or *Allosyncarpia* (Anbinik) forest.

The 2022–2023 camera trapping surveys targeted areas where there were historical records of the species. These were rocky habitats along the western edge of the Arnhem Plateau in Kakadu National Park, typically along the edge of escarpments and nearby scree/boulder slopes and steep gorges. Sites were often near water and with monsoon or Anbinik (*Allosyncarpia*) forest with dense canopy cover.

Selecting sample plots

To select which plots to sample with camera traps, we first divided the general survey areas into grid cells of 1 hectare (100 m x 100 m) (Figure 1).

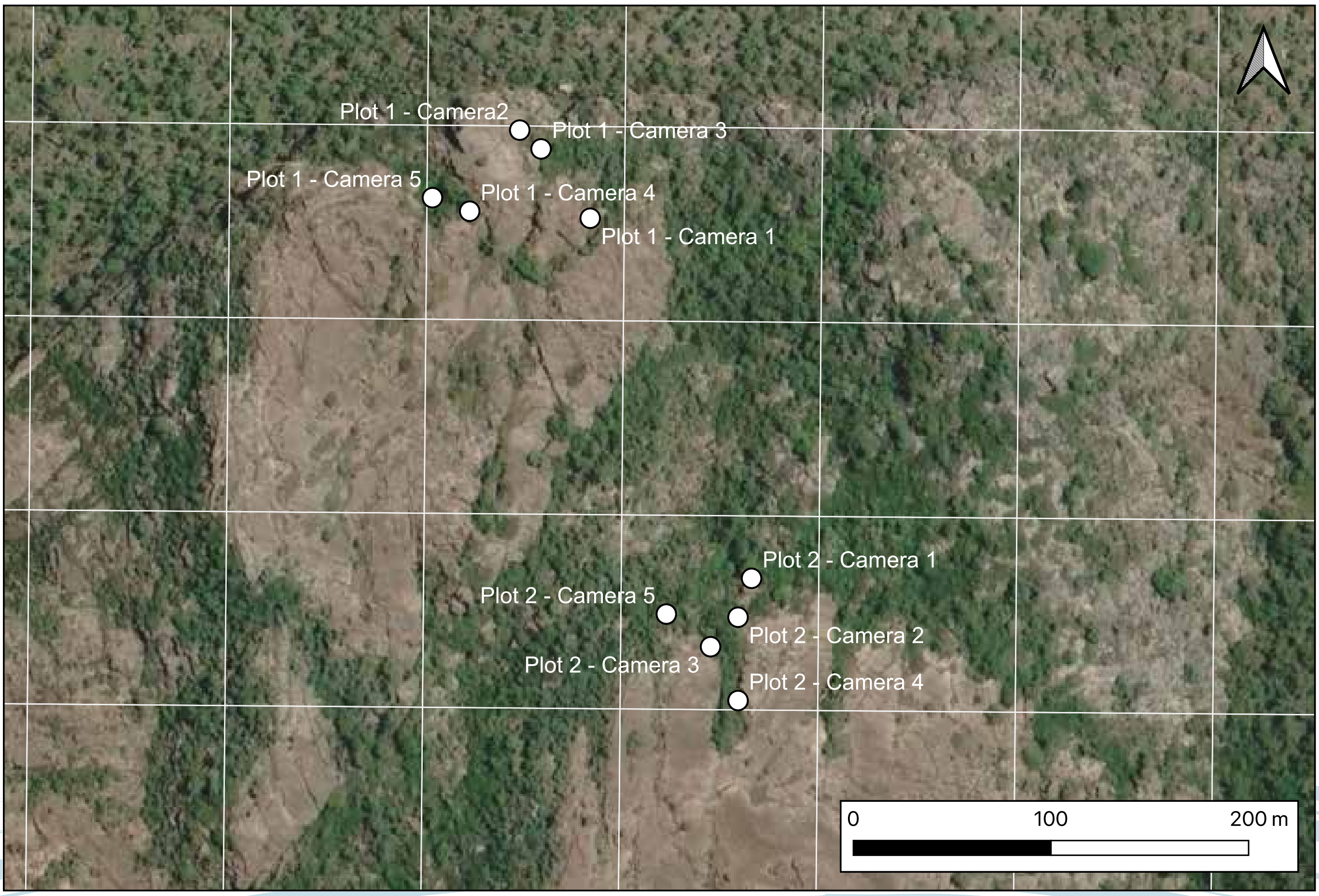
We selected grid cells based on that they were areas that: a) were near historical records; b) had rocky terrain with numerous crevices; and c) had dense and moist habitat such as monsoon forest. We used satellite imagery initially to get an idea of potential areas to search and then inspected the locations on foot.

We selected a minimum of two plots (each 1 hectare in size) to sample at each general location that we thought were the 'best' looking habitat, and where possible covered a range of conditions (e.g., elevation, vegetation, types of crevices – boulders/scree vs. deep wall crevices).

Number of cameras and duration

Using the pilot data collected by NTG and KNP in 2021–2022, we calculated and compared the detection probabilities of Arnhem rock skinks (the chance of detecting a skink if they are there) with different numbers of cameras and deployment durations. We found that for a 1 ha area (100 m x 100 m) with low skink density, deploying five cameras for a period of four months had a very high (>95%) confidence of detecting skinks if they were present. Whilst it is

Figure 1. Example of the sampling design with a 100 m grid overlaying the study area and five cameras set up within selected 1 ha plots that were chosen based on ground searches for potential suitable habitat and crevices.



possible to set more cameras per 1 ha plot, it is likely to be a trade off with the number of plots that can be sampled. In 2022–2023, it was a high priority to sample as many areas as possible.

Findings from the 2022–2023 camera trapping using this method validated that the proposed intensity (five cameras per ha, for four months) was sufficient sampling effort to detect skinks. Therefore, we recommend setting a minimum of five cameras (100m x 100m) for 4 months, per 1 ha plot.

Note - If the survey is for an environmental impact assessment (e.g., surveying prior to habitat disturbance or development activities) we recommend using a higher density of cameras to increase the confidence of detecting any occurrence of Arnhem rock skinks.

Survey timing

Year-long sampling at one site by NTG and KNP has shown that detection of Arnhem rock skinks is highly seasonal. The number of skink detections peaked during the wet season (December–March), and there were very few detections during the dry season (May–July) (Figure 2). Therefore, the optimal time of year to survey is during the wet season, between November and April.

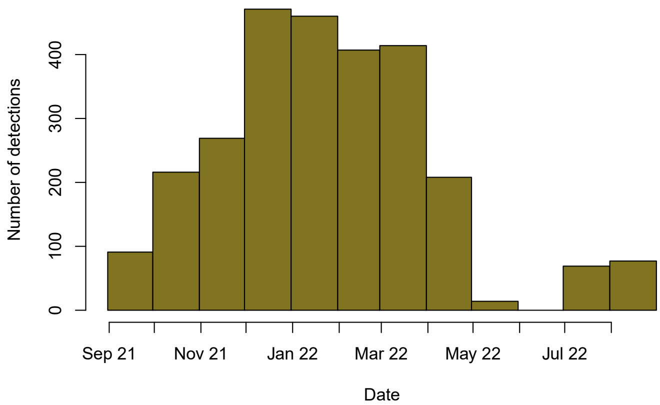


Figure 2. Seasonality of detections of Arnhem rock skinks on camera traps set at one site in 2021–2022 (Data source: NTG and KNP).

Camera type and focal distance

We trialled two different camera types in 2022–2023: Reconyx Hyperfire 2 with white flash (HP2W) and modified short (0.9 m) focal distance, and Reconyx Hyperfire with white flash (PC850) and standard focus (Figure 3).

The average number of images and number of cameras with detections of Arnhem rock skink was higher for the newer model cameras (HP2W), but the difference was not significant (Figure 4). The older model had substantially fewer motion-triggered photos per camera, compared to time-lapse and the newer model cameras (more information about time-lapse and motion trigger is detailed in the Camera Settings section below). We also found the newer models were much more reliable; they had considerably fewer failures over the 4-month survey period and therefore the newer model Reconyx cameras performed better overall.

Whilst the images were clearer and sharper from cameras that had modified short focus compared to those with standard focus, we could clearly identify Arnhem rock skinks from both of the focal distances (see example in Figure 5 below). Therefore, short-focus cameras are useful but not essential for detecting Arnhem rock skinks.

Figure 3. The two different camera models used in the 2022–2023 targeted survey; Reconyx Hyperfire with white flash (PC850) and standard focus (left) and Reconyx Hyperfire 2 with white flash (HP2W) and modified 0.9 m focal distance (right).

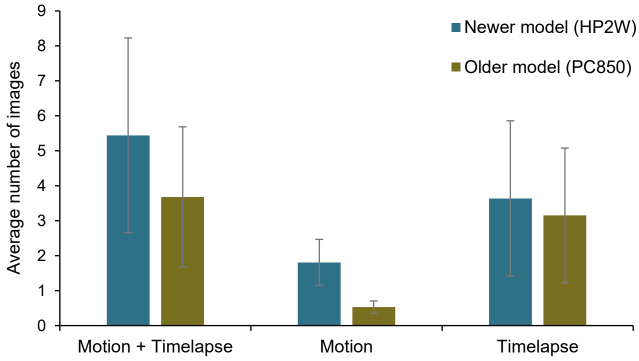


Figure 4. More images were captured with newer Reconyx cameras (model HP2W) compared to older models (PC850).

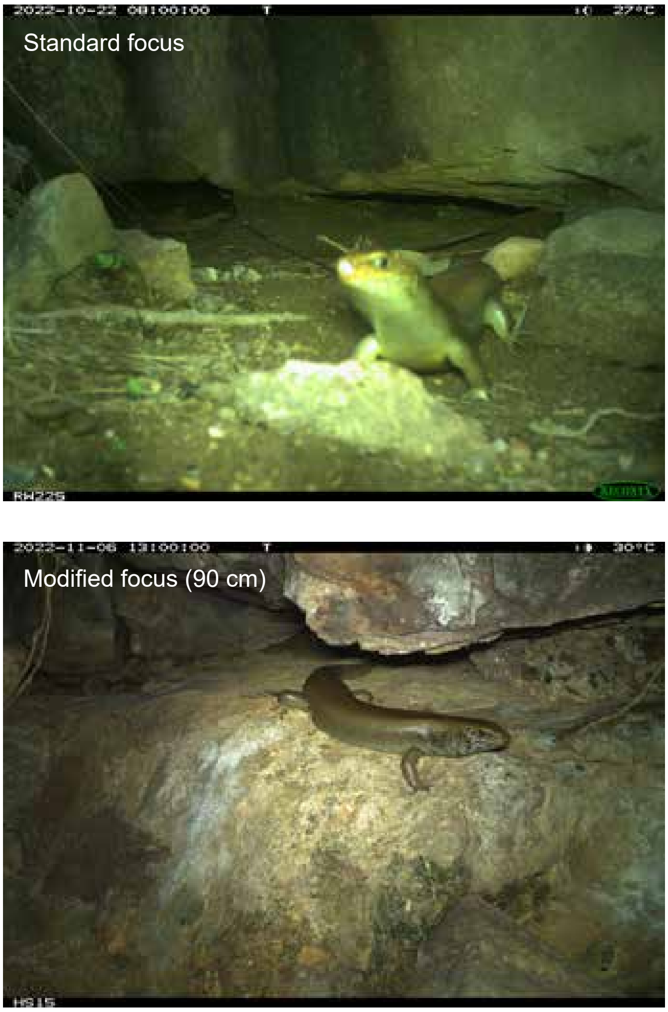


Figure 5. Comparison of images from cameras with standard focus and modified short focus. Arnhem rock skinks are clearly identifiable in both types.

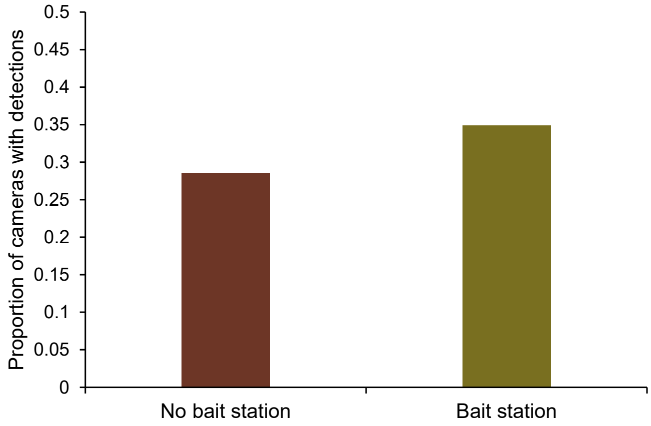
Bait stations

During the 2022–2023 camera trapping survey, bait stations were randomly deployed at three of the five cameras in each grid. A bait station consisted of a ball of bait contained within a PVC pipe bait canister, with a slotted end to allow scent dispersal but not direct access to the bait (Figure 6). Bait balls were made of 'universal bait' (peanut butter and oats) with the addition of canned fruit (peaches) and sardines.

The proportion of cameras with Arnhem rock skink detections was similar for those with or without bait stations, suggesting that the use of bait is not necessary when targeting the species (35% and 29% respectively). The number of days until the first detection was lower on average baited cameras, but the difference was not significant (Figure 7). However, baits may also be useful for increasing the detection of other off-target species (e.g., small mammals).

If used, we recommend placing the bait station at a standardised distance from the camera (if possible), such as 1 m in front and visible in the camera frame, but not blocking the main view of the crevices. Securing the bait station with a small rock or similar is useful to stop the bait being moved or lost.

Figure 6. A bait station consisting of balls of bait made of peanut butter, oats, fruit and sardines, and deployed in PVC pipe canisters.



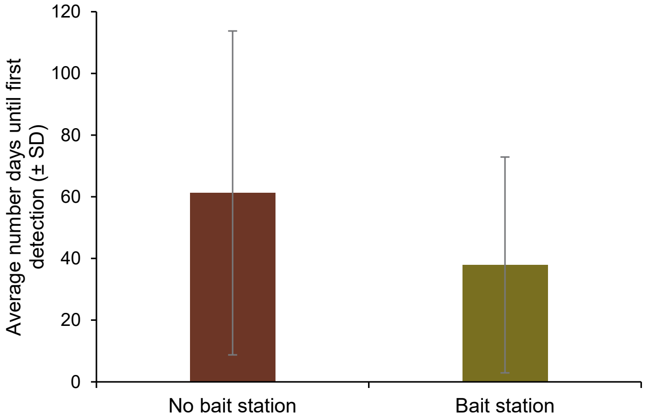


Figure 7. The proportion of cameras with Arnhem rock skink detections and the average number of days until the first detection for cameras deployed with and without bait stations.

Camera placement and setup

Camera locations

Once a 1 ha plot of potentially suitable habitat was selected, the deployment team spent approximately one hour searching the area thoroughly to identify and inspect potential crevices (using a head torch or phone torch was useful). We then chose five crevices that looked potentially suitable. If possible, crevices were selected so that they spanned throughout the plot area (e.g., not all closely clustered), but this depended on the availability of crevice habitats.

In 2022–2023, we targeted a range of crevice types. Preliminary results showed that crevices where skinks were detected were narrower in height (generally around 15 cm high, with the most active crevices < 10 cm, measured at 1 m depth). Used crevices were fairly horizontal in slope (flatter), although the terrain around the crevices was often steep (~35 degrees). Crevices where skinks were detected were an average of 1.5 m deep, but depth was hard to accurately assess due to the interior complexity of some crevices. Some examples of crevices used by Arnhem rock skinks are given in Figure 8.

Camera locations were recorded with a GPS and/or on a phone using a GPS app (GeoTracker). If the locations were not too visible to the public, the locations were marked with flagging tape. We found flagging tape made finding the cameras during the retrieval trips considerably easier.

TIP

Consider if the cameras may get flooded during the wet season by looking for evidence of flooding (tree debris, water lines etc). Try and set cameras well above any visible flood lines and off the ground (e.g., by sitting the camera on a small rock, Figure 11).

Figure 8. Examples of crevices that had 'high activity' by Arnhem rock skinks. Left photos show the camera location, and right photos show the crevice from the camera's field of view.

Camera direction/angle

We set cameras just outside (within ~1 m) or immediately inside the entrance of crevices, facing inwards. The exact camera placement was crevice specific and based on where the camera could be attached with a clear view of the crevice.

For Reconyx Hyperfire cameras, the motion trigger uses a Passive Infrared motion detector that is triggered when an object of a different temperature to the background (warmer or cooler than the ambient temperature) moves across the active zone (see Figure 9). Therefore, it is ideal to have the bottom half of the field of view focused on the area where skinks are likely to move through or past.

It is recommended that the position and field of view of the cameras is checked in the field so that the camera is set up correctly. This can be done by turning on the camera, triggering the motion sensor to take some test photos and then reviewing the images on the cameras SD card using a small camera or SD card reader and a phone or small laptop (Figure 10). This can be done multiple times until the camera field of view is satisfactory, and then the SD card can be returned, and the camera turned on and left.

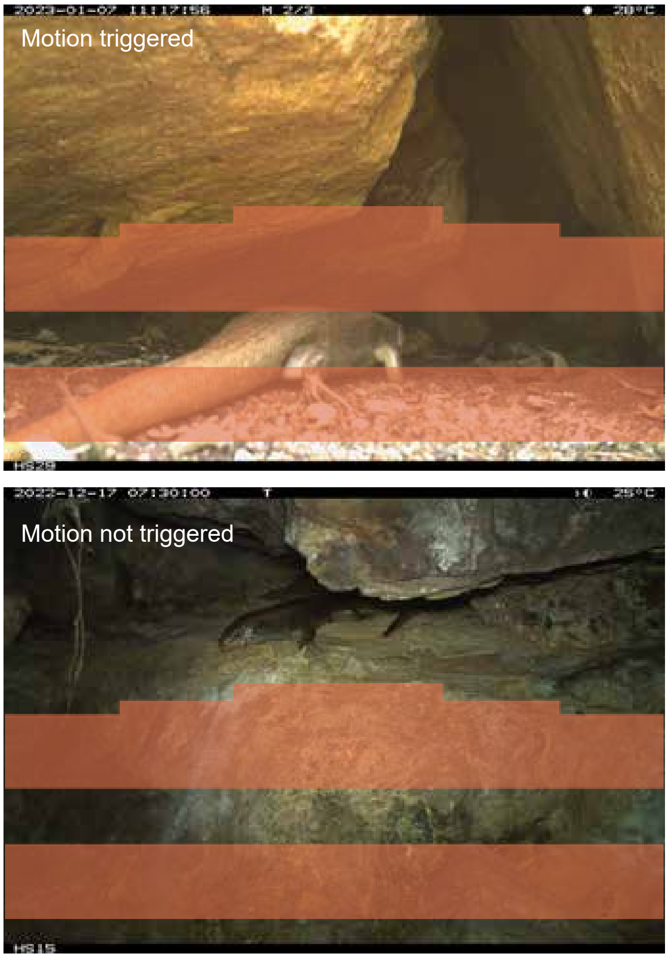


Figure 9. Example photos where (top) an Arnhem rock skink moved through the frame and triggered the PIR motion sensor and (bottom) where the motion sensor was not triggered, as the skink was higher than the sensor area (captured via time-lapse interval trigger). The camera PIR motion sensor detection zones are overlaid in red.

TIP

Clean up fallen leaves or vegetation in front of the camera to reduce the number of false triggers.

Watch for overhanging rocks close to top of camera. These can block the flash and make it difficult to see any objects in the images during low light and at night.

Figure 10. Checking the camera position and field of view by triggering and reviewing the photos with an SD card reader connected to a phone (or small handheld camera) is recommended during the camera set up to refine the camera position.

Attachment methods

We found the easiest deployment method was to attach the camera to a large rock, using smaller rocks or sticks to aid with setting the camera angle and tightening the attachment strap. We used bungee cords or a flat adjustable strap depending on the camera type. We also sat most cameras on top of a small rock to get the camera off the ground to reduce flooding in many areas (Figure 11). We found this attachment method was very stable and had few cases where the camera moved during the deployment period.

Alternatively, strapping a ball mount to a large rock also worked and was easy to refine the camera angle. However, we found that sometimes this meant the camera may sit too high for lower crevices and required additional straps to stabilise the mount (Figure 12). Metal stakes are a suitable alternative where no in-situ anchor point is available or suitable (Figure 12). We sometimes also used tree trunks when they were present but avoided using small trees as they may move in even light or moderate winds and falsely trigger the camera.

Note – Camera security: consider visibility of the cameras to the public if setting near public access points and tracks as secure attachment (e.g., with a lock) may be difficult.

Figure 11. Example attachment of the camera using nearby rocks. Smaller rocks or sticks were used to sit the camera on and to angle the camera in towards the crevice.

Figure 12. Cameras can also be mounted on an adjustable ball mount or metal stake.

TIP

Check the batteries are securely in place in the field during deployment, as some can pop out during transport.

Photo: James Morgan

Camera settings

Time-lapse vs. Motion trigger

The 2021–2022 pilot study trialled motion trigger for detecting skinks, taking three images per trigger. In 2022–2023, we simultaneously used both motion and time-lapse (30-minute interval) triggers on all cameras (Table 1). Both methods were successful in detecting Arnhem rock skinks (Figure 13).

Time-lapse triggers collected more rock skink images overall, but motion trigger appeared to be the most consistent, with motion trigger detecting skinks on the majority (82%) of the cameras with detections. Arnhem rock skinks were detected exclusively by one trigger method on many cameras, with 18% of camera detections being time-lapse only, and 42% via motion-only trigger.

Therefore, the best method, with the highest rate of detection, is to set both trigger methods if possible. However, if only one trigger can be used, motion trigger is preferred. Motion trigger detected skinks more consistently than time-lapse and collected far fewer empty images.

Note: Battery life – We found batteries lasted for four months when set on both motion and time-lapse triggers (30-minute intervals), and greater than six months if only set on motion trigger.

Note: Memory capacity – For a four-month deployment, where cameras are set on both motion and 30-minute time-lapse triggers, we collected an average of ~6000 photos per camera (~1.5 GB). Therefore, we recommend a minimum memory card that can store at least 2 GB.

TIP

Pre-program all cameras with the required settings so that no adjustment of the camera settings is needed in the field.

Activation time

Our findings from 2022–2023 showed that the majority of motion-triggered detections occurred during the day, but time-lapse collected many detections outside of that period (Figure 14). Given so little is known about this species, it is recommended to sample for 24 hours a day to maximise detections.

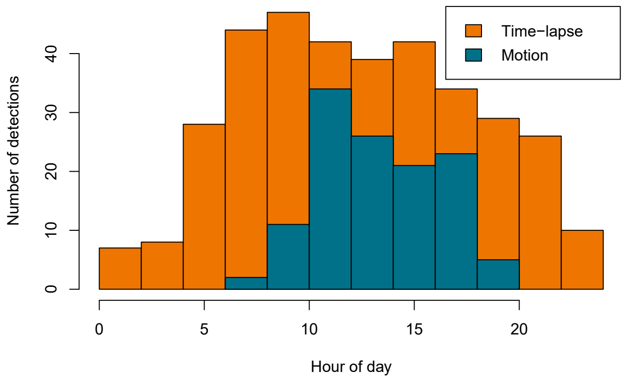


Figure 14. Frequency of Arnhem rock skink detections at different times of day (0-24 hours) from camera traps in 2022–2023. Colours show different trigger mechanisms: time-lapse (orange) and motion (blue).

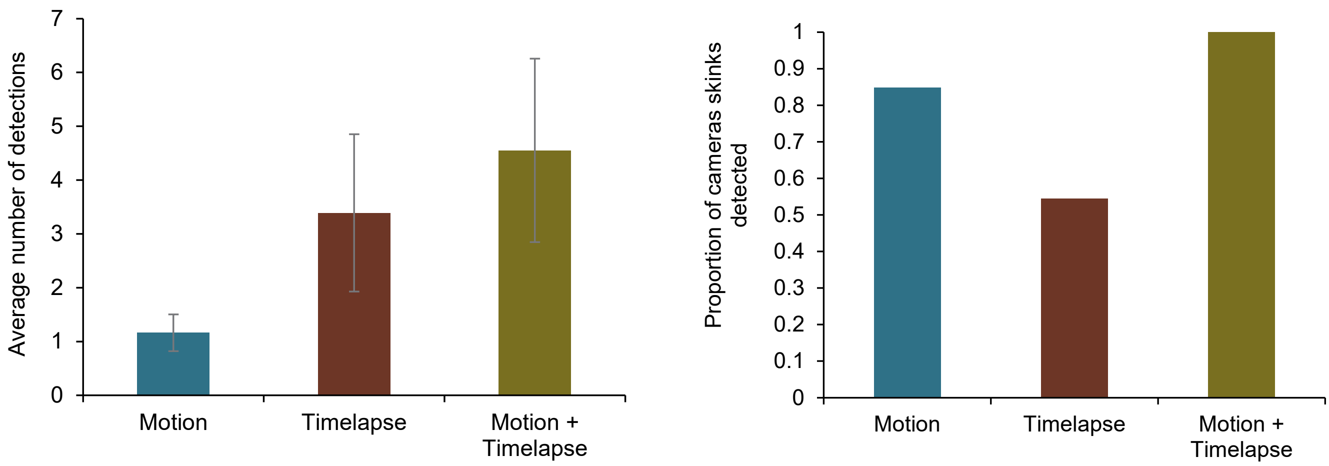


Figure 13. Average number of Arnhem rock skinks detections (left) and proportion of cameras skinks were detected (right) via motion trigger, time-lapse or both trigger methods.

Table 1. Key Reconyx Hyperfire camera settings used for targeting Arnhem rock skinks.

Motion	Time-lapse	General camera settings
Number of pictures – 3	*Number of pictures* – 1	*Take pictures* – both day and night
Time between pictures – RapidFire	*Time between pictures* – NA	*Flash output* – High
Quiet period – no delay	*Time-lapse interval* - 30 minute	*Min shutter speed* – 1/480th
Sensitivity – High		*Max ISO* - 3200
		PIR type – Hyperfire Legacy

Data management and photo processing

The long detection period (multiple months) and the time-lapse trigger setting will result in the collection of a large volume of data that will require careful management and processing. It is important to carefully record the relevant site, plot, and camera numbers as well as the location data and deployment and retrieval dates for each camera. Images can be kept in separate folders with unique site, plot, and camera codes.

Other resources are available with more detailed guidance on how to manage and process camera trapping data (e.g., Gillespie et al., 2015).

Using AI models to filter empty images

Camera trapping, particularly with the use of a time-lapse trigger, will often result in a large number of false triggers, or 'empty images'. MegaDetector is a model trained to detect objects—animals, people, and vehicles—in camera trap images (Beery et al., 2019; Microsoft, 2022). By separating the majority of animal vs non-animal photos from camera traps it can greatly speed up manual image processing. The outputs of the model (recogniser files) can be imported directly into a photo processing database (e.g., Timelapse software) and then images can be selected by the model classification (e.g., all images with animals in them).

We used EcoAssist software (van Lunteren, 2022) to run the MegaDetector model and imported the detection output files into Timelapse photo processing software (version 2.3.0.6; Greenberg Consulting Inc.) to efficiently sort and tag images. Pilot testing was carried out on a subset of images to determine how effectively the model classified Arnhem rock skink images as an 'animal'. We found the model, set at most conservative confidence threshold (10%), was very effective at detecting Arnhem rock skinks in images, with over 95% recall. That is, nearly all (> 95%) images containing Arnhem rock skinks were classified as 'animals', verifying that the model is a useful tool for classifying rock skink images and filtering empty images.

Photo: Emily Hoffmann

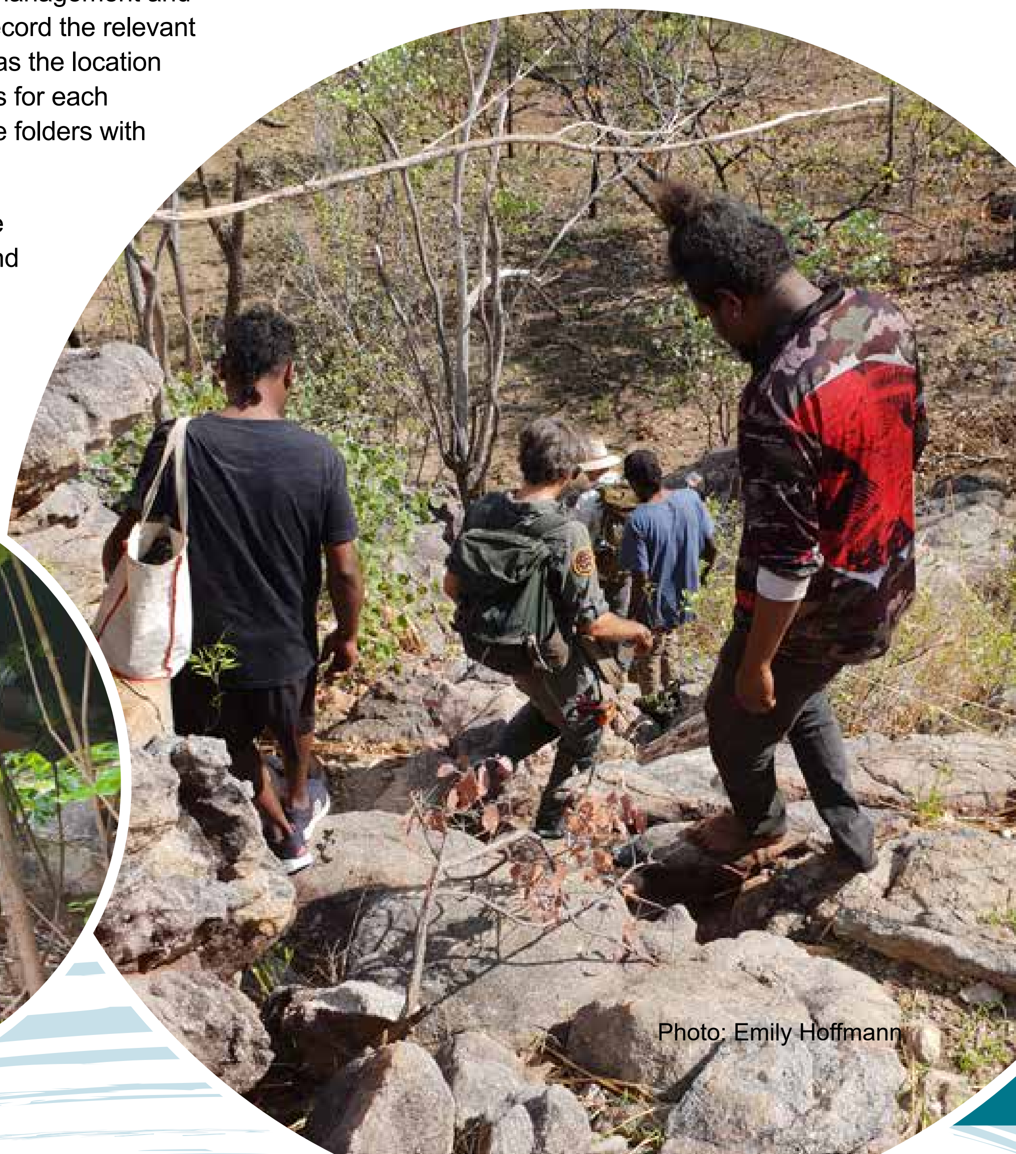


Photo: Emily Hoffmann

Misidentification with similar species

Findings from the 2022–2023 camera trapping suggested there was little chance of misidentification with other species. There were very few skinks of a similar large size, with the exception of northern blue-tongues (*Tiliqua scincoides intermedia*). The few detections of northern blue-tongued skinks could readily be distinguished from Arnhem rock skinks by their distinct patterning, broader and more triangular heads, and shorter tail relative to body length (Figure 15). Smaller striped skinks, such as brown-backed ctenotus (*Ctenotus coggeri*), could more easily be mistaken as they can be brown and patternless, but are significantly smaller in size and have longer and more slender limbs and tails (Figure 15).

Figure 15. Northern blue-tongue skink (top) and Cogger's ctenotus (bottom) were easily distinguished from Arnhem rock skinks by their different size, shape, and pattern in camera trap images.

Photo: Jordan Mulder

Photo: Emily Hoffmann

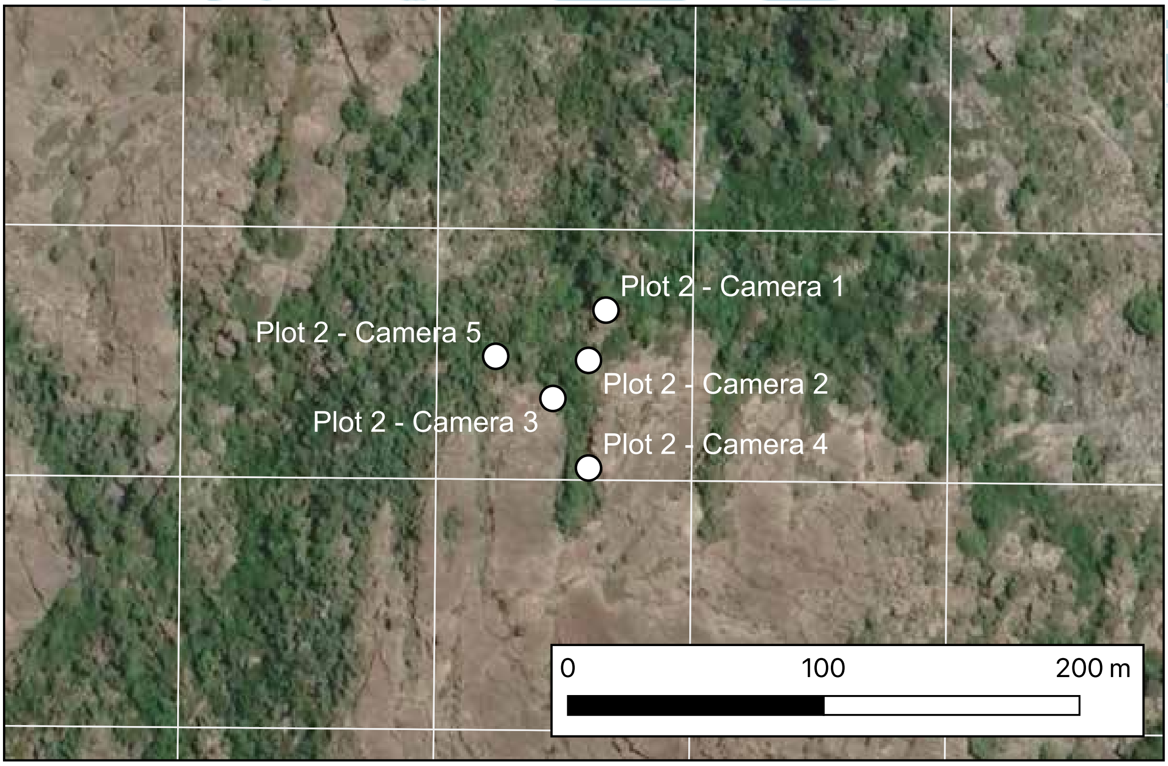
QUICK GUIDE

Photo: Chris Jolly

CAMERA TRAPPING TO TARGET ARNHEM ROCK SKINKS

Where?	Arnhem rock skinks are found in rocky habitats near sandstone escarpments of the Arnhem Plateau. They often occur in thickly vegetated gorges near water, but also in nearby scree slopes with open woodland. Select a minimum of two plots, each 1 hectare (100m x 100m) in size, to sample at each general location. Overlaying a 100m grid over the area of interest to help aid the selection of plot areas.
When?	Set cameras over the wet season (when the skinks are much more active), ideally between October and April.
How long?	A deployment period of four months is ideal (e.g., November to February).
How many?	Set a minimum of five cameras per 1-hectare plot. Spend 30 minutes searching through the plot area to identify and inspect potential crevices. Select five suitable crevices to set up cameras. Suitable crevices are likely those that are narrow in height (less than 20 cm), horizontal/flat, and deep > 1m depth.
Camera set-up	Set cameras just outside (within ~1 m) or immediately inside the entrance of crevices, facing inwards. Use both motion as well as time-lapse trigger settings (set at 30-minute intervals) if possible. Otherwise use just motion trigger (3 photos/trigger). Set the cameras to operate for 24 hours a day to maximise detections. Attach the camera to nearby rocks, by moving a large/larger rocks to face into the crevice and smaller rocks (or small bits of wood) to refine the height and angle. Sometimes nearby trees or metal stakes can also be useful.
Camera type	Cameras with short-range focus will give clearer images but aren't necessary.

Survey design - 5 cameras per 1 ha (100m x 100m), in rocky crevices



Camera set-up – placed just outside or inside a crevice, facing inwards.

Check camera field of view – motion sensor operates on the lower half of the frame

APPENDIX C: CAMERA TRAPPING SPECIES LISTS

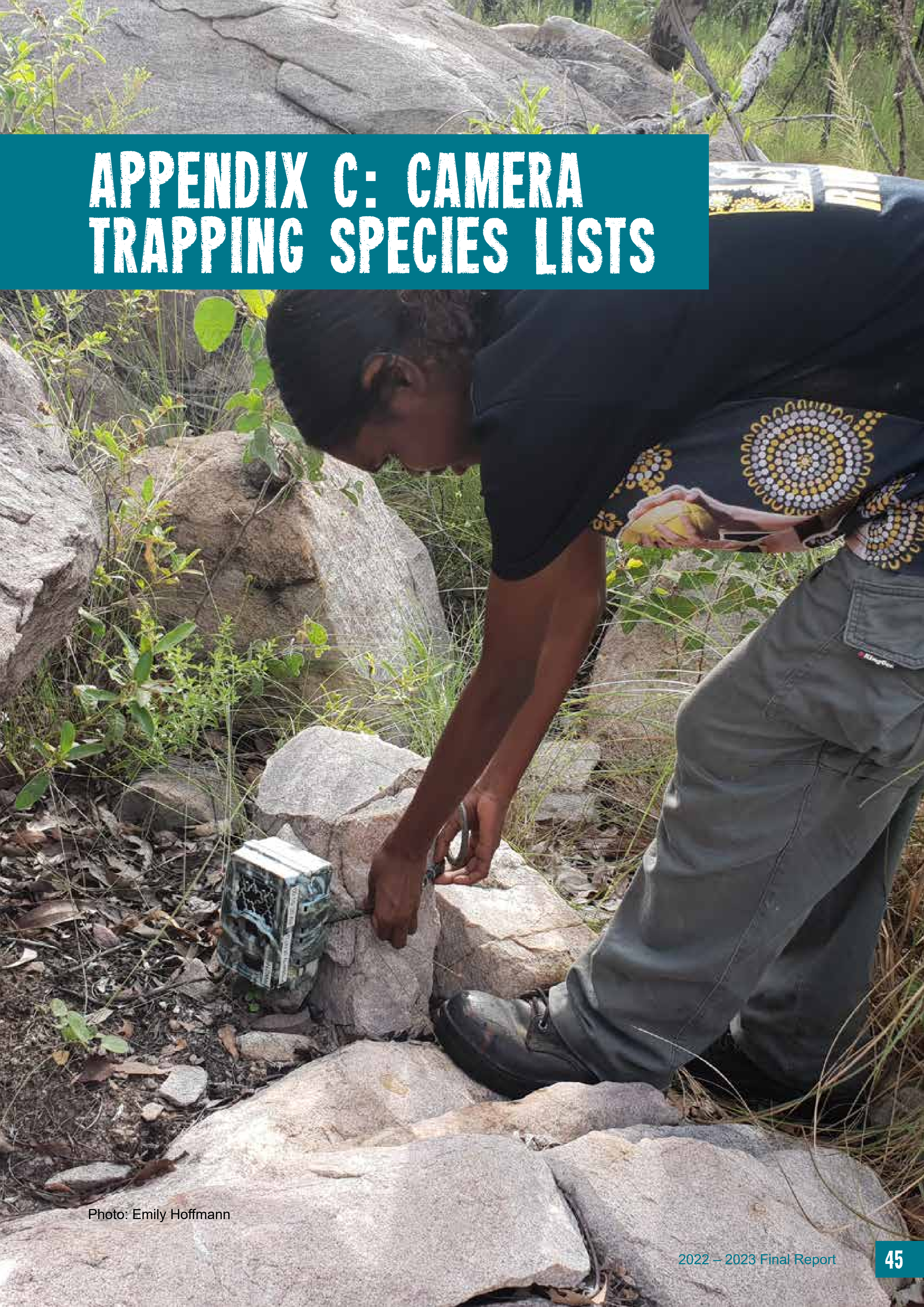


Photo: Emily Hoffmann

Species list: Arnhem rock skink camera trapping 2022–2023

Table 1. List of species detected via camera traps as part of targeted Arnhem rock skink surveys in 2022–2023. *Asterisk denotes introduced species.

	Common name	Scientific name	Status	# images
Lizards	Arnhem Land spotted dtella	*Gehyra pamela*		1648
	Black-palmed rock monitor	*Varanus glebopalma*		863
	Spiny-tailed monitor	*Varanus insulanicus*		819
	Arnhem rock skink	*Bellatorias obiri*	Endangered	704
	Kimberley rock monitor	*Varanus glauerti*		216
	Northern spotted rock dtella	*Gehyra nana*		209
	Brown-backed ctenotus	*Ctenotus coggeri*		194
	Unknown skink			175
	Dtella sp.v	*Gehyra sp.*		167
	Northern bar-lipped skink	*Eremiascincus isolepis*		165
	Bauxite rainbow-skink	*Carlia amax*		124
	Mitchell's water monitor	*Varanus mitchelli*	Vulnerable	120
	Northern blue-tongued skink	*Tiliqua scincoides intermedia*		106
	Lined firetail skink	*Morethia ruficauda*		98
	Giant cave gecko	*Pseudothecadactylus lindneri*		94
	Unknown gecko			72
	Orange-sided bar-lipped skink	*Eremiascincus douglasi*		41
	Northern knob-tailed gecko	*Nephrurus sheai*		24
	Unknown goanna			16
	Dotted velvet gecko	*Oedura gemmata*		11
	Unknown lizard			11
	Rainbow skink	*Carlia sp.*		8
	Bynoe's gecko	*Heteronotia binoei*		6
	Top End firetail skink	*Morethia storri*		1
Snakes	Oenpelli python	*Morelia oenpelliensis*	Vulnerable	65
	Olive python	*Liasis olivaceus*		36
	Children's python	*Antaresia childreni*		27
	Unknown snake			23
	Pygmy mulga snake	*Pseudechis weigeli*		9
	Greater black whipsnake	*Demansia papuensis*		7
	Northern shovel-nosed snake	*Brachyurophis roperi*		4
	Golden tree snake	*Dendrelaphis punctulatus*		3
	Orange-naped snake	*Furina ornata*		2
	Slaty-grey snake	*Stegonotus cucullatus*		1

	Common name	Scientific name	Status	# images
Mammals	Sandstone false antechinus	*Pseudantechinus bilarni*		2040
	Black rat*	*Rattus rattus**		1403
	Common rock-rat	*Zyzomys argurus*		1203
	Black wallaroo	*Osphranter bernardus*		1138
	Short-eared Rock-wallaby	*Petrogale wilkinsi*		713
	Common planigale	*Planigale maculata*		529
	Unknown mammal			441
	Arnhem rock-rat	*Zyzomys maini*	Vulnerable	258
	Short-beaked Echidna	*Tachyglossus aculeatus*		113
	Dingo	*Canis familiaris dingo*		73
	Rock ringtail possum	*Petropseudes dahli*		54
	Eastern short-eared rock-wallaby	*Petrogale wilkinsi*		46
	Rock-rat sp.	*Zyzomys sp.*		39
	Unknown bat			26
	Rakali	*Hydromys chrysogaster*		14
	Common wallaroo	*Macropus robustus)*		9
	Feral cat*	*Felis catus**		9
Frogs	Cane toad*	*Rhinella marina**		155
	Unknown frog			102
	Carpenter frog	*Limnodynastes lignarius*		38
	Tree frog sp.	*Litoria sp.*		23
	Toadlet	*Uperoleia sp.*		3
	Ornate burrowing frog	*Platyplectrum ornatum*		0
Birds	Bar-shouldered dove	*Geopelia humeralis*		17
	Sandstone shrike-thrush	*Colluricincla woodwardi*		14
	Orange-footed scrub fowl	*Megapodius reinwardt*		9
	Unknown bird			2
	White-lined honeyeater	*Territornis albilineata*		1


Alana de Laive