Northern Australia Environmental Resources Hub

National Environmental Science Programme

# Terrestrial fauna monitoring in Kakadu National Park

Final report

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Kakadu NATIONAL PARK

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Cover photographs

Front cover: Arnhem Escarpment in Kakadu National Park (photo Kym Brennen).

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# Acronyms and abbreviations

**DEPWS** ......... Department of Environment, Parks and Water Security (Northern Territory)

**EPBC Act**...... Environment Protection and Biodiversity Conservation Act 1999

**NESP**............. National Environmental Science Program

# Acknowledgements

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# Executive summary

Biodiversity monitoring is essential for evaluating and reporting ecological condition, including species trends and threatening processes, and can play a key role in directing management interventions and assessing their success. The effectiveness of a monitoring program in meeting its objectives depends entirely on its design and implementation, as well as the type and quality of data collected. Since 1996, the Northern Territory (NT) Government, in conjunction with Parks Australia and Traditional Owners, has implemented fauna monitoring across Kakadu, Nitmiluk and Litchfield national parks in the NT. Operating in conjunction with long-term flora monitoring, this program was collectively known as the 'Three Parks Fireplot Monitoring Program'. It has provided a large and valuable data set for examining changes in vertebrate species and communities, and for evaluating the roles of important environmental and management drivers.

In 2018 the NT Department of Environment, Parks and Water Security (DEPWS), in conjunction with the Threatened Species Recovery Hub of the National Environmental Science Program (NESP) project 3.2.5, undertook an evaluation of the fauna monitoring and developed an optimised ecological monitoring framework to address several issues: improvements to overall sampling design to meet park management needs; addressing various methodical limitations; incorporation of new methods in order to increase statistical power; and rationalisation of the number of sites to reduce costs. We trialled the implementation of the revised ecological monitoring framework in Kakadu National Park and evaluated its performance against monitoring objectives and management needs. Here we report on the effectiveness of the revised monitoring framework in Kakadu for evaluating condition and trends in fauna, along with key threats and management issues, such as fire regimes, feral cats and feral herbivores.

In 2019, surveys were implemented at 49 monitoring sites identified through consultation between scientists, Traditional Owners and park managers. Using a revised, standardised set of sampling methods, data were collected on 255 mammal, bird and reptile species, along with metrics of habitat structure and ecological condition. Various elements of the revised design increased detectability of numerous species, enhancing the accuracy and reliability of monitoring data. Assessment of how readily species were detected and the number of sites where they occurred revealed a substantial increase in the number of vertebrate species that can be monitored effectively with the revised program design. This group included 40% of threatened terrestrial mammals, birds and reptiles, and most feral mammal species including feral cats. Another group of species was identified that can be monitored effectively either by increasing the current number of sampling sites or implementing targeted sampling of key habitats. A further group of species are inherently more challenging to monitor with generalised plot-based sampling methods because they are rare, patchily distributed, cryptic and/or nomadic, and/or habitat specialists. Effective monitoring of these species will require carefully tailored, targeted sampling methods. The results of the revised monitoring trial also provide insights into the development of targeted methods for some species.

The trial provides a valuable update on where threatened species and feral animals occur, as well as spatial patterns of faunal diversity and an evaluation of long-term trends in some vertebrate groups. For example, analysis of long-term trends reveals that the mammal community has not recovered from the marked declines of recent decades yet are persisting in some parts of the park where fire conditions are more favourable.

The revised Top End Parks Ecological Monitoring Program builds on a history of monitoring in Kakadu, which has played a crucial role in informing and directing management interventions and tracking progress. The revised approach, in combination with more frequent monitoring (3-year to 4-year sampling instead of 5-year) will increase the power of the program to detected changes in ecological condition across major biomes within the park.

Integrated ecological monitoring across Kakadu National Park and other NT protected areas provides a valuable source of evidence-based information for park managers to evaluate and report on the health of country, and supports evaluation of the Kakadu National Park Management Plan. This program also plays an important role in improving understanding of environmental drivers of biodiversity change, such as altered fire regimes, feral herbivores, feral cats and weeds, supporting fire and feral animal strategies. The improved power for monitoring a broad cross-section of threatened fauna species also delivers key actions in Kakadu's Threatened Species and Communities Strategy and assists with evaluating progress. These examples demonstrate how well-designed biodiversity monitoring can support adaptive management. Continuation of the program into the long-term is important to gauge the effectiveness of management actions in maintaining biodiversity, and detecting recovery in threatened species and communities, or future declines in other species.

This trial also provided valuable insights into important planning and consultation steps required prior to and during future rollouts of this program in Kakadu. Further progress is needed in several key areas including park-specific refinement of species and geographic priorities for monitoring, improved data accessibility and integration by Kakadu management, and increased direct participation of Kakadu staff and Traditional Owners in the program to build capacity, knowledge and support for the program.

# 1. Introduction

Monitoring and evaluating patterns of change in biodiversity is essential to inform land managers, policy-makers and planners about the condition of biodiversity and ecological responses to management activities and environmental change (Yoccoz et al. 2001, Lindenmayer et al. 2012). Monitoring contributes to evidence-based management, which is essential to justify management decision-making and expenditure, and ultimately to maintain credibility with stakeholders and the wider community. Monitoring also contributes to adaptive management through evaluating where environmental management actions are working effectively and where refinements or improvements to management are required. Well-conceived and well-executed monitoring enables evaluation of and reporting on (i) ecological condition, (ii) species trends, and (iii) current and emerging threatening processes over manageable timeframes. Despite this, fit-for-purpose biodiversity monitoring is rarely implemented as part of protected area management in Australia. Where monitoring is conducted, it is often poorly designed, resourced and implemented (Yoccoz et al. 2001, Nichols and Williams 2006, Lindenmayer et al. 2012), limiting its utility to inform and influence management decisions.

Monitoring intended to detect temporal changes in biodiversity should be designed to maximise the statistical power to detect trends in relevant predetermined ecological metrics (Guillera-Arroita and Lahoz-Monfort 2012, Sewell et al. 2012). Ecological metrics may include species richness, species composition, population density, species distribution and/or various aspects of ecological condition. The most suitable metrics will be those most relevant to management goals that can be measured with good precision consistently, at appropriate geographic scales and within resource constraints. The science of biodiversity monitoring has received considerable attention in recent years, providing the opportunity to refine existing and devise new monitoring programs to better inform protected area management in Australia (e.g. Robinson et al. 2018, Lindenmayer et al. 2020).

## 1.1 Terrestrial monitoring in Northern Territory national parks

Over the past 24 years, the NT Department of Environment, Parks and Water Security (DEPWS), in collaboration with Parks Australia and Traditional Owners, has implemented a terrestrial fauna monitoring program across Kakadu, Nitmiluk and Litchfield national parks. This program was undertaken in conjunction with fire and flora monitoring (Russell-Smith et al. 2009) and is collectively known as the ‘Three Parks Fireplot Monitoring Program’. This program has provided extensive records of wildlife and plant species, along with changes in habitat condition and occurrence of some species over time. In particular, the program was largely responsible for documenting marked declines of native mammals in the region (Woinarski et al. 2010, Ziembicki et al. 2015), leading to significant research and management attention to address these declines across northern Australia (e.g. Lawes et al. 2015, Stobo-Wilson et al. 2020).

However, several aspects of the program’s design, including sampling methods, site locations, and the timing and frequency of surveying, limited its power to detect trends in the status of many faunal species and to evaluate the role of various environmental and management drivers such as fire and invasive species. Furthermore, the monitoring needs and priorities of Kakadu National Park and other protected areas in the region have evolved over time (e.g. Woinarski and Winderlich 2014, Kakadu National Park Management Plan

2016–2026). These limitations and new priorities, along with emergence of new sampling methods, and considerations of long-term financial sustainability, led to the re-evaluation of the purpose of the monitoring program and revision of its design (Einoder et al. 2018a, 2018b).

The overall goal of the revised Top End Parks Ecological Monitoring Program is to evaluate and report long-term changes in terrestrial vertebrate fauna and ecological condition in relation to major environmental drivers across major protected areas and biomes of the Northern Territory. To achieve this in the wet–dry tropics region of the NT, the revised program needed to:

- better detect trends in as many other species as possible, including priority indicator species
- include three more Top End Parks – Judbarra/Gregory, Garig Gunak Barlu and Limmen national parks
- better evaluate ecological responses to fire – a key management driver across all parks with a major influence on biodiversity
- maintain adequate continuity with the Three Parks Fireplot Monitoring Program but be able to incorporate new technologies (e.g. camera traps, song meters, eDNA, etc.)
- be financially feasible
- be adaptable to expansion or extension to other land management areas, including Indigenous Protected Areas.

Key features of the revised Top End Parks Ecological Monitoring Program include incorporation of a comprehensive set of complementary sampling methods with rigorous survey effort at carefully chosen sites to maximise ecological, geographic and management representation. These design aspects enable stronger inference from a core set of monitoring sites about ecological conditions more broadly across the landscape. A balance has been sought between maximising power to detect trends in a large range of species (particularly some threatened species) and adequate spatial representation of major habitats across major parks. This approach is intended to maximise general inference about ecological trends by measuring flux in a representative cross-section of vertebrate species, coupled with site-specific and landscape environmental parameters (Einoder et al. 2018a).

The revised design is predicated to occur on a 3 to 4 year rotational basis to report changes in timeframes that are relevant to managers and decision-makers. Working across six parks broadens the spectrum of environmental and ecological variability, and allows for better contextualisation of local patterns recorded within individual parks across the broader region for improved interpretation of the data. In 2017 and 2018, the revised methods were trialled in Nitmiluk, Judbarra/Gregory and Garig Gunak Barlu national parks. Kakadu is a much larger and more ecologically diverse park and, commensurate with this, a much larger number of monitoring sites have been identified there. Trialling of the revised program in Kakadu was therefore needed in order to identify any outstanding technical and logistical issues and further refine the program if needed.

## 1.2 Objectives

This project aimed to trial the revised terrestrial fauna monitoring design in the largest of the focal parks, Kakadu National Park. Specific objectives were to:

- assess any logistical and technical issues of the revised monitoring framework
- evaluate the effectiveness of the monitoring framework for detecting and reporting trends in a suite of terrestrial vertebrates, including threatened species
- assess the effectiveness of the monitoring framework to evaluate habitat condition and key threatening processes, such as fire, feral herbivores and feral cats
- identify options for further optimisation of the monitoring framework to maximise cost-effectiveness, and meet the park's management and reporting priorities
- inform the design of targeted threatened species monitoring.

Here we report on progress against these aims, lessons learned and next steps. The outcomes of this project will also inform improved ecological monitoring methodology across northern Australia, including other protected areas.

# 2. Methodology

## 2.1 Biological scope

The revised NT Parks Terrestrial Monitoring Framework identified that marked improvements could be gained in effective sampling of a large proportion of terrestrial and arboreal mammals, birds and reptiles with relatively minor modifications and additions to the set of sampling methods previously employed. This approach is expected not only to maintain continuity with historic monitoring data, but also to avoid drastically increased effort and costs, and undermined efficacy. To maximise the number of species that can be effectively monitored, trade-offs were made in the design of the revised monitoring framework in terms of focal species and habitats (Einoder et al. 2018a). Consequently, the following fauna groups were not considered within the scope of this monitoring program because effective methods of sampling are not currently available or they require specific additional methods that were not considered logistically feasible to incorporate in to the current framework:

- **Microbats**. Previous research undertaken in the NT has not yet determined methods for effectively monitoring bat species or assemblages, such that species are detected consistently and with adequate sensitivity to properly evaluate spatial and temporal patterns of occurrence.
- **Frogs**. Some frog species are recorded with some of the methods currently used in plot-based fauna monitoring surveys in the NT; however, they are not detected consistently or with adequate detection probabilities for the data to be informative of trends. Frogs are most active in the wet season, which would require specific additional field sampling. Furthermore, the spatial occurrence of most frog species is most strongly influenced by availability and proximity of reproductive habitats, most of which are aquatic. Therefore, effective monitoring of frogs requires sampling different habitat types from other terrestrial vertebrates, and sampling in the wet season when many areas are inaccessible.
- **Migratory waterbirds and shorebirds**. Constraining the timing of sampling to the dry season is not effective for many waterbirds, many of which are migratory. Monitoring waterbirds effectively requires specific additional field sampling, and their spatial occurrence is strongly associated with wetlands. Established monitoring methods are available for waterbirds and some monitoring is already undertaken in Kakadu as part of annual magpie geese population surveys (Clancy 2020).
- **Semi-aquatic reptiles**. Monitoring of this group requires sampling different habitat types from terrestrial vertebrates (mostly perennial streams and wetlands), requires completely different methods, and in some cases effective monitoring methods are yet to be developed.
- **Invertebrates**. Except for ants, effective monitoring methods are yet to be developed for invertebrate groups. A further limitation is a lack of taxonomic expertise in Australia to identify taxa to taxonomic levels adequate for meaningful ecological monitoring (A. Andersen, Charles Darwin University pers. comm. 5 July 2020). Methods have been developed for ants that have in the past been incorporated into terrestrial fauna surveys in the NT, but this was considered logistically beyond the scope of this trial.

Full floristic surveys of plot-based ecological monitoring sites are preferable for monitoring plant species, but this was beyond the scope of the current study. Dominant plant species and vegetation structural characteristics were sampled, rather than full floristic surveys, as these could be efficiently measured within the methodical and logistical framework of this program, are informative about ecological condition, and are more informative about patterns of fauna species occurrence.

The representation of various habitat types was revisited for the revised monitoring framework. Previous fauna monitoring in Kakadu National Park had included sites in floodplain habitat. Many of these sites have unreliable access and, due to habitat characteristics such as regular inundation, consistent implementation of the suite of proposed methods to sample floodplain fauna is problematic. Therefore, it was decided to discontinue sampling floodplain habitat. Additionally, some previous monitoring sites were positioned in stands of *Callitris* and lancewood. These patches were small and considered part of the broader mosaic of woodland vegetation communities. Since the original monitoring sites were rationalised, seasonal alignment in sampling across habitat types was achieved, and an increased trend detection sensitivity was gained for many species.

## 2.2 Site selection

The revised monitoring program had identified the need for approximately 50 ecological monitoring sites in Kakadu National Park. DEPWS worked with Parks Australia and in consultation with Traditional Owners to identify a set of 50 sites in the park for sampling in 2019. A major criterion of site selection was agreement across all parties. An initial set of sites was proposed by DEPWS to meet a predetermined level of site replication across the major habitat and priority habitat types: lowland woodland, riparian woodland, sandstone woodland, rugged sandstone woodland/heathland, wet rainforest, dry rainforest and *Allosyncarpia* forest (Einoder et al. 2018a, Table 1). Most of the sites were drawn from the 133 existing fire plots with a history of fauna monitoring to maximise continuity with previous long-term monitoring, thereby providing an opportunity to assess long-term trends across a common set of sites. Sites were chosen that maximised geographic spread and, where possible, had long time series of prior monitoring. Sites were allocated across habitat types proportional to their relative geographic extents (Table 1). However, in some cases new sites were required to achieve adequate sampling replication in several habitats with limited extent (Figure 1).

*Table 1. Number of monitoring sites sampled in each major habitat type in Kakadu National Park.*

| Habitat type | No. sites |
|---|---|
| Lowland woodland | 13 |
| Sandstone woodland/heath | 12 |
| Riparian/*Melaleuca* woodland | 9 |
| Wet/spring rainforest | 6 |
| Dry rainforest | 3 |
| *Allosyncarpia* forest (Anbinik) | 7 |

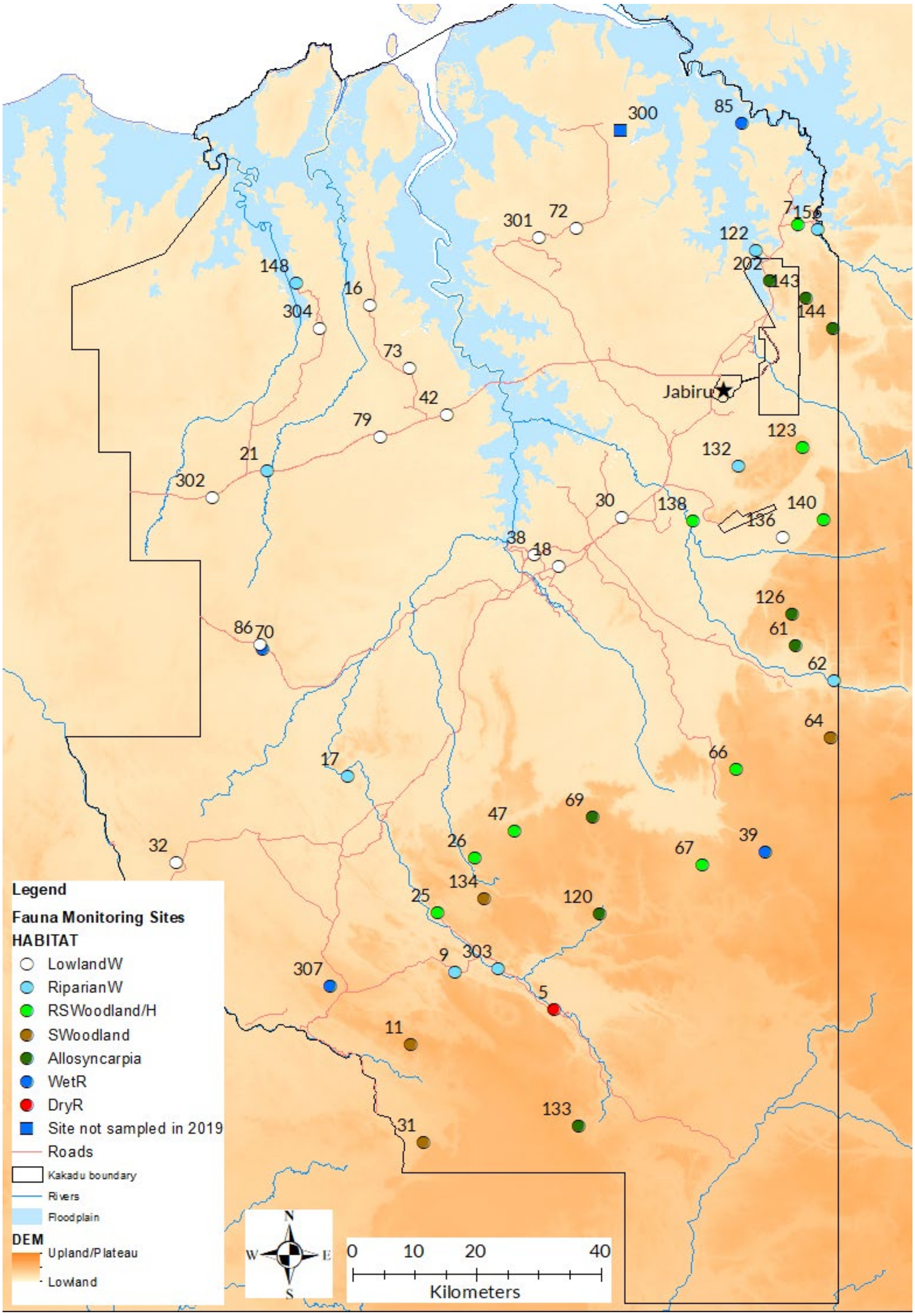


*Figure 1. Kakadu National Park showing the location of 50 ecological monitoring sites denoted by habitat.*

## 2.3 Traditional Owner consultation and engagement

In November 2018, endorsements were granted by the Kakadu Indigenous Research Committee and Kakadu Board of Management for DEPWS to undertake the project. Traditional Owner consultation regarding monitoring site location and access was formally managed by Kakadu National Park. DEPWS liaised closely with relevant Parks Australia staff to address any queries raised during the process of consultation and attaining permits. Traditional Owner approvals and the relevant permits (Permit No. RK934, CKM 027) were granted to access clan estates, camp on Country and conduct monitoring at specific site locations (see below). Gundjeihmi Aboriginal Corporation requested ground clearance work at all sites in the Mirarr estate, so DEPWS contracted a Gundjeihmi Aboriginal Corporation archaeologist and Djurrubu Rangers to undertake this task.

To increase awareness and encourage participation, DEPWS delivered several presentations to a range of Traditional Owners and ranger groups throughout the field season. DEPWS identified dates through the field season and preselected a range of sites most suitable for Traditional Owner participation. Payment for participation was offered, and assistance was provided by the NESP Indigenous Liaison Officer and the Kakadu Cultural Heritage Officer to identify and organise participants.

## 2.4 Sampling methods

A standard operating procedures manual was prepared that describes in detail all the field and data collection methods (Appendix I). In summary, each site was surveyed for terrestrial vertebrates and habitat structure over four day/nights by two people using a range of highly standardised sampling methods (Figure 2). Each site comprised two adjacent 1-ha plots. Plot 1 was positioned on the original sample plot at sites previously surveyed during the Three Parks Fireplot Monitoring Program, and all sampling methods previously employed were replicated in that plot for continuity. The second adjacent plot enabled inclusion of additional sampling effort without compromising consistency and continuity of standardised historic sampling in plot 1. Major refinements to the sampling methods employed previously in the Three Parks Fireplot Monitoring Program included:

- increased sampling time from three to four nights
- increased number of pitfall traps (Figure 2)
- increased number, and consistent use of, funnel traps (Figure 2, Figure 3)
- inclusion of an array of five camera traps with multi-method deployment (Figure 4)
- increased numbers of bird and reptile active searches.

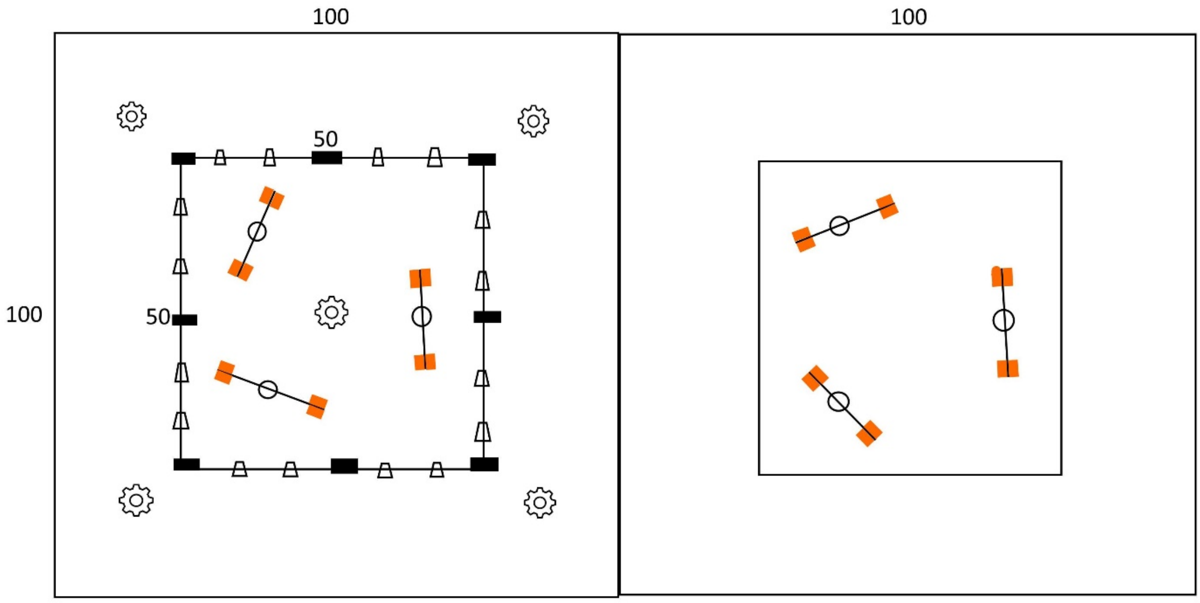


*Figure 2. Sample site configuration, comprising two adjacent 1-ha plots and showing the locations of various trapping devices. Plot 1 contains 24 mammal traps, comprising eight cages (black rectangles) and 16 Elliott traps (open squares) deployed around the edge of 50 x 50 m quadrats, and five camera traps (cog wheels). Each plot contains three pitfall traps with drift fences (circles with lines) and 12 funnel traps (orange rectangles).*

*Figure 3. Six rather than three pit traps with individual drift fences were installed at each site. A pair of funnel traps was deployed at each end of each pitfall trap drift fence.*

*Figure 4. At each site, five camera traps were deployed in several different configurations. Left: camera trap set up with a bait station positioned either 1.5 or 2.5 m in front of the camera, for maximising detection of medium and large mammals. Right: Short focal-length camera set up facing a cork board with a drift fence and bait station, for maximising detection of small mammals and reptiles.*

These refinements and additions to previous methods have been shown to increase detection probabilities of a larger suite of species without markedly increasing costs (Einoder et al. 2018a, 2018b).

Environmental covariates known to be useful indicators of ecological condition, habitat attributes for fauna sensitive to fire regimes, and feral animal disturbance were measured at each site. These included structural habitat measurements and broad floristic data, along with measurements of recent fire history and disturbance (Table 2). A standardised photo point was also established at each site to capture a visual assessment of change through time.

The bulk of field sampling was undertaken between 1 April and 16 July 2019 by up to six teams (two people per team) working concurrently. Teams either travelled by vehicle from a bush-camp to operate two sites concurrently or travelled by helicopter to operate a single site from a remote bush-camp. Camera traps were deployed for a minimum of six weeks and were subsequently recovered between 12 July and 28 August.

*Table 2. Habitat and vegetation structural information recorded at each site (see Appendix I for details).*

| Parameter | Method |
|---|---|
| Perennial grass cover and height | Point intercept |
| Annual grass cover and height | Point intercept |
| Hummock grass cover and height | Point intercept |
| Sedge cover and height | Point intercept |
| Weed cover | Point intercept |
| Shrub cover and height | Point intercept |
| Bare ground | Point intercept |
| Litter cover | Point intercept |
| Exposed rock | Point intercept |
| Logs | Point intercept |
| Surface water | Point intercept |
| Projected foliage cover | Point intercept |
| Mid-storey (shrub) woody stem size and density, and species | Tape measure and plots |
| Canopy (tree) stem size and density, and species | Tape measure and plots |
| Feral herbivore/pig sign | Occurrence in plots |
| Extent of recent fire | Occurrence in plots |

## 2.5 Data analysis

To assess and report on where species currently occur across Kakadu, we combined detection records across all methods for each species then converted them to presence/absence (0, 1) data. To examine spatial patterns of faunal diversity we calculated species richness of mammals, reptiles and birds at monitoring sites then pooled sites by habitat type and calculated means and standard errors.

We examined long-term trends in fauna at a subset of the original Three Parks Fireplot Monitoring Program sites where repeat sampling had occurred since the 1990s. We combined capture data across all methods then calculated species richness of three groups of animals: reptiles, birds, and small to medium-sized native mammals (including 24 species ranging in size from planigales [*Planigale* spp.] to Wilkins' rock-wallaby [*Petrogale wilkinsi]*). To address the increased sampling effort in 2019, only capture data from the original fire plot (plot 1) and the first three nights of sampling were included in comparisons with earlier sampling sessions. Furthermore, reptiles captured in funnel traps from plot 1 in 2019 were removed from analysis, as this trap type was rarely used in earlier sampling sessions.

To examine the value of including new sampling methods and increasing sampling effort in the revised monitoring framework, we compared species detection rates between trap types, paired plots and day of survey. This approach provides a real-time measure of the effectiveness of the revised design to that of the traditional sampling methods.

We evaluated the effectiveness of each sampling method by applying occupancy-detectability models to presence/absence data on species with enough detections for modelling (usually occurrence at >5 sites). Species models generated estimates of probability of occupancy (the proportion of sites sampled that are occupied) and probability of detection (the probability that a species present at a site is detected), which is an estimate of how hard each species is to detect using the methods applied (Mackenzie and Royle 2005). For all species that were captured, we assessed the suitability of the current monitoring framework to detect changes in their populations into the future. The assessment involved consideration of both occupancy and detection probability, as these are the two important factors in power analyses. Generally, species deemed to be monitored with confidence were (i) those that were relatively easy to detect (detection probability >0.8) and occurred at more than 20% of sites (occupancy >0.2), and (ii) species that have declined in the park that are expected to be easily detectable with the methods employed, and may potentially recover in response to appropriate management.

# 3. Results

## 3.1 Species occurrence

We sampled 49 of the 50 sites in Kakadu National Park, falling short of our target due to logistical and time constraints. In total, 255 bird, reptile and mammal species were recorded. Birds were the most speciose fauna group (132 species), followed by reptiles (91 species), and mammals (32 species) (Appendix II, Appendix III, Appendix IV). Across all habitats, the highest bird species richness occurred at sites in riparian woodland, with a mean of 28.8 (± 2.0 standard error) species per site (Figure 5). Bird species richness was also high at sites in wet rainforest, with a mean of 27.7 (± 5.2 standard error) species per site (Figure 5).

Reptile taxon richness was highest in dryer habitats of both lowland and upland areas, and the fewest species were detected in wet habitats (wet rainforest, riparian woodland (i). Large numbers of species were detected in the genera *Ctenotus* (13) and *Varanus* (11) (Appendix IV). The most widespread reptile taxa were two-spined rainbow skink (*Carlia amax*), snake-eyed skinks (*Cryptoblepharus* spp.), and Bynoe's gecko (*Heteronotia binoei*) with each recorded at most sites across most habitats. However most other species (n=55) were rarely encountered, detected at less than five sites (Appendix IV). This included a combination of threatened species (e.g. Mertens' water monitor [*Varanus mertensi*], Mitchell's water monitor [*Varanus mitchelli*], and yellow-snouted gecko [*Lucasium occultum*]), secretive species (e.g. uplands death adder [*Acanthophis rugosus*; Figure 6]), and species restricted in distribution and/or with narrow habitat associations (e.g. Kakadu phasmid gecko [*Strophurus horneri*; Figure 7]). However, rarely encountered species also included numerous habitat generalist species considered to be relatively conspicuous and widespread in the park, such as frilled lizard (*Chlamydosaurus kingii*; Figure 8), northern hooded scaly-foot (*Pygopus steelescotti*), and sand monitor (*Varanus gouldi*).

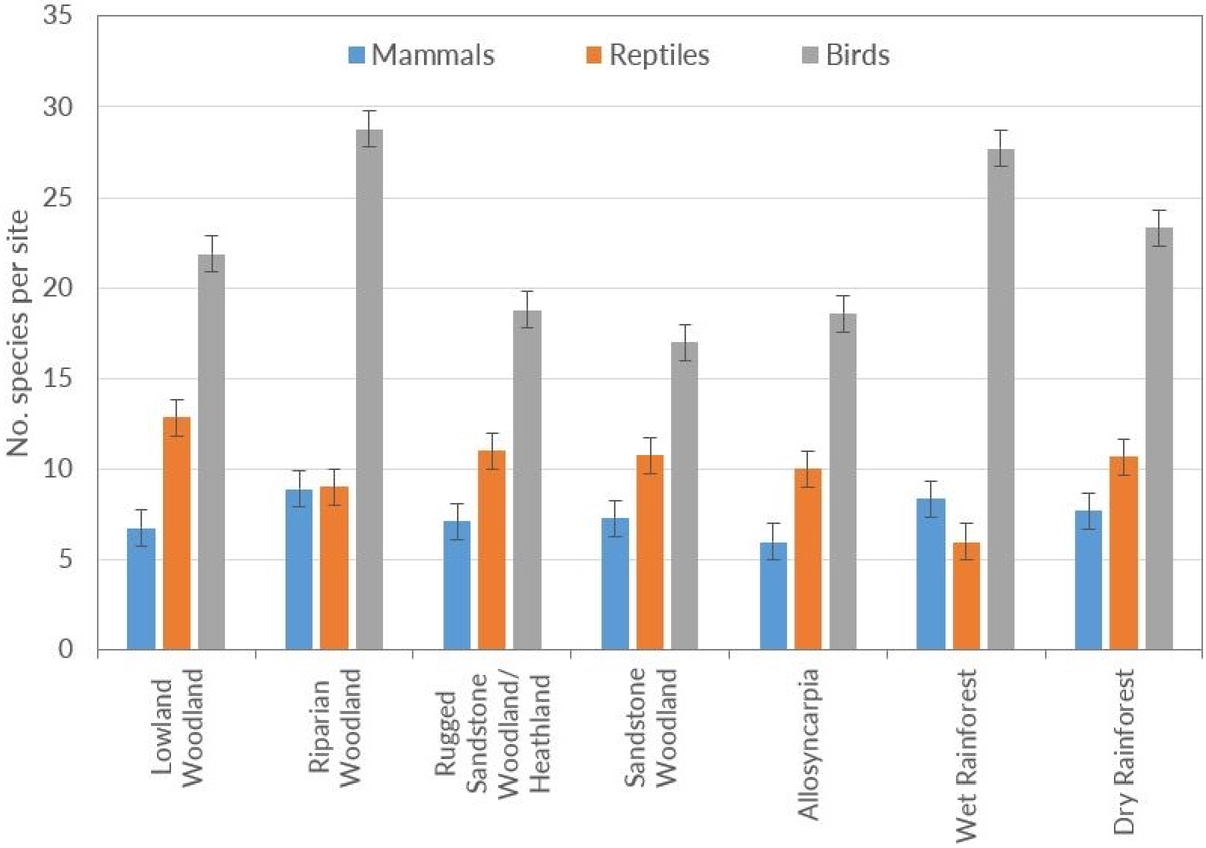


*Figure 5. Spatial patterns of fauna richness across major habitat types of Kakadu National Park in 2019, showing mean (± standard error) number of species recorded per site within the habitats.*

*Figure 6. The uplands death adder suffered a marked population decline with the arrival of cane toads in Kakadu; however, this secretive species persists in low numbers in woodland and sandstone heathland.*

*Figure 7. The Kakadu phasmid gecko is a highly cryptic species restricted to long-unburnt spinifex thickets on sandstone.*

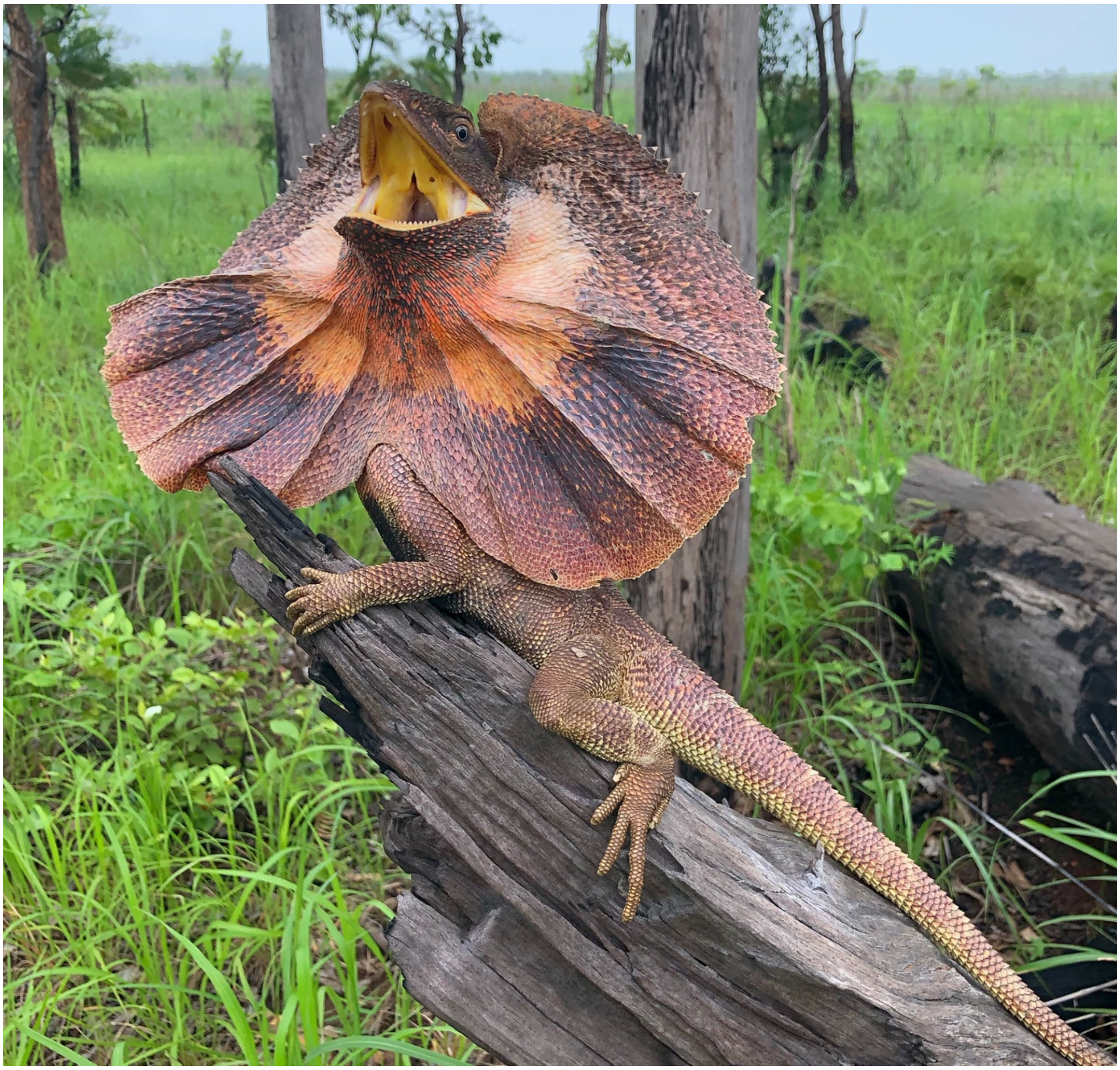

*Figure 8. The frilled lizard may also have suffered population declines with the arrival of cane toads in Kakadu; however, they persist throughout lowland woodland habitats.*

Of 32 mammal species recorded, dingo (*Canis familiaris*) and feral cat (*Felis catus*) were the most widespread, occurring at 30 and 32 sites respectively across all habitat types (Appendix II, Figure 9). Introduced black rats (*Rattus rattus*) were also relatively widespread, occurring at over half the sites and recorded in all habitat types (Figure 10). Agile wallabies (*Notamacropus agilis*) were recorded at 27 sites largely restricted to lowland habitats (Appendix II). Feral pigs (*Sus scrofa*) were the most widespread of the large feral animals, occurring at most of the lowland woodland and riparian woodland sites, and all the wet rainforest sites. Buffalo (*Bubalus bubalis*), donkey (*Equus asinus*), cattle (*Bos taurus*) and horses (*Equus caballus*) primarily occurred in lowland habitats (Appendix II). A suite of native mammals not listed as threatened were recorded at only one or two sites. These rarely detected mammals included delicate mouse (*Pseudomys delicatulus*), Kakadu pebble-mouse (*P. calabyi*), western chestnut mouse (*P. nanus*), red-cheeked dunnart (*Sminthopsis virginiae*), *Planigale* sp., and rock ringtail possum (*Petropseudes dahli*) (Appendix II). Of the 25 native mammal species recorded, richness was highest at sites located in riparian woodland and lowest at sites in lowland woodland, sandstone woodland and *Allosyncarpia* forest (Figure 5).

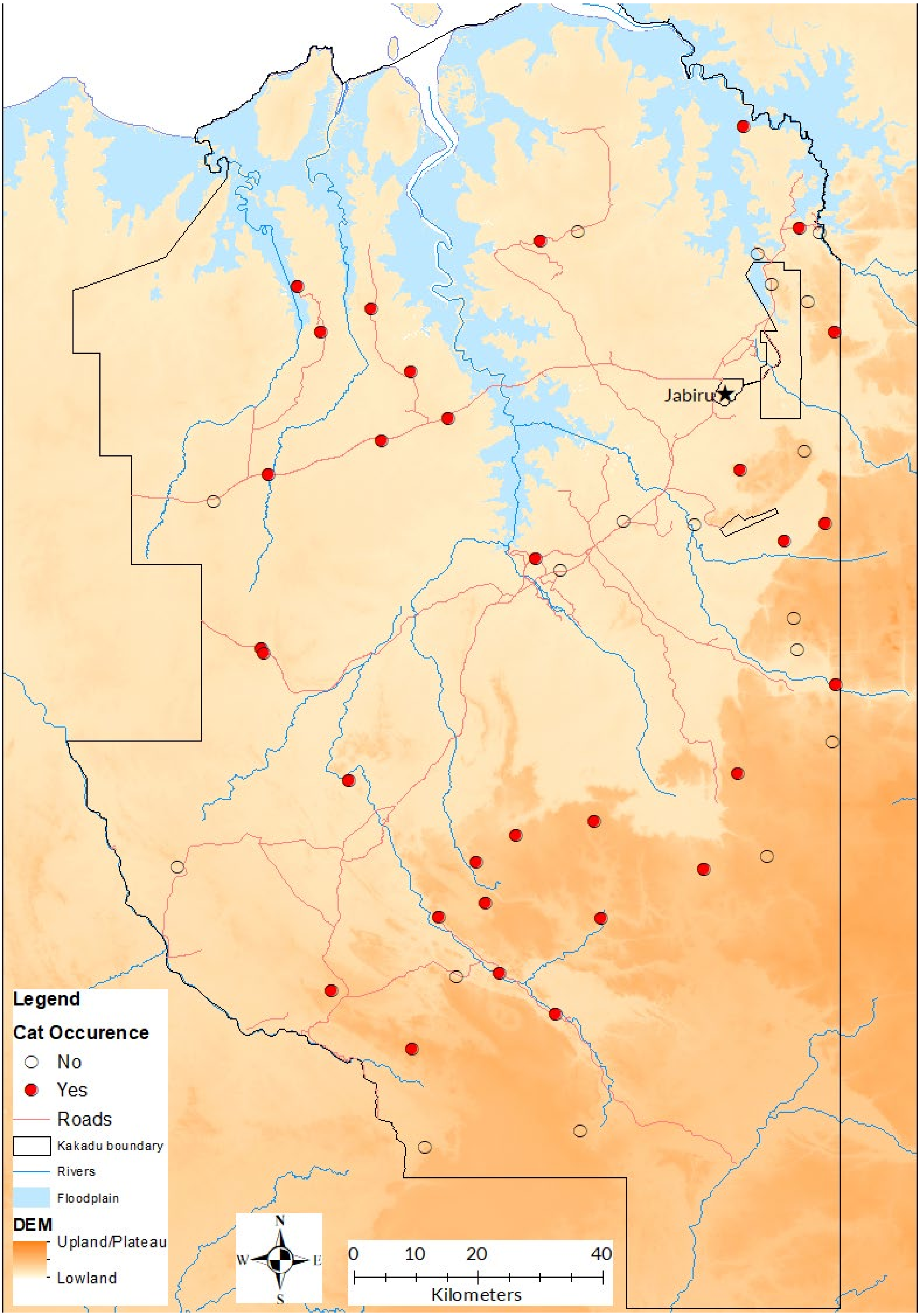


*Figure 9. Monitoring sites where feral cats were recorded in 2019.*

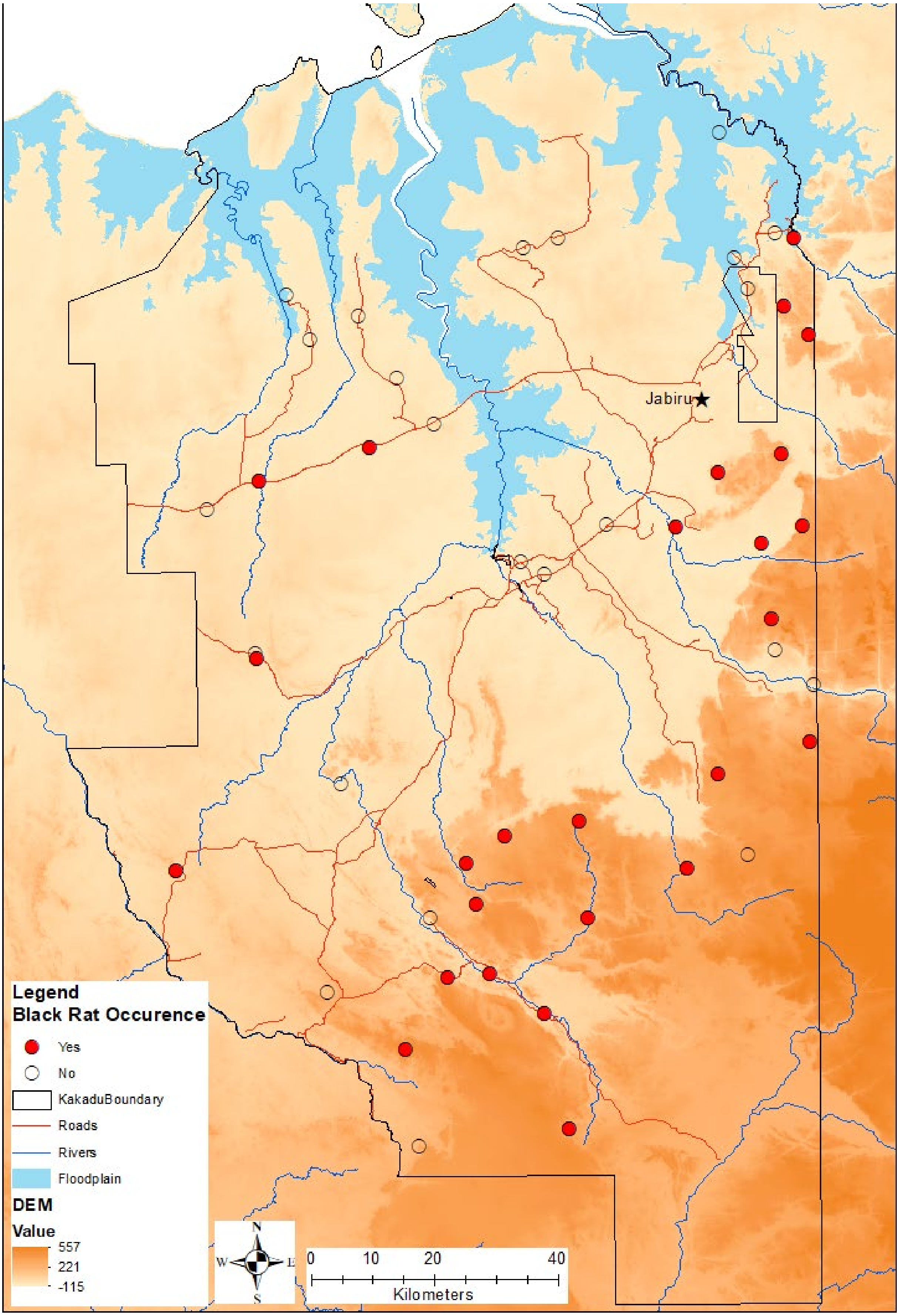


*Figure 10. Monitoring sites where black rats were recorded in 2019.*

## 3.2 Evaluation of long-term trends in fauna

In Kakadu National Park, five rounds of monitoring over a 24-year period have revealed strong trends in some faunal groups. Small to medium-sized mammals have declined markedly in terms of the mean number of species captured per site (Figure 11), with a similar pattern in total abundance. Similar declines have also been recorded across other Top End parks where monitoring has occurred (Nitmiluk and Litchfield). Within Kakadu, mammal declines have largely occurred in lowland woodland, sandstone woodland and dry rainforest habitats (Figure 11). In contrast, mammal richness in riparian woodland, rugged sandstone woodland/heathland, wet rainforest and *Allosyncarpia* has been more stable over time (Figure 11). The most recent round of sampling has revealed that more mammal species persist in moist habitats (riparian woodland, wet rainforest) as well as rugged sandstone woodland and *Allosyncarpia*, compared to other habitats (Figure 11). A more detailed analysis of the patterns of mammal decline in Kakadu, Nitmiluk and Litchfield national parks will be reported elsewhere (Einoder et al. in review).

Also of note was the marked increase in occurrence of introduced black rats across Kakadu. In the initial sessions of monitoring (1996), no black rats were detected. In the following three sessions, black rats were recorded at 1% to 3% of sites sampled. In 2019, black rats were recorded at 14.3% (7/49) of sites using the same sampling methods as previous rounds of monitoring. Furthermore, with the inclusion of camera traps in 2019, this species was recorded at 53% (26/49) sites (Figure 10).

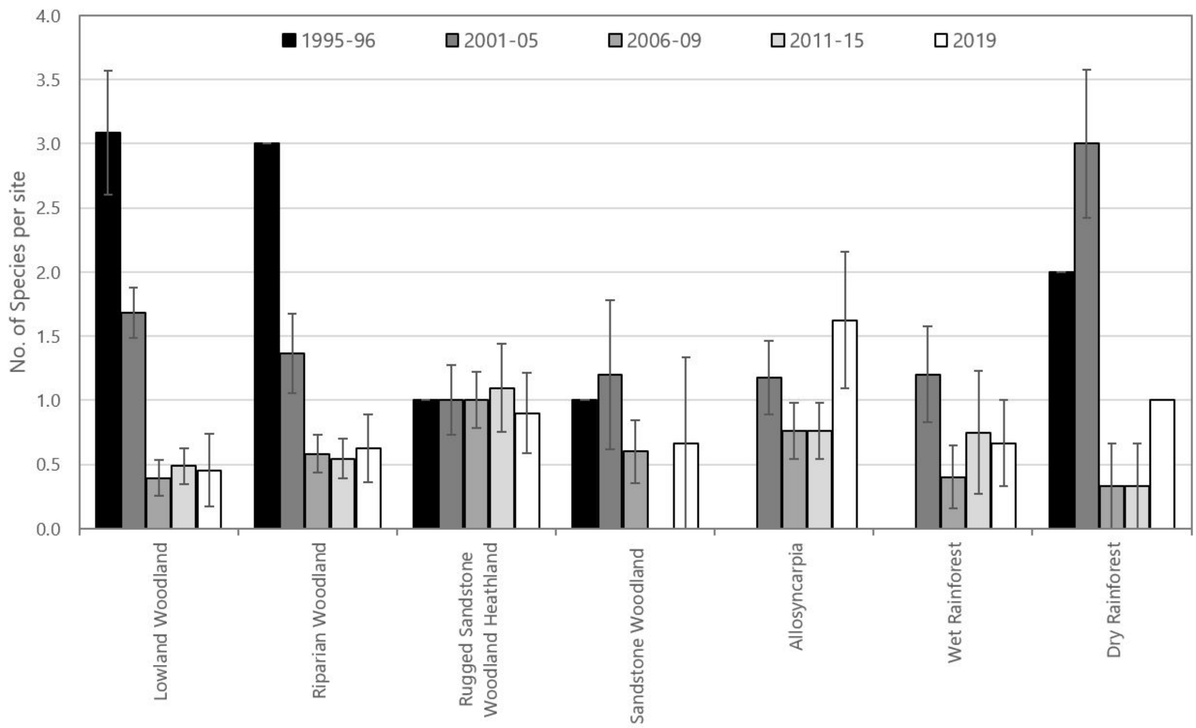


*Figure 11. Long-term trends in mean (± standard error) richness of mammals in major vegetation communities over five sessions of sampling spanning 24 years.*

Trends in mean number of reptile species captured appear to be relatively stable in most habitats, except for sandstone woodland and dry rainforest where species richness has increased over time (Figure 12). In lowland woodland, reptile richness was stable in the first four sessions of sampling then there was a dramatic increase in species captured in 2019. Trends in bird richness were highly variable between habitats, with no clear patterns of change in any one habitat (Figure 13). More detailed analyses of reptile and bird diversity trends will be reported elsewhere (Einoder et al. in review, NT Government unpub. data).

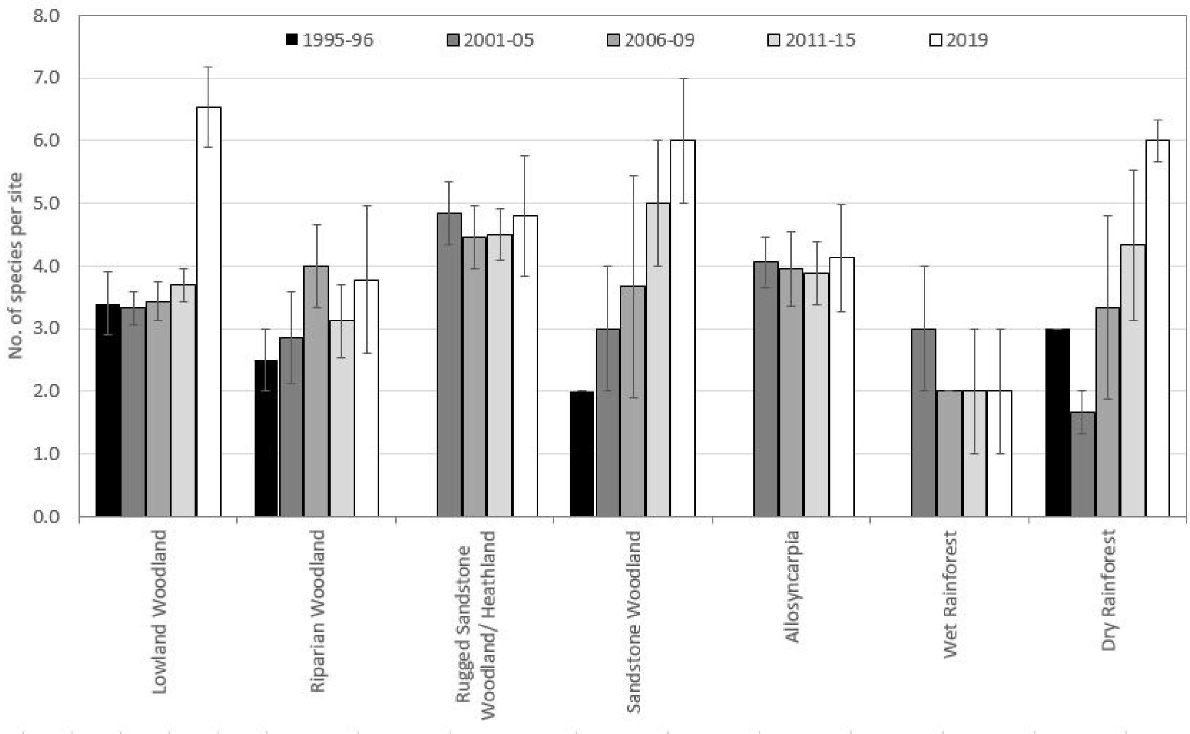


*Figure 12. Long-term trends of reptile species richness in major habitat types based upon data from the subset of trapping methods consistently used across five sampling periods approximately five years apart from 1995 to 2019. Mean (± standard error) species richness at monitoring sites with repeat sampling in Kakadu is shown.*

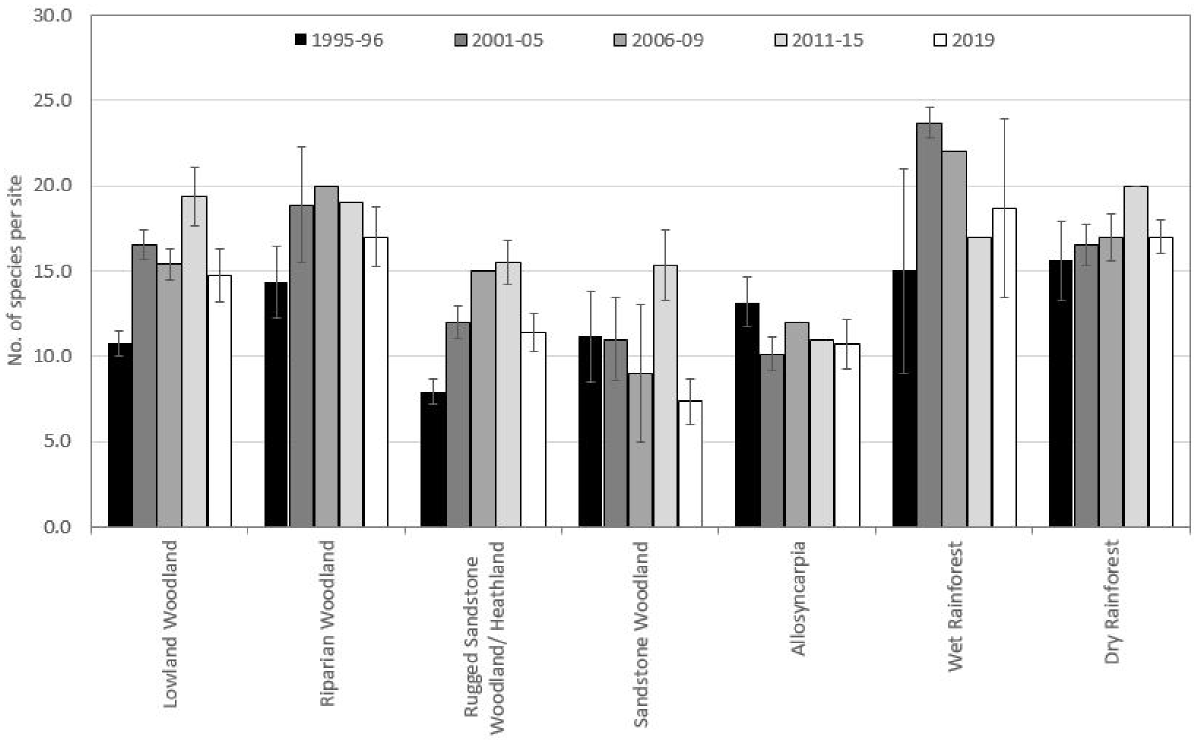


*Figure 13. Long-term trends of birds in major habitat types based upon data from the subset of survey methods consistently used across five sampling periods approximately five years apart from 1995 to 2019. Mean (± standard error) species richness at monitoring sites with repeat sampling in Kakadu is shown.*

## 3.3 Threatened species occurrence and trends

Six threatened mammal species were detected, the most frequent being Arnhem rock-rat (*Zyzomys maini*), which was recorded at nine sites, mainly in rugged sandstone and *Allosyncarpia* (Appendix II, Figure 14, Figure 19). Northern brushtail possum (*Trichosurus vulpecula arnhemensis*), listed as Vulnerable in the Environment Protection and Biodiversity Conservation Act (EPBC Act) since May 2021, was detected at eight sites (Appendix II). The northern quoll (*Dasyurus hallucatus*) was recorded at six sites in lowland and riparian woodland and one site located in a remote area of rugged sandstone (Appendix II, Figure 15). Pale field-rat (*Rattus tunneyi*) was also detected at six sites in various woodland habitats (Appendix II).The black-footed tree-rat (*Mesembriomys gouldii*) was recorded at four sites in lowland and riparian woodland (Figure 16), and at two of these sites, fawn antechinus (*Antechinus bellus*) also occurred (Appendix II, Figure 17).

Live captures of most threatened mammals have declined markedly, with no captures of northern quoll or fawn antechinus in the most recent round of sampling (Figure 18). In contrast, captures of Arnhem rock-rat have increased over time. Detection of these threatened mammals on camera traps at sites where they were not live-trapped reveals that failure to capture this species in conventional traps does not mean that the species is actually absent from the site.

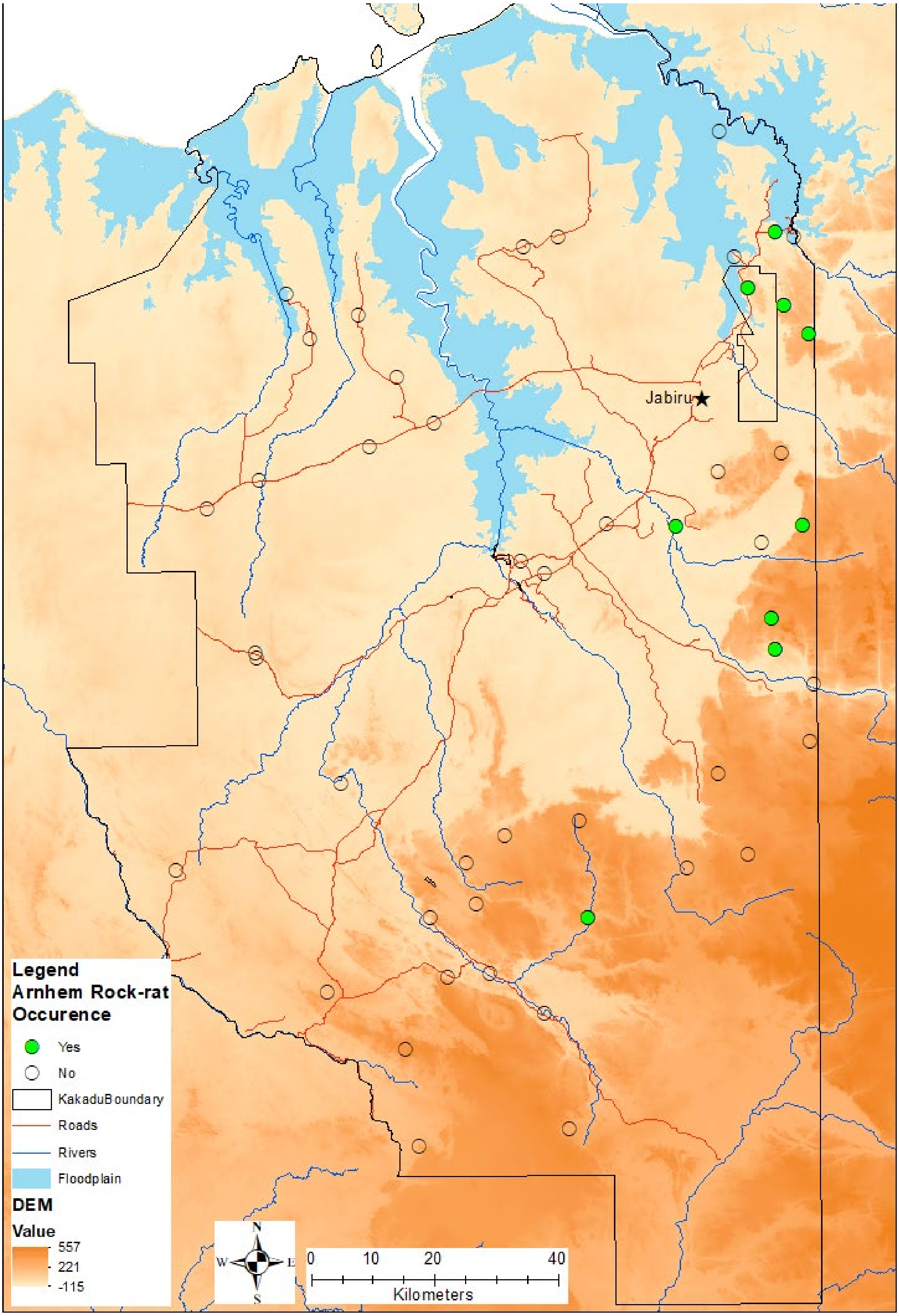


*Figure 14. Monitoring sites where Arnhem rock-rat were recorded in 2019.*

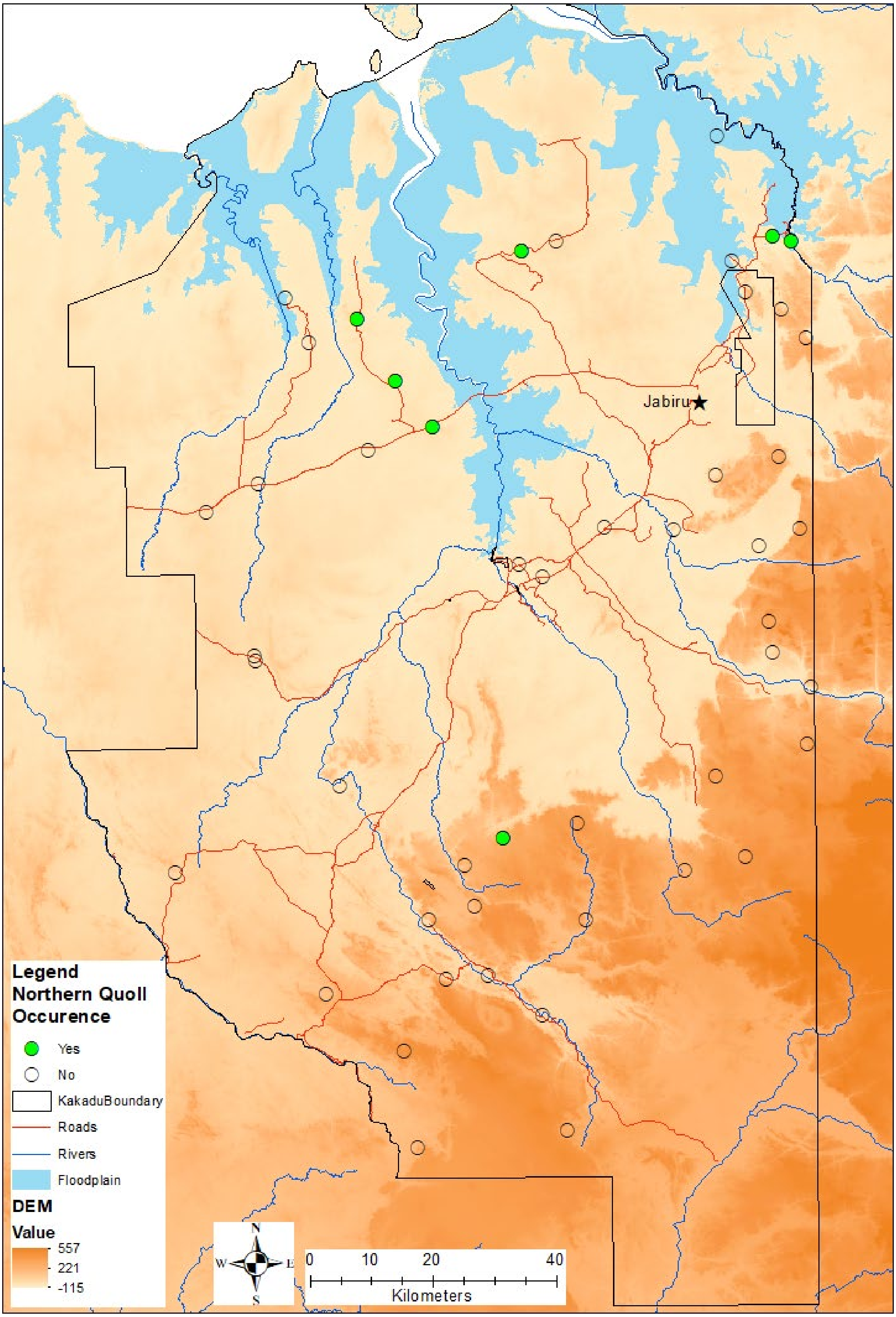


*Figure 15. Monitoring sites where northern quoll were recorded in 2019.*

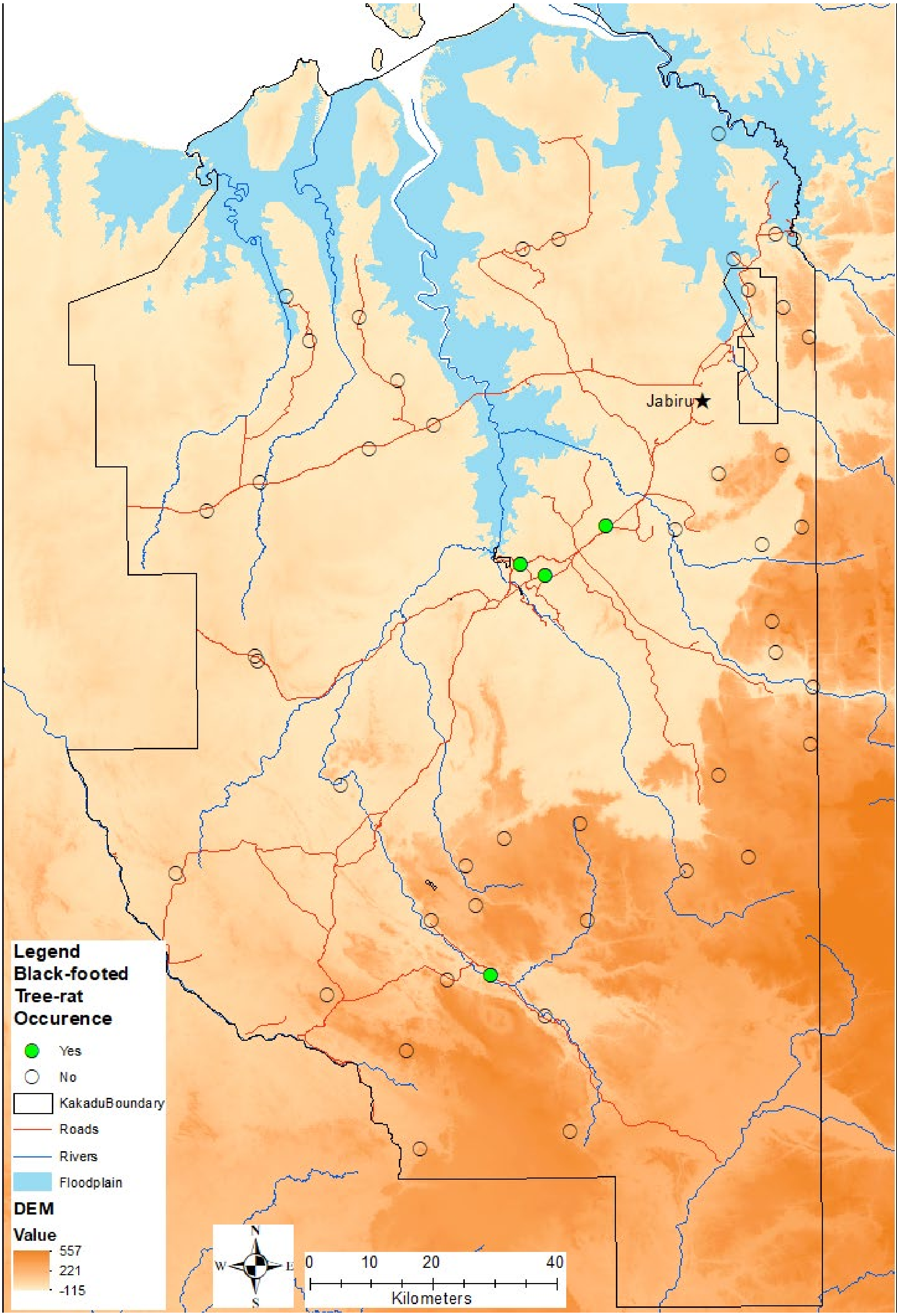


*Figure 16. Monitoring sites where black-footed tree-rat were recorded in 2019.*

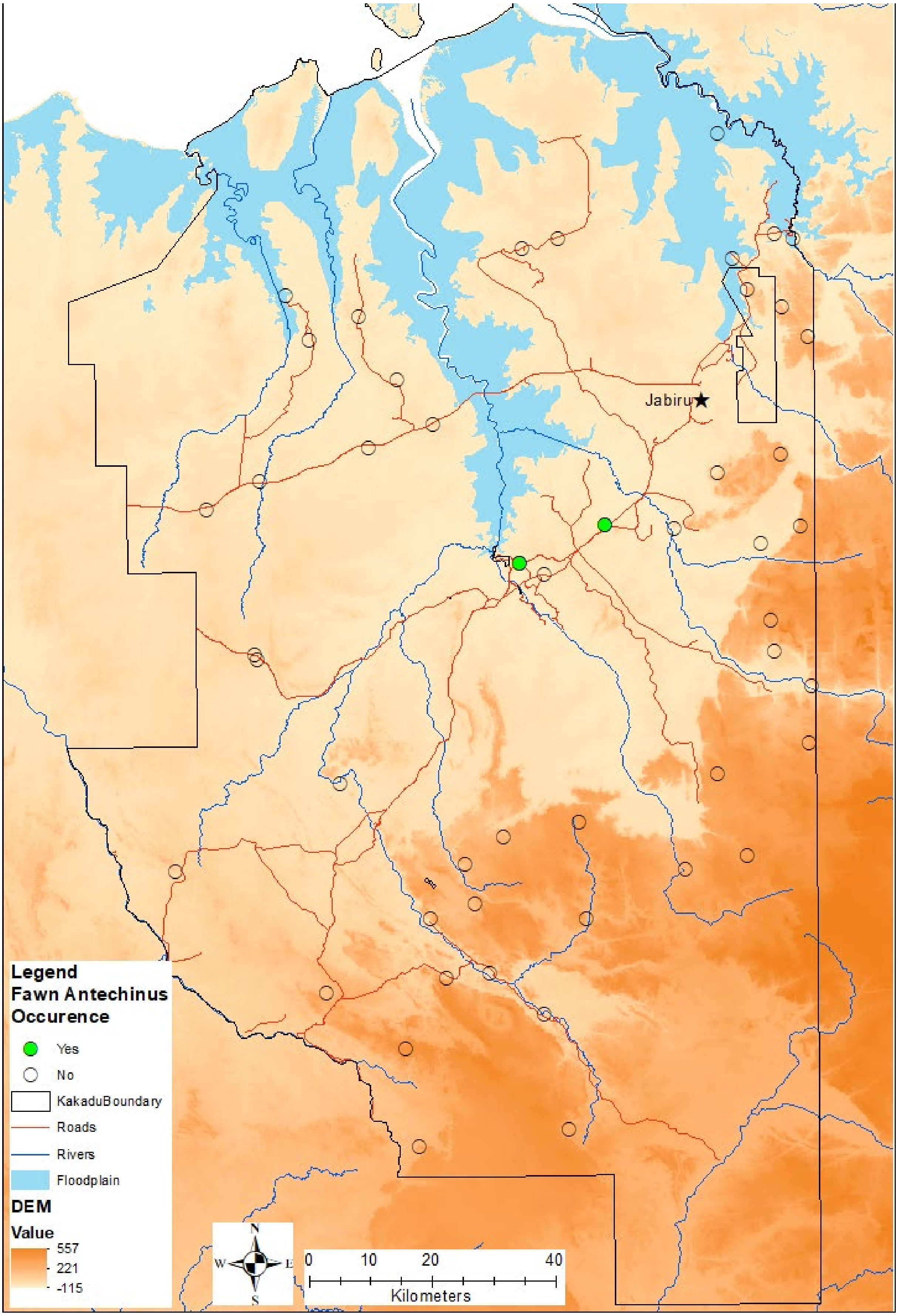


*Figure 17. Monitoring sites where fawn antechinus were recorded in 2019.*

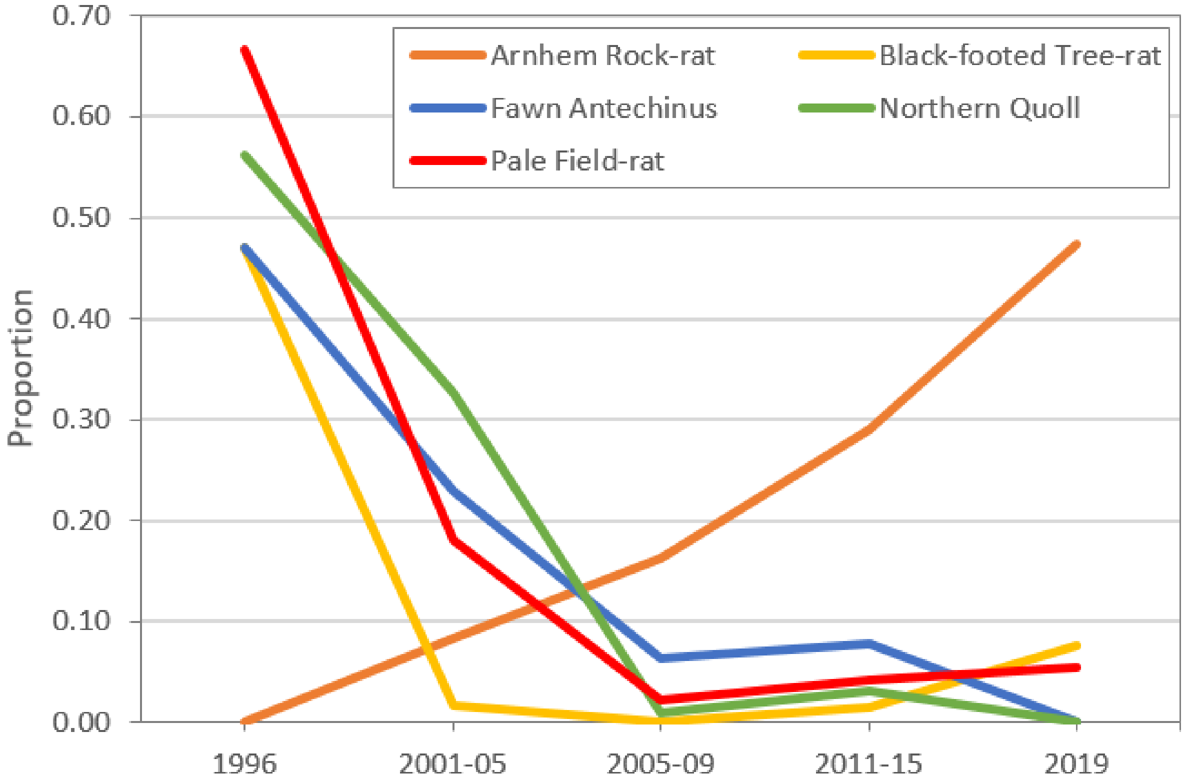


*Figure 18. Trends in some threatened mammals in Kakadu across five sampling periods roughly five years apart from 1996 to 2019, showing the reporting rate across all sites (i.e. naïve occupancy – proportion of sites occupied) within each session of monitoring.*

*Figure 19. The Arnhem rock-rat is the only threatened mammal species with evidence of increasing occurrence in Kakadu National Park.*

Of the three threatened bird species found, white-throated grass-wren (*Amytornis woodwardi*) was detected at one of nine sites located in their preferred habitat (rugged sandstone woodland), and partridge pigeon (*Geophaps smithii*) was detected at two of 14 sites in their preferred habitat (lowland woodland) (Appendix III). White-throated grass-wren were recorded at three sites in 1996 but were not recorded again until this most recent round of monitoring surveys (Table 3). A group of four white-throated grass-wrens was recorded incidentally at one site (i.e. separately from any of the standardised sampling methods) (Figure 20). The reporting rate of partridge pigeon during bird surveys has declined steadily over time (Table 3). All of the partridge pigeon records were from camera traps rather than during any of the bird surveys conducted during the four-day sampling period at sites. Finally, one threatened red goshawk (*Erythrotriorchis radiatus*) was detected at a wet rainforest site.

Four of the five threatened reptile species detected were recorded at two or more sites: yellow-snouted ground gecko (*Lucasium occultum*), Mertens' water, Mitchell's water monitor and yellow-spotted monitor (*Varanus panoptes*; Appendix IV). In addition, an Oenpelli python (*Nyctophilopython oenpelliensis*) was recorded incidentally at one site. The yellow-snouted gecko and Oenpelli python were not detected in any prior rounds of monitoring, despite sites being located within the habitats, and ranges of range and potential habitat (Table 3, Figure 21). The three threatened monitor species have been recorded at low numbers of sites and intermittently over the monitoring period. Due to these low reporting rates, there are no apparent trends over 25 years of monitoring.

*Table 3. Number of sites where threatened bird and reptile species were recorded over 25 years of sampling fire plots in Kakadu National Park.*

| Common name | Scientific name | 1996 | 2001–05 | 2006–09 | 2011–15 | 2019 |
|---|---|---|---|---|---|---|
| Mertens' water monitor | *Varanus mertensi* | 1 | 3 | 5 | 0 | 3 |
| Mitchell's water monitor | *Varanus mitchelli* | 0 | 2 | 2 | 0 | 2 |
| Oenpelli python | *Nyctophilopython oenpelliensis* | 0 | 0 | 0 | 0 | 1 |
| Partridge pigeon | *Geophaps smithii* | 7 | 8 | 2 | 3 | 2 |
| Red goshawk | *Erythrotriorchis radiatus* | 0 | 0 | 0 | 0 | 1 |
| White-throated grass-wren | *Amytornis woodwardi* | 3 | 0 | 0 | 0 | 1 |
| Yellow-snouted ground gecko | *Lucasium occultum* | 0 | 0 | 0 | 0 | 2 |
| Yellow-spotted monitor | *Varanus panoptes* | 0 | 1 | 1 | 0 | 4 |

*Figure 20. The threatened white-throated grass-wren was seen at one site, but not by any of the standardised survey methods.*

*Figure 21. The threatened yellow-snouted gecko has not previously been detected during fauna monitoring in Kakadu National Park.*

## 3.4 Assessment of program performance

The increased sampling effort and expanded set of survey methods employed in the revised ecological monitoring framework resulted in substantial increases in reporting rates and detection probabilities across the three focal vertebrate groups.

### *3.4.1 Mammals*

Changes made to mammal sampling methods comprised doubling the area over which spotlight surveys were undertaken, increasing the number of spotlighting nights from three to four and deploying five camera traps at each site. Of these changes, incorporation of camera trapping had by far the greatest influence on mammal detections, boosting the reporting rate of most species and providing the only detections of seven native species, including two threatened species, the northern quoll and fawn antechinus (Figure 22e). Camera traps generated the majority of records of ground dwelling species and also readily detected several arboreal mammals, including all except one record of the rock ringtail possum, a species rarely recorded in previous monitoring surveys. Almost all detections of dingos and cats (Figure 23) were from camera traps, with very few detections from scat or active searches. Almost all records of other introduced mammal species – buffalo, donkey, cattle and horse – were from camera traps.


*Figure 22. The northern quoll was recorded exclusively on camera traps at seven sites during the trial.*


*Figure 23. The implementation of multi-camera-trap array methods has demonstrated that feral cats are widespread throughout Kakadu National Park.*

### *3.4.2 Birds*

Changes made to bird sampling methods comprised doubling the area surveyed with a corresponding increase in the number of formal bird surveys from nine to 18, spread over four rather than three days. The number of nocturnal searches was also increased from three to four and extended across the larger survey area. These changes increased the average number of bird species detected per site from 13 to 17 (Figure 24). Furthermore, these changes improved the detection probabilities of numerous species.

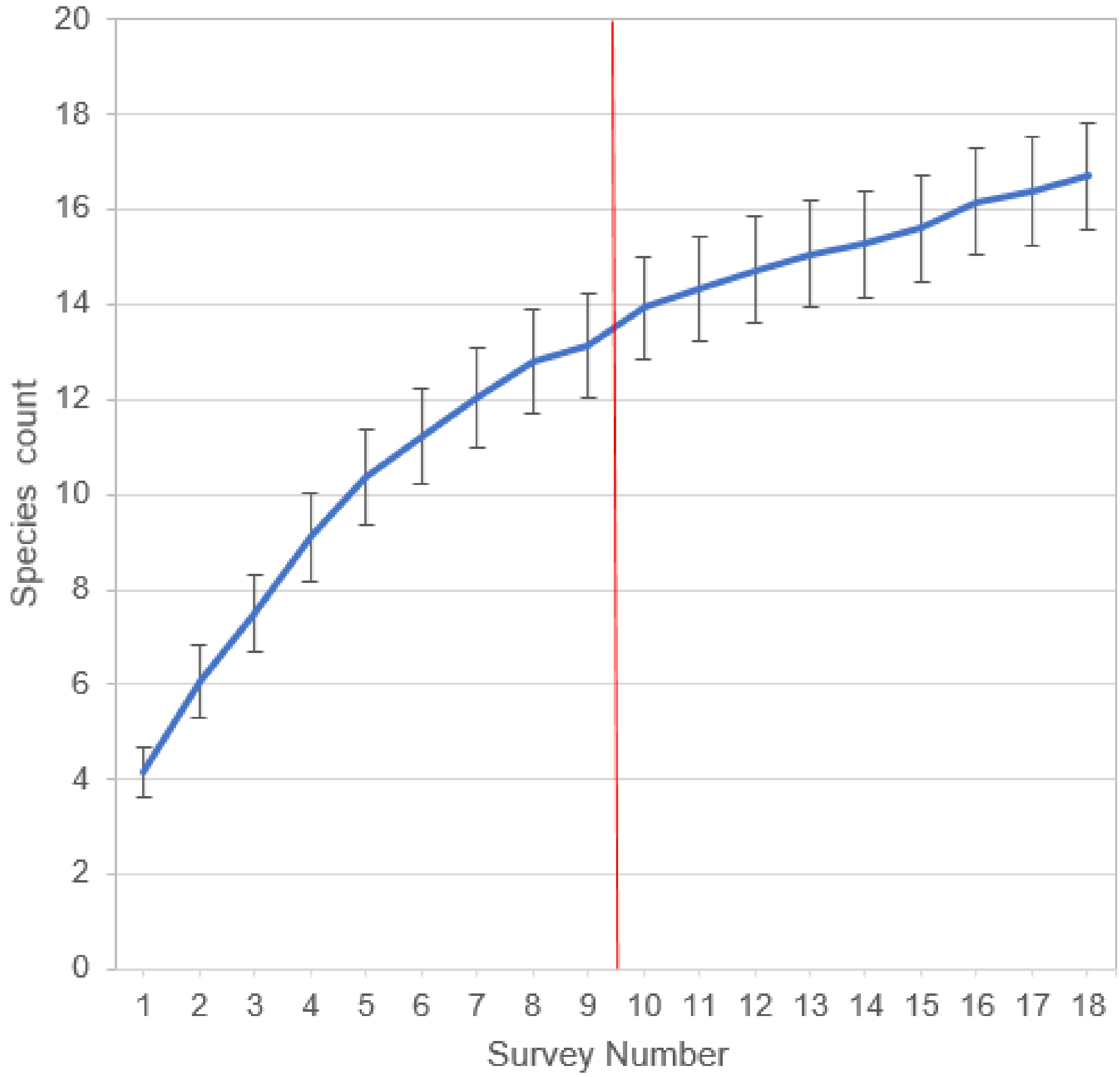


*Figure 24. Accumulation of bird species with repeated bird surveys, showing the mean (± standard error) count of species detected in surveys 1–9 at the 1-ha fire plot, and the contribution of additional species from surveys 10–18 at the adjacent 1ha plot.*

Camera trapping also contributed significantly to detection rates of a suite of bird species (Table 4). Five species were exclusively detected by camera traps, including the vulnerable partridge pigeon *(Geophaps smithii smithii*), detected at two sites (Figure 25). Four species were detected mostly by camera traps. Detection and occupancy rates were also significantly improved over diurnal and nocturnal searches for a further 10 species (Appendix II).


*Figure 25. The vulnerable partridge pigeon was detected exclusively by camera traps.*

*Table 4. Bird species that were either exclusively or mostly detected on camera traps.*

| Common name | Scientific name | Naïve occupancy | Camera trap | Diurnal search | Nocturnal search |
|---|---|---|---|---|---|
| Australian bustard | *Ardeotis australis* | 1 | 1 | | |
| Australian owlet-nightjar | *Aegotheles cristatus* | 11 | 10 | | 3 |
| Bush stone-curlew | *Burhinus grallarius* | 1 | 1 | | |
| Chestnut-backed button-quail | *Turnix castanotus* | 2 | 2 | | |
| Emerald dove | *Chalcophaps indica* | 11 | 10 | | |
| Nankeen night heron | *Nycticorax caledonicus* | 4 | 3 | 1 | |
| Partridge pigeon | *Geophaps smithii smithii* | 2 | 2 | | |
| Pheasant coucal | *Centropus phasianinus* | 11 | 11 | 3 | |
| Rainbow pitta | *Pitta iris* | 9 | 9 | 7 | |

### 3.4.3 Reptiles

Changes made to reptile sampling methods comprised:

- increased the number of pitfall traps from four to six per site
- incorporation of four funnels on each pitfall drift fence line
- doubling the area over which active diurnal and nocturnal surveys were undertaken, and increasing their replication per site
- deploying camera traps at each site
- sampling all habitats early in the dry season, rather than across the late dry season when reptile activity is lower.

These changes collectively contributed to a marked increase in the mean number of reptile species detected per site, and an overall increase in the number of reptile species detected across Kakadu, despite sampling a much small number of sites this round.

Funnel traps were very effective at catching reptiles, accounting for 73% of all live trapped individuals. Funnel traps also boosted the mean number of reptile species captured per site from 3.3 (pitfall traps) to 6.1 (pitfalls and funnel traps), thereby contributing to a higher reporting rate of reptile species across all sites (i.e. naïve occupancy – proportion of sites occupied) (Table 5). Of the 61 reptile species detected by either pit traps or funnels, 18 were only detected in funnels; they were most effective at trapping small to medium-sized snakes and several gecko species, but they also increased detections of a suite of other species caught in pit traps (Figure 26, Table 5).

Camera traps greatly increased detections of larger-bodied snakes, monitors and dragons. Twelve reptile species were detected exclusively by camera traps, including the data-deficient northern blue-tongue lizard (*Tiliqua scincoides intermedia*). The set of sampling methods used previously was relatively ineffective at detecting this suite of species. For example, of the 11 monitor species recorded, five were detected exclusively on camera traps and the majority of records of the other species were also from camera traps. Similarly, of the 25 snake species recorded, seven were detected exclusively on camera traps and the majority of records of the other species were also from camera traps (Table 6).

*Table 5. Reporting rate of reptile species across all sites with pits compared to pits and funnels, showing the value of funnel traps for boosting detection of a suite of reptiles. Grey shading indicates an increase in reporting rate attributable to funnel traps.*

| Common name | Scientific name | Pitfall | Pitfall and funnel |
|---|---|---|---|
| **Lizards** | | | |
| Two-spined rainbow skink | *Carlia amax* | 0.29 | 0.59 |
| Slender rainbow skink | *Carlia gracilis* | 0.1 | 0.24 |
| Striped rainbow-skink | *Carlia munda* | 0.14 | 0.16 |
| Red-sided rainbow skink | *Carlia rufilatus* | 0 | 0.04 |
| Three-spined rainbow skink | *Carlia triacantha* | 0.04 | 0.06 |
| Arnhem Land ctenotus | *Ctenotus arnhemensis* | 0.06 | 0.06 |
| Northern ctenotus | *Ctenotus borealis* | 0.06 | 0.1 |

| Common name | Scientific name | Pitfall | Pitfall and funnel |
|---|---|---|---|
| Cogger's ctenotus | *Ctenotus coggeri* | 0.02 | 0.06 |
| Ten-lined ctenotus | *Ctenotus decaneurus* | 0.02 | 0.02 |
| Port Essington ctenotus | *Ctenotus essingtonii* | 0.24 | 0.31 |
| Kakadu ctenotus | *Ctenotus gagudju* | 0.04 | 0.04 |
| Hill's ctenotus | *Ctenotus hilli* | 0.02 | 0.02 |
| Plain ctenotus | *Ctenotus inornatus* | 0.12 | 0.18 |
| Kurnbudj ctenotus | *Ctenotus kurnbudj* | 0.02 | 0.02 |
| Spalding's ctenotus | *Ctenotus spaldingi* | 0.02 | 0.02 |
| Storr's ctenotus | *Ctenotus storri* | 0.02 | 0.06 |
| Sharp-browed ctenotus | *Ctenotus superciliaris* | 0.04 | 0.14 |
| Scant-striped ctenotus | *Ctenotus vertebralis* | 0.14 | 0.16 |
| Rusty-topped delma | *Delma borea* | 0.02 | 0.06 |
| White-lipped two-lined dragon | *Diporiphora* | 0.02 | 0.02 |
| Two-lined dragon | *Diporiphora bilineata* | 0.31 | 0.37 |
| Northern savannah two-pored dragon | *Diporiphora sobria* | 0.02 | 0.04 |
| Orange-sided bar-lipped skink | *Eremiascincus douglasi* | 0 | 0.02 |
| Northern bar-lipped skink | *Eremiascincus isolepis* | 0.1 | 0.24 |
| Northern dtella | *Gehyra australis* | 0.02 | 0.08 |
| Northern spotted rock dtella | *Gehyra nana* | 0 | 0.06 |
| Arnhem Land spotted dtella | *Gehyra pamela* | 0 | 0.02 |
| Northern mulch-skink | *Glaphyromorphus darwiniensis* | 0.12 | 0.22 |
| Bynoe's gecko | *Heteronotia binoei* | 0.24 | 0.45 |
| Banded prickly gecko | *Heteronotia planiceps* | 0.02 | 0.06 |
| Eastern lerista | *Lerista orientalis* | 0.04 | 0.04 |
| Burton's legless lizard | *Lialis burtonis* | 0.04 | 0.04 |
| Pale-striped ground gecko | *Lucasium immaculatum* | 0 | 0.02 |
| Neat menetia | *Menetia concinna* | 0.06 | 0.06 |
| Grey's menetia | *Menetia greyii* | 0.06 | 0.06 |
| Main's menetia | *Menetia maini* | 0.04 | 0.04 |
| Red-tailed snake-eyed skink | *Morethia ruficauda* | 0.1 | 0.12 |
| Top end firetail skink | *Morethia storri* | 0.14 | 0.18 |
| Northern knob-tailed gecko | *Nephrurus sheai* | 0 | 0.06 |
| Ornate snake-eyed skink | *Notoscincus ornatus* | 0.08 | 0.1 |
| Jewelled velvet gecko | *Oedura gemmata* | 0 | 0.02 |
| Slender Snake-eyed skink | *Proablepharus tenuis* | 0.06 | 0.1 |
| Northern hooded scaly-foot | *Pygopus steelescotti* | 0 | 0.04 |
| Black-spotted ridge-tailed monitor | *Varanus baritji* | 0.02 | 0.04 |
| Kimberley mock monitor | *Varanus glauerti* | 0.02 | 0.02 |
| Northern ridge-tailed monitor | *Varanus primordius* | 0.02 | 0.02 |
| Black-tailed monitor | *Varanus tristis* | 0.02 | 0.06 |
| **Snakes** | | | |
| Uplands death adder | *Acanthophis.rugosus* | 0 | 0.02 |

| Common name | Scientific name | Pitfall | Pitfall and funnel |
|---|---|---|---|
| Northern blind snake | *Anilios diversus* | 0.02 | 0.02 |
| Darwin blind snake | *Anilios tovelli* | 0.02 | 0.02 |
| Northern shovel-nosed snake | *Brachyurophis roperi* | 0 | 0.12 |
| Northern small-eyed snake | *Cryptophis pallidiceps* | 0 | 0.06 |
| Olive whip snake | *Demansia olivacea* | 0 | 0.02 |
| Papuan whip snake | *Demansia papuensis* | 0 | 0.06 |
| Black whip snake | *Demansia vestigiata* | 0 | 0.02 |
| Moon snake | *Furina ornata* | 0.02 | 0.12 |
| Slaty-grey snake | *Stegonotus cucullatus* | 0 | 0.04 |
| Little spotted snake | *Suta punctata* | 0 | 0.02 |
| Keelback | *Tropidonophis mairii* | 0 | 0.04 |
| Wide-banded northern bandy bandy | *Vermicella intermedia* | 0.02 | 0.02 |
| Western brown snake | *Pseudonaja nuchalis* | 0 | 0.06 |


*Figure 26. Camera trapping and funnels increased detections of numerous reptile species rarely, or never, encountered during previous monitoring in the Three Parks Fireplot Monitoring Program. Top: Western pygmy mulga snake (Pseudechis weigeli). Bottom left: Mitchell's water monitor. Bottom right: Kimberley rock monitor (Varanus glauerti).*

*Table 6. Number of records of monitor and snake species detected by camera traps compared with other methods.*

| Common name | Scientific name | Naïve occupancy | Camera trapping | Live trapping | Active search |
|---|---|---|---|---|---|
| **Monitor lizards** | | | | | |
| Ridge-tailed monitor | *Varanus acanthurus* | 2 | 2 | | |
| Black-spotted ridge-tailed monitor | *Varanus baritji* | 5 | 3 | 2 | |
| Kimberley rock monitor | *Varanus glauerti* | 3 | 3 | 1 | |
| Long-tailed rock monitor | *Varanus glebopalma* | 8 | | 8 | |
| Sand goanna | *Varanus gouldii* | 1 | 1 | | |
| Mertens' water monitor | *Varanus mertensi* | 3 | 3 | | 1 |
| Mitchell's water monitor | *Varanus mitchelli* | 2 | 2 | | |
| Floodplain monitor | *Varanus panoptes* | 4 | | 4 | |
| Northern ridge-tailed monitor | *Varanus primordius* | 1 | | 1 | |
| Spotted tree monitor | *Varanus scalaris* | 13 | 11 | | 2 |
| Black-tailed monitor | *Varanus tristis* | 10 | 7 | 3 | 1 |
| **Snakes** | | | | | |
| Uplands death adder | *Acanthophis rugosus* | 3 | 1 | 1 | 1 |
| Northern blind snake | *Anilios diversus* | 1 | | 1 | |
| Darwin blind snake | *Anilios tovelli* | 1 | | 1 | |
| Children's python | *Antaresia childreni* | 4 | | | 4 |
| Black-headed python | *Aspidites melanocephalus* | 2 | | | 2 |
| Brown tree snake | *Boiga irregularis* | 2 | | | 2 |
| Northern shovel-nosed snake | *Brachyurophis roperi* | 6 | | 6 | |
| Northern small-eyed snake | *Cryptophis pallidiceps* | 5 | | 3 | 2 |
| Olive whip snake | *Demansia olivacea* | 1 | | 1 | |
| Papuan whip snake | *Demansia papuensis* | 8 | 3 | 3 | 2 |
| Sombre ship snake | *Demansia quaesitor* | 1 | 1 | | |
| Black whip snake | *Demansia vestigiata* | 3 | 2 | 1 | |
| Green tree snake | *Dendrelaphis punctulatus* | 3 | 3 | | |
| Moon snake | *Furina ornata* | 7 | | 6 | 2 |
| Water python | *Liasis fuscus* | 1 | 1 | | |
| Olive python | *Liasis olivaceus* | 1 | | | 1 |
| Carpet python | *Morelia spilota* | 1 | | | 1 |
| Oenpelli python | *Nyctophilopython oenpelliensis* | 1 | | | 1 |
| Coastal taipan | *Oxyuranus scutellatus* | 1 | 1 | | |
| Weigel's black snake | *Pseudechis weigeli* | 2 | 2 | | |
| Western brown snake | *Pseudonaja nuchalis* | 4 | | 3 | 1 |
| Slaty-grey snake | *Stegonotus cucullatus* | 5 | | 2 | 1 |
| Little spotted snake | *Suta punctata* | 1 | | 1 | |
| Keelback | *Tropidonophis mairii* | 3 | | 2 | 1 |

| Common name | Scientific name | Naïve occupancy | Camera trapping | Live trapping | Active search |
|---|---|---|---|---|---|
| Wide-banded northern bandy-bandy | *Vermicella intermedia* | 1 | | 1 | |

### 3.4.4 Monitoring effectiveness

Excluding fish and marine species, 536 vertebrate species have been recorded in Kakadu National Park. Of these, 100 species had adequate detection probabilities and occupancy rates to be monitored highly effectively with the revised general ecological monitoring methods trialled (Appendix V). These species comprised:

- highly detectable species that occurred at more than 20% of sites (86 species)
- highly detectable species that have declined and are now rare (occurring at less than 20% of sites; 15 species) but have the potential for future recovery
- highly detectable species that have disappeared from the park but, based on studies elsewhere, are expected to be highly detectable with current methods
- ten threatened species (Table 7).

There were 46 species for which the revised general ecological monitoring methods trialled were adequate; however, more monitoring sites would be required across habitats in which they occur to detect trends with confidence (Appendix VI). This group includes three threatened reptile species occurring in Kakadu (Table 7).

Based upon low detection probabilities and occupancy, the revised general ecological monitoring methods were inadequate for detecting population trends in the remaining species. For 77 of these species, more targeted monitoring designs are required that incorporate additional tailored methods and, in most cases, additional sites in key habitats used by those species (Appendix VII). This group includes five threatened species occurring in Kakadu (Table 7).

For the remaining, including 14 threatened species (Table 7), further refinements of the current suite of methods employed and/or inclusion of additional monitoring sites are unlikely to significantly improve monitoring effectiveness. Improved monitoring effectiveness of these species will require development and application of targeted methods, typically not compatible with plot-based monitoring, and in many cases focusing on particular species' habitat types (Appendix VII).

*Table 7. Relative effectiveness of revised general ecological monitoring design for monitoring threatened terrestrial vertebrate species in Kakadu National Park. Waterbirds and shorebirds not included.*

| | |
|---|---|
| **Species monitored highly effectively** | |
| Arnhem rock-rat | *Zyzomys maini* |
| Black-footed tree-rat | *Mesembriomys gouldii gouldii* |
| Fawn antechinus | *Antechinus bellus* |
| Common brushtail possum | *Trichosurus vulpecula arnhemensis* |
| Kakadu pebble mouse | *Pseudomys calabyi* |
| Northern quoll | *Dasyurus hallucatus* |
| Pale field-rat | *Rattus tunneyi* |
| Partridge pigeon | *Geophaps smithii smithii* |
| **Species that can be monitored effectively with additional sites** | |
| Yellow-snouted ground gecko | *Lucasium occultum* |
| Floodplain monitor | *Varanus panoptes* |
| Northern blue-tongue lizard | *Tiliqua scincoides intermedia* |
| **Species that can be monitored effectively with refinements to existing methods and additional sites** | |
| Northern brush-tailed phascogale | *Phascogale pirata* |
| Crested shrike-tit | *Falcunculus frontatus whitei* |
| Gouldian finch | *Erythrura gouldiae* |
| Masked owl | *Tyto novaehollandiae kimberli* |
| White-throated grass-wren | *Amytornis woodwardi* |
| **Species requiring development and application of targeted specialised methods for effective monitoring** | |
| Nabarlek | *Petrogale concinna canescens* |
| Water mouse | *Xeromys myoides* |
| Ghost bat | *Macroderma gigas* |
| Arnhem leaf-nosed bat | *Hipposideros inornatus* |
| Northern leaf-nose bat | *Hipposideros stenotis* |
| Bare-rumped sheath-tailed bat | *Saccolaimus saccolaimus nudiclunitus* |
| Yellow chat | *Epthianura crocea tunneyi* |
| Arnhemland gorges skink | *Bellatorias obiri* |
| Oenpelli python | *Nyctophilopython oenpelliensis* |
| Mertens' water monitor | *Varanus mertensi* |
| Mitchell's water monitor | *Varanus mitchelli* |
| Plains death adder | *Acanthopsis hawkei* |
| **Species considered highly intractable to monitor effectively** | |
| Red goshawk | *Erythrotriorchis radiatus* |
| Grey falcon | *Falco hypoleucos* |

### 3.4.5 Program costs

The total cost of implementing the trial, including planning and liaison with Kakadu management, fieldwork, data analyses (including camera-trap photo processing) and report preparation is summarised in Table 8. These costs do not include start-up costs. For example, depreciation and replacement costs for major equipment items are presented, rather than full cost of initial purchases. Approximately 250 camera traps were used in this project, each worth about $900, but only the cost of replacement from wear and tear of 20 units is presented.

*Table 8. Summary of full costs of implementing the revised monitoring program design in Kakadu National Park. Actual costs at 2020 prices estimated by the DEPWS are presented, along with units of measure. Salary costs are based upon average NT Government Flora and Fauna Division salaries and associate on-costs of staff with appropriate experience and expertise to implement the project work.*

| Activity | Units | $ @ DEPWS in 2020 |
|---|---|---|
| Fieldwork | 2 FTEs (~8 FTEs for ~3.5 months) | $230,000 |
| Data management | 0.25 FTE | $30,000 |
| Project planning and reporting | 0.25 FTE | $35,000 |
| Personal field expenses and protective equipment | 342 days (field and office) | $37,000 |
| 4WD drive vehicles | 4 vehicles and 14,000 km | $15,000 |
| Helicopter charter | 52 hours of flying | $77,000 |
| Camera trap replacement/depreciation | 20 units | $18,000 |
| Other equipment replacement/depreciation | Various trapping equipment, GPS units, camping equipment etc. | $5,000 |
| **Total cost** | | **$447,000** |

# 4. Discussion

## 4.1 Major biological findings

Below is a summary of the main fauna monitoring findings from the revised monitoring trial.

Overall, small and medium-sized mammals have continued to decline in Kakadu National Park, albeit at a slow rate. However, some species are now absent or have declined to very low levels, reducing the power of the program to elucidate further declines in populations. The inclusion of camera traps will significantly alleviate this constraint in the future. The pattern of decline varies markedly among major habitat types, being most pronounced in woodlands. This pattern suggests that riparian habitats may be important refuge areas for many mammal species, consistent with the findings of other recent studies (Stobo-Wilson et al. 2020). Analyses have also revealed strong relationships between the pattern of mammal declines and availability of long unburnt (5+ years unburnt) vegetation, details of which will be reported separately. These findings have important implications for how fire management is undertaken, not just in Kakadu but more broadly across savanna ecosystems.

In contrast to other small and medium-sized mammals, the occurrence and trap rate of the threatened Arnhem rock-rat increased. The underlying reasons for this are not entirely clear, but this could reflect improvements to fire regimes in sandstone woodland/heath and escarpment rainforest habitats.

Northern quolls were found to persist at more sites than detected in the two previous rounds of monitoring, as a result of inclusion of camera trap arrays in the sampling methods. Quolls have suffered declines due to poisoning from cane toads and the interactive impacts of altered fire regimes and predation (Jolly et al. 2017). Discovery of quolls at an increased number of sites adds further weight to evidence from other studies (e.g. Stokeld et al. in review) that this species is now avoiding toads to some extent, providing the opportunity for future recovery given appropriate fire management.

Several threatened reptile species, including floodplain monitor (*Varanus panoptes*), Mertens' water monitor and Mitchell's water monitor, were almost extirpated from Kakadu and other regions by the arrival of cane toads. These species were all detected, albeit at low rates, demonstrating their persistence in the park.

The threatened partridge pigeon underwent a marked decline in Kakadu over the past 30 years (Woinarski et al. 2004). Camera trapping has been demonstrated to be a highly effective method for surveying this species (Davies et al. 2019), so the few records detected during this round reaffirm the extent of this species' decline in the park with no evidence of recovery.

For the first time, inclusion of camera trap arrays enabled meaningful assessment of the occurrence of feral cats as part of the monitoring. Cats were found to be highly prevalent throughout the park across virtually all habitat types. Cats are a major contributing factor in the decline of mammals in the region but they also have significant predatory impacts on birds, reptiles and frogs. It remains to be seen how the prevalence of cats may change over time and how their impacts on other biota are manifested.

Invasive black rats have continued to increase in prevalence. The inclusion of camera traps suggests that not only was the extent of their occurrence likely to be underestimated previously, but they are now well established across the park. The expansion of black rats in the region has coincided with the decline of native mammals, suggesting that they may be filling a niche vacated by native rodents.

Preliminary analyses of long-term trends in bird and reptile assemblage data suggest that there have not been any marked declines in species richness overall. However further analyses are needed to evaluate patterns of change in guilds or species composition.

## 4.2 Evaluation of program performance

The overall objective of the Top End Parks Ecological Monitoring Program is to evaluate and report long-term changes in terrestrial vertebrate fauna and ecological condition in relation to major environmental drivers across major protected areas and biomes of the Northern Territory.

In order to achieve this objective, the program needs to be able to detect biologically important levels of change over periods of time, which are both useful to managers in the short term and are sustainable in the long term. Detecting change in fauna is notoriously challenging due to a range of factors such as imperfect detection (i.e. failing to detect a species at a site when it is present), inherent population flux, limitations on the number of sites and frequency of monitoring that is affordable, and/or poor placement of sites (Yoccoz et al. 2001; Kellner and Swihart 2014). The location of monitoring sites is important because species are not uniformly distributed across the landscape. Hence, a set of poorly placed sites may not encounter the species or communities of interest at enough sites to confidently report on current conditions. Together these factors influence the power of a monitoring program to detect trends in species (Guillera-Arroita and Lahoz-Monfort 2012).

This program has focused on terrestrial vertebrate fauna (mammals, reptiles and birds) for several reasons.

- Both Indigenous and non-Indigenous people generally place more importance on vertebrates than other biota.
- Most threatened species and many species in decline in Kakadu National Park are vertebrates.
- We know more about the biology and ecological relationships of vertebrates than most other biota.
- Monitoring methods and capability are more advanced for vertebrates than other groups.
- There is a history of prior monitoring to build upon (see Einoder et al. 2018a, 2018b).

The revised monitoring framework attained high detection probabilities for a broad cross-section of mammal, reptile and bird species (Appendix V), with marked improvements compared to the previous design. For example, increase in sampling effort at each site (Appendix I) boosted detection probabilities for a range of reptiles and birds while incorporation of funnel traps boosted detection probabilities for many reptile species, in particular species groups previously poorly represented in the monitoring program. Historic use of funnel traps had been hampered due to high capture rates for rodent species, which chewed their way out, damaging and compromising the traps in the process. Ironically, the marked decline of small mammals has alleviated this problem and improved the utility of these traps. Incorporation of camera trap arrays boosted detection probabilities of nearly all mammal species, many larger-bodied terrestrial reptiles and several elusive bird species. Importantly, the inclusion of camera traps, along with other method refinements to a lesser extent, has extended the effective ecological scope of the monitoring program to include several faunal groups previously poorly sampled, such as feral cats, feral herbivores, macropods, monitor lizards and elapid snakes.

The 536 non-marine and non-fish vertebrates in Kakadu National Park includes 109 waterbird and shorebird, 28 bat, 27 frog and 15 predominantly aquatic reptile species, which are considered out of scope for this monitoring program. Of the remaining 357 terrestrial vertebrate species considered in scope for this trial, 30% can be confidently monitored using the revised monitoring framework. This means that if there is any marked shift in patterns of occurrence of any of these species across Kakadu between sampling periods, then this program should detect it. In addition to a range of 'least concerned' native species, this 'high confidence' group comprises most introduced mammal species, including feral cats, and 40% of threatened species, including several with low occurrence but high detection probabilities (e.g. fawn antechinus, black-footed tree-rat, pale field-rat, partridge pigeon). These threatened species are included in the high confidence group based on the reasoning that the monitoring objective for them is primarily to detect a recovery, rather than further decline from already low occurrence. If there were also a requirement to detect further decline in any of these threatened species, then it would be necessary to complement the current program with additional sites targeting key habitat where populations still occur.

The remaining species fall into several groups:

1. Species for which the suite of plot-based monitoring methods are suitable but more sites are needed in relevant habitat types to boost monitoring power to high confidence. For example, these methods would be highly effective at monitoring yellow-spotted monitors if there were more plots on the edges of flood plains.
2. Species for which plot-based monitoring methods are suitable but further refinement of existing methods or inclusion of additional targeted methods would be required in relevant habitat types to boost monitoring power to high confidence. Additional sites may also be required in relevant habitat types. For example, call playback methods are well established for masked owls and these could be incorporated into nocturnal surveys at an increased number of plots.
3. Species for which development and application of specific targeted methods are required, including emerging technologies such as environmental DNA (eDNA), automated acoustic recorders or infrared camera technology, to boost monitoring power to high confidence. These methods may not be compatible with plot-based approaches. For example, several plot-based methods for surveying microbats are available, but further trials and refinement are needed to optimise them for effectively monitoring bat species or communities. Genetic analysis of scats can be used to survey for nabarlek (*Petrogale concinna canescens*) but this method needs refinement to be an effective monitoring tool. Also, while scat surveys are undertaken within plots, effective monitoring for this species probably needs to occur over a larger spatial scale.
4. Species for which plot-based methods are not suitable and alternative well-established methods may exist. Examples include waterbirds and shorebirds, frogs, and freshwater

turtles. Established methods exist for monitoring these groups involving either specific trapping methods, aerial, boat, vehicle or foot transects at larger spatial scales, in suitable habitat, and at specific times of the year and/or weather conditions.

5. Species for which plot-based methods are unlikely to be suitable and require alternative methods to be developed or refined. Examples include threatened species such as Oenpelli python, plains death adder (*Acanthophis hawkei*), Arnhem gorges skink (*Bellatorias obiri*), and ghost bats (*Macroderma gigas*).
6. Intractable species that cannot be effectively monitored. These species are too sparsely distributed, or have highly dynamic populations with large temporal and/or spatial fluctuations, to reliably sample for them. For example, the red goshawk is very sparsely distributed across northern Australia. Very few individuals (<10) are estimated to occur in Kakadu and they have extensive home ranges. It is therefore not practical to effectively monitor this species at the scale of the park. Other species, such as the chameleon dragon (*Chelosania brunnea*), are extraordinarily cryptic – at this stage the only known way to reliably detect them is to cut down numerous trees to manually search hollows, which is not practical.

It should be kept in mind that it is not necessary, practical or cost-effective to monitor every species within Kakadu National Park, or the wider protected area network, for the following reasons:

- Monitoring a representative proportion of species and other environmental metrics should serve as proxies or indicators for wider biodiversity and ecosystem condition.
- For some taxonomic groups, metrics of assemblage or community composition are potentially more useful than measures of the abundance of individual species within groups.
- Some species are extremely intractable because their populations are too sparse, they operate on much larger spatial scales than the park, individuals may be extremely cryptic, or their population dynamics are too complex with large inherent flux.
- The more difficult a species, assemblage or community is to monitor, the more expensive it is likely to be. Resources will always be finite so trade-offs are necessary between the value of expanding monitoring and other needs and priorities.

This trial has established a representative set of 50 ecological monitoring sites across Kakadu that provide a good representation of the major terrestrial habitat types in line with intended park-level and landscape-level stratification (Einoder et al. 2018a). The selected sites also maintain a high level of continuity with previous long-term monitoring in the park. Although the reduced number of sites results in less spatial coverage and geographic representativeness compared to previous monitoring, this was a necessary trade-off in order to increase species detection probabilities and the sensitivity of the program to detect trends over time. From this set of sites we can assess and report on various metrics of faunal diversity (e.g. species richness, assemblage composition, patterns of individual species occurrence) and key management issues (e.g. invasive species occurrence, habitat structure and condition).

Despite the reduced number of sites, the program was able to effectively evaluate ongoing trends in small and medium-sized mammals across major habitat types in Kakadu, and the influence of altered fire regimes on these patterns. Importantly, in addition to improvements made in sensitivity for trend detection of a suite of native species, after future rounds of monitoring with the revised framework it will also be possible to evaluate these trends for a suite of invasive species, including feral cats which were previously intractable, enabling integrated evaluation of their ongoing ecological influence and their responses to management actions.

## 4.3 Further optimisation

The revised monitoring framework has also been trialled in several other NT parks in recent years (Nitmiluk, Garig Gunak Barlu and Judbarra/Gregory national parks). The set of 50 sites chosen in this trial was considered to be the minimum number needed in Kakadu to achieve the objectives of the Top End Parks Ecological Monitoring Program. In conjunction with national, regional and park-specific objectives and planning needs, the findings provide guidance for further refinement of this program, depending on which species or ecological factors are considered a priority in Kakadu National Park or more broadly. Refinements might include addition of sites in particular habitat types or locations of particular interest. For example, floodplain habitat could be included using these methods, but sampling would need to be later in the year to increase consistent reliability of access.

In conjunction with the findings of other recent studies, the results can be used to further develop targeted monitoring of particular species of concern. These programs may build on the existing set of plots and/or target additional sites but without necessarily incorporating the full set of plot methods. The following are examples of further refinements of targeted threatened species monitoring that would be potentially additive or complimentary to Top End Parks Ecological Monitoring Program.

1. The threatened northern masked owl (*Tyto novaehollandiae kimberli*) and other owl species could be effectively monitored by incorporation of established call playback methods at the existing set of plots without much additional time impost or cost. Additional sites could also be added in selected habitats.
2. The threatened northern quoll and black-footed tree-rat persist in several areas of Kakadu. While the status of these species can be monitored with reasonable confidence using the existing monitoring program, sampling a larger number of sites across focal areas with camera traps alone would provide finer-scale information on areas of persistence, and detect subtle changes in occupancy and abundance.
3. Similarly, the threatened floodplain monitor and Mertens' water monitor persist in lowland woodland and riparian areas of Kakadu. These species (and other monitor species) can also be monitored effectively with camera traps with the addition of more sites in suitable habitat.
4. The white-throated grass-wren is a threatened species rarely recorded at long-term monitoring plots. In addition to locating additional monitoring sites in its preferred habitat – rugged sandstone woodland/heathland – species-specific survey methods are required to boost detectability of the white-throated grass-wren. A more refined timed-area search method has been designed for this species, aimed at increasing search effort in combination with call-playback. In addition, acoustic recorders have shown some potential for detecting the closely related Carpentarian grass-wren (*Amytornis dorotheae*) and may also be effective for the white-throated grass-wren.

5. The yellow-snouted gecko has a highly restricted distribution in the South Alligator region of the park. This species could be monitored with reasonable confidence by sampling a larger number of sites within its range during the wet season when this species is likely to be most active. Sampling methods could be simplified by using just funnel traps with drift fences and nocturnal searches.

Several trials are also currently underway in the NT to develop targeted monitoring methods for several threatened species that are either highly cryptic, mobile, sparsely distributed or otherwise currently challenging to survey or monitor effectively.

1. The NESP Northern Australia Environmental Resources Hub, Charles Darwin University and the NT Flora and Fauna Division have advanced eDNA methods for monitoring occurrence of Gouldian finches (*Erythrura gouldiae*) at watering points. Further work is required to optimise the method in conjunction with active searches.
2. A collaborative project between the NT Flora and Fauna Division and Kakadu National Park will commence trials to evaluate and refine camera trapping methods for surveying and monitoring the Arnhem gorge skink.
3. The NT Flora and Fauna Division has recently successfully developed a method to survey and potentially monitor ghost bat activity away from roost sites, involving call playback and near-infrared video. This approach could be incorporated into plot-based monitoring.

It is possible to conceptualise, subject to resource availability, a more sophisticated biodiversity monitoring program that integrates broad, general plot-based ecological monitoring of a wide range of species and ecological condition metrics (as trialled here) with a combination of other well-designed monitoring activities focused on threatened, other specific species or places of particular interest, or other biological groups not conducive to plot-based approaches. Careful planning should ensure maximum complementation and synergies, whereby common use of sites and methods are maximised where possible. For example, the current program could be modified by:

- including additional sites in certain habitats or places with the same methods to boost monitoring power for a suite of species
- including additional sites in certain habitats or places with a subset of methods to boost monitoring power for selected species
- incorporating additional methods to boost monitoring power for selected species in certain habitat types
- developing stand-alone targeted monitoring methods (and sites) for significant species not conducive to plot-based methods but, where possible, aligning these geographically to maximise logistical synergies (e.g. undertaking white-throated grass-wren monitoring at locations where nabarlek and Arnhem gorge skink surveys can also be undertaken).

## 4.4 Management implications

The Top End Parks Ecological Monitoring Program is a highly valuable assessment and reporting tool that can play an important role in guiding management decisions in Kakadu National Park. A key consideration throughout the redesign process was to develop a program that meets the needs of park managers (Einoder et al. 2018a). Building on previous systematic monitoring in Kakadu National Park (Three Parks Fireplot Monitoring Program), each round of monitoring provides an updated 'snapshot' on long-term changes in fauna, habitat and management issues in the park. The revised monitoring framework includes an increased frequency of monitoring (every 3–4 years, up from 5 years) that will provide more regular updates on conditions within the park, and more closely track progress towards specific targets. Specifically, the revised program will provide data to inform the following Kakadu National Park strategies and management plans.

**Kakadu National Park Management Plan 2016–2026**

Monitoring provides a regular update on trends in faunal diversity that directly align with several performance indicators in the management plan. The current program provides valuable long-term information on spatial and temporal patterns in fauna that can help direct management interventions. For example, emerging patterns of higher residual mammal diversity in more productive parts of the landscape and rugged areas suggest that management interventions directed to these areas will be more effective in supporting persistence or recovery of this group of species. More generally, measuring faunal responses to management can feed back to further refine management.

**Threatened Species and Communities Strategy**

Each round of monitoring provides a consistent set of data that informs conservation status assessments (Territory Parks and Wildlife Conservation Act and federal Environmental Protection and Biodiversity Conservation Act [EPBC]) of a range of threatened species. The Three Parks Fireplot Monitoring Program has been the primary source of information on the trajectories of many threatened species that have been incorporated into species recovery plans and the Kakadu's Threatened Species and Communities Strategy (Woinarski and Winderlich 2014). As demonstrated here, the revised framework enhances monitoring capabilities to detect and report on trends in a suite of threatened species and threatening processes. The Kakadu Threatened Species and Communities Strategy recognises the importance of continuation of the program and of analysis of species and community responses to management intervention as a means of informing and updating habitat-specific management actions. Aspects of this framework can be adopted to develop species-specific threatened-species monitoring to evaluate and report on the effectiveness of management interventions.

**Fire strategy**

Data collected in the early rounds of the Three Parks Fireplot Monitoring Program have been used to assess faunal responses to fire and inform fire management targets within Kakadu. For example, the Threatened Species and Communities Strategy (Woinarski and Winderlich 2014) identifies specific fire management objectives for floodplain, lowland woodland and stone country. It is unclear if and how these objectives are being adopted as draft fire strategies are most often not publicly available. Recent analysis from 25 years of monitoring has provided further valuable insights into fire–faunal relationships and demonstrated what constitutes improved fire-management practices in Kakadu (e.g. long unburnt vegetation supports diverse mammal communities; Einoder et al. in review.). These results highlight the need to revisit and refine fire targets and incorporate new approaches (e.g. establishment of a network of long-unburnt habitat patches) across Kakadu to meet priority actions and conservation objectives outlined in the Kakadu National Park Management Plan 2016–2026 (Australian Government 2016) and Threatened Species and Communities Strategy. Continuation of the program provides a process for reviewing and adjusting fire management informed by monitoring.

**Feral animal strategy**

This program provides valuable information on temporal and spatial patterns of invasive feral cats, black rats and feral herbivores that can be used to inform feral animal management in a number of ways. Occurrence or abundance thresholds of certain feral animals across monitoring sites could be used to trigger management intervention, while fine-scale spatial information can direct control activities strategically within Kakadu National Park. This information is valuable for decision-making as it provides the opportunity to evaluate on-ground management outcomes, both in terms of effectiveness of actions (e.g. reducing feral animals) and ecological outcomes in terms of native vertebrate responses.

**Cost of monitoring**

The costs provided are based upon ‘full cost recovery’; that is, if all salary and operating costs were completely additional to all other park management and operational costs. Some of these costs are often in kind, such as using recurrent salaried DEPWS or Parks Australia staff. Sharing the costs between agencies is mutually beneficial because it helps support the implementation of the overall Top End Parks Ecological Monitoring Program. Plots are sampled by a team leader with an assistant and it is not essential that the latter has extensive technical ecological knowledge. In the past, rangers, Traditional Owners, volunteers and students have often filled this assistant role, which has contributed to reducing costs.

Breaking this budget down further, based upon a costing model developed by DEPWS, the actual cost of each monitoring plot accessible by a vehicle is approximately $5,000, whereas the cost of surveying a plot only accessible by helicopter is approximately $8,200. This difference reflects the additional costs of helicopter flights and the efficiencies gained by teams sampling vehicle-based sites in pairs. This provides a basis for estimating the cost of adding additional sites to the monitoring. Obviously other, more targeted monitoring approaches will have different costs, but the experiences gained from costing these large surveys will help in estimating those costs as well.

## 4.5 Lessons learned

There were several aspects of the 2019 fauna monitoring in Kakadu National Park that could be improved. Key lessons learned centre around the following areas.

1. **Planning, communication and consultation.** Greater lead-in time was needed to enable adequate consultation with Traditional Owners and park operations staff. This

approach would have avoided some issues that arose during the season, such as cultural assessments and permissions to access sites, logistical constraints on accessing sites and exploration of alternative sites. Given the preferred timing of the field program (i.e. April onwards), in future this process needs to commence in the previous calendar year.

2. **Traditional Owner participation.** Despite effort by DEPWS, Kakadu, and NESP to involve Traditional Owners in the program, there was limited uptake of this opportunity. Three members of the Mumukala community were involved in four days of monitoring, and Djurrubu Rangers participated in monitoring at sites 122 and 202 (Figure 27). This was far lower than our aspirations at the commencement of the project. It is highly desirable to maximise opportunities for Traditional Owner participation in these kinds of programs and there are a range of benefits likely to flow from this. Feedback from the Kakadu Science and Research Advisory Committee has identified the need for more opportunities for involvement at the start of the program. In addition, project organisers need to build greater flexibility into the works program and timeline to fit in with the availability of participants. Impediments to participation include a lack of familiarity and experience undertaking fauna survey and monitoring activities. More opportunities for *Bininj* to gain experience in and familiarity with undertaking this kind of work could be generated by other ecological and biodiversity project work undertaken by the park. Other options for consideration include establishing a small set of 'demonstration' sites across the park identified by Traditional Owners and operating them as a community activity with a focus on engagement and participation.
3. **Traditional Owner feedback.** Through the field season, some Traditional Owners had growing concerns about several aspects of the program but had limited opportunities to provide feedback to DEPWS scientists managing the project. Prior to and during the field season, DEPWS and Parks Australia need to host several meetings or community events where Traditional Owners can communicate their concerns. Other NESP projects have designed and distributed feedback forms among the Science and Research Advisory Committee and other community groups. This approach provides further opportunity for Traditional Owners to have their voices heard.
4. **Contingency planning.** One unforeseen challenge was associated with the helicopter crash that occurred midway through the field season. Grounding of helicopters for about five weeks resulted in a major delay in fieldwork as plans were modified to redeploy survey teams to vehicle sites. Another challenge was late wet-season rains in early April, flooding creeks and rivers and blocking vehicle access to some sites in the park. These experiences highlighted the need to have more flexibility in the work program and pre-prepared contingency plans in place to modify the works program where necessary. There is a need to broaden the field season by several weeks to provide added flexibility to accommodate weather events, access issues and other delays. It might be prudent to identify several auxiliary sites across each habitat type that meet the needs of the monitoring program and can be sampled as alternatives if, for whatever reason, established sites cannot be accessed.

*Figure 27. Traditional Owner participation in the 2019 Kakadu fauna monitoring program – Gundjeihmi Aboriginal Corporation archaeologists and Djurrubu Rangers conduct ground clearance work at a discontinued site in Kakadu.*

## 4.6 Next steps

Further work is required to improve data accessibility and integration by Kakadu National Park management for a range of specific uses, and for further optimisation to better meet park-specific needs. Specifically, key areas for further work include:

1. **Data accessibility and reporting tools.** There is a need to identify the fauna metrics for extraction from DEPWS databases after each round of monitoring to align directly with relevant performance indicators in the Kakadu Management Plan. This process and a timeline for data delivery need to be formalised. There is potential to develop data visualisation tools in the future that will enable Kakadu staff and planners to view trends and interrogate the data. The development of this type of data management has a wide range of valuable applications but will require careful development.

2. **Data integration with the park planning processes.** Ecological monitoring data and analysis results can be readily used to inform fire planning, feral and weed management, threatened species management, as well as research priorities. Further work is required to identify products to assist Kakadu in their planning, such as feral and weed management. However, key results from recent fire–fauna analyses are already available and can be incorporated into fire planning.
3. **Park-specific optimisation of monitoring.** There is some flexibility in design and implementation of the monitoring program that can be modified on a park-by-park basis to suit the needs of individual parks. As outlined previously, there is a range of criteria that need to be considered and the methodological pathways exist to achieve this. The current program design is interdependent across multiple parks in the Top End of the NT. Therefore, any refinements and changes to the Kakadu component of this program would ideally be done in consultation with DEPWS to ensure mutually beneficial outcomes.
4. **Further data analysis.** Further, more detailed analysis of temporal and spatial patterns in bird and reptile diversity across Kakadu and nearby parks are planned by DEPWS and Kakadu Park staff involved with this program.

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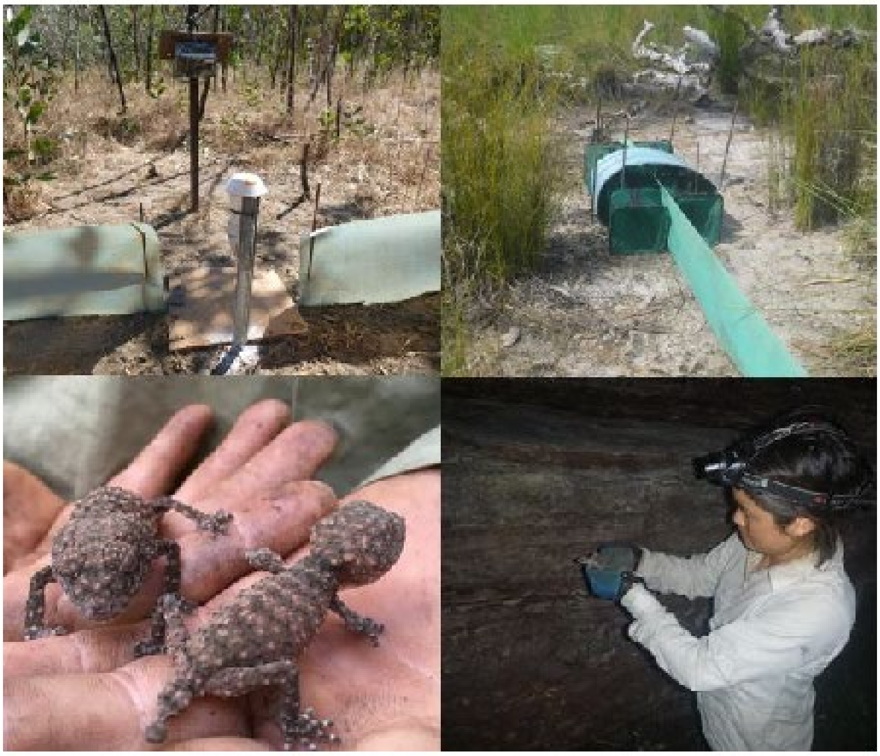
# Appendix I. Methods and operating procedures for the revised monitoring trial

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
FLORA AND FAUNA DIVISION

**Standard Operating Procedure**

**Top End Ecological Monitoring Program Sampling Methods**



www.denr.nt.gov.au

NORTHERN TERRITORY GOVERNMENT

## Contents

Flora and Fauna Division
Department of Environment and Natural Resources
GPO Box 496

PALMERSTON NT 0831



Pre-survey requirements

## Permits

This program operates under the following permits:

All wildlife surveys require a permit to undertake scientific research on wildlife - termed a *'Permit To Take Wildlife For Commercial Purposes'* - issued by the Parks and Wildlife Permits and Concessions Office. The current permit, Number 62773, expires on 31 December 2022.

Animal ethics approval is required to capture animals and collect voucher specimens and is linked to the parks research permit. Approval is through the Charles Darwin University Animal Ethics Committee. Application forms and additional information about animal welfare issues, survey procedures and contingencies for injured wildlife are available on the CDU website. An animal usage report is due at the end of each financial year. The current permit, A17021, expires in November 2021.

Approvals and permits are required to undertake research on Aboriginal land; these should be obtained through the relevant Board of Management and Land Council (e.g. Gregory

Board of Management, Northern Land Council). Note that consultation with relevant traditional owners and collaboration with the local community may need to occur in addition to securing this permit.

A permit is required for each round of monitoring in Kakadu; see http://www.environment.gov.au/node/33433

## Planning

### Communication plans, vehicle booking, movement requisitions, and volunteer registration

All field work under this program requires an approved communication plan that is signed by all participants, including volunteers, as well as vehicle bookings and movement requisitions for all staff. Typically, separate communication plans are required for each field trip into different parks.

The *'Flora and Fauna Communications Plan Template'* is available on the Flora and Fauna WHS sharepoint site under 'Templates and forms'. *http://sharepoint.denr.nt.gov.au/bioconservation*

Examples of past communications plans can be found on TRIM BD2019/0003

Vehicles are booked through the NT Fleet Online Booking System on the intranet site http://finke.nt.gov.au/dcis/NTFLEET_VBS.nsf

For Movement requisitions, use TRIPS – this is available through the 'Online databases' menu on the DENR intranet site.

The *'Volunteer Work Experience Application Form'* is also available on the Flora and Fauna WHS Sharepoint site under 'Templates and forms'.

The Remote Area SOP is available on the Flora and Fauna WHS Sharepoint site under 'Policies and procedures'

### Maps and aerial photography

Aerial imagery (Google Earth), past site photos, topographic maps, and other relevant mapping (e.g. aerial imagery with appropriate layers of roads, vegetation, soils etc.) can be found at: U:\Working\Biodiversity\Survey\Top End Ecological Monitoring Program\mapping, imagery, species list

### Species lists

Lists of species known to occur in each park have been compiled and can be found at: U:\Working\Biodiversity\Survey\Top End Ecological Monitoring Program\mapping, imagery, species list

If you want species lists from particular areas within a park, these can be extracted from the NT Fauna and Flora atlases by using the *Infonet* web interface.

Checklists of NT species are available at: https://denr.nt.gov.au/land-resource-management.

Useful published references and field guides for species identification are listed in Appendix 1.Field guides on mobile devices can also be helpful for species identification (e.g. bird guides, frog guides).

## Survey design

The Top End Ecological Monitoring Program comprises 150 survey sites at fixed locations spread across six parks: Kakadu, Litchfield, Nitmiluk, Cobourg/Garig Gunak Barlu, Gregory/Judburra and Limmen. The survey sites represent the major and/or priority vegetation types within each park, with the stratification by habitat in each park shown in Table 1.

Table 1. Major habitat types across the six parks, showing the desired breakdown of the number of sites to be sampled per habitat per park, and the proposed timing of sampling within each 3 year round of the revised monitoring program.

| Parks | Garig Gunak Barlu | Gregory | Kakadu | Limmen | Litchfield | Nitmiluk | Total |
|---|---|---|---|---|---|---|---|
| Year 1 | 15 | 23 | | | | 12 | 50 |
| Year 2 | | | | 23 | 19 | 8 | 50 |
| Year 3 | | | 50 | | | | 50 |
| Total | 15 | 23 | 50 | 23 | 19 | 20 | 150 |
| Habitats: | | | | | | | |
| Lowland Woodland | 7 | 5 | 13 | 6 | 5 | 3 | 39 |
| Sandstone Woodland/Heath | | 7 | 12 | 6 | 6 | 5 | 36 |
| Riparian/Melaleuca Woodland | 5 | 5 | 9 | 5 | 5 | 3 | 32 |
| Wet/Spring Rainforest | | 3 | 6 | 3 | 3 | 3 | 18 |
| Dry Rainforest | 3 | 3 | 3 | 3 | | 3 | 15 |
| Allosyncarpia Forest | | | 7 | | | 3 | 10 |

Sites will be surveyed every 3 years using the set of standard survey methods described herein

Each site will be surveyed by a minimum of two people over four days and four nights.

It is important that the standard methods be applied consistently, with the same sampling effort across all sites every time they are visited for the data to be useful for assessing long term changes in species numbers and community composition.

Any variations from standard methods should be recorded thoroughly on datasheets so they can be accounted for in future analyses.

# Locating and establishing sites

## Locating sites

For existing Bushfire Centre fire plots, the site's waypoint may either represent the centre of the traditional 50 x 50 m trapping grid, or the centre of the fire plot to which we navigate, and at which we then set up fauna trapping grid as per Figure 1.

For new sites (i.e. not fire plots, no history of sampling), the waypoint provided is a guide to the approximate location of the middle of Plot 1; however, there are various situations where the site may need to be moved (see below).

Beyond 2019, the already-established Top End Ecological Monitoring Sites must be located and resurveyed.

From now on, we are interested in the location of Plot 1 and 2, so in the first round of monitoring each site for the Top End Ecological Monitoring Program a series of waypoints needs to be collected to represent the corners of Plot 1 and Plot 2.

Permanent markers will be installed at the corners of Plot 1 and Plot 2 during their establishment (described below) and a precise waypoint attained with a handheld GPS (see below) to aid in re-locating sites in future.

## Site establishment (2017 – 2021)

Upon arrival, and prior to set-up and survey, it is imperative to walk around the broad area to gain a good picture of the lay of the land. Delaying the start of the survey by several hours, or until the following day, to scope out an area is preferred over the poor placement of sites. A good set-up is higher priority than a complete survey. It is important to carefully consider the location of the site and the orientation of paired plots in the landscape to maximise their long-term value — poorly placed sites may need moving. Important considerations include:

Does the site sample the intended habitat?

Is the site adequately offset from roads, tracks, and other sources of disturbance? Sites should be offset from roads and tracks so than no part of the 200 x 100 m paired site is closer than 100 m to a track or road.

How should Plots 1 and 2 be oriented to best capture the desired habitat, and fit with local landscape features (e.g. cliffs, waterbodies)?

Recent fire (including in the days to weeks prior to arrival) should not influence the location of a site or orientation of plots; this means there is no need to avoid recently-burnt areas when installing permanent plots.

When establishing sites at fire plots at which prior surveys have occurred, it is important to undertake a reconnaissance of the site. When a site is directly adjacent to a road, it should be moved so that it is set back at least 100 m from tracks and roads. Small moves <100 m do not require confirmation with the survey designer. However, if a site needs moving >100 m from the fire plot for any reason, contact must be made with the survey designer. The objective of this is to confirm the move and discuss the best options. Keep in mind that delaying the start of the survey is preferred over the poor placement of sites.

Waypoints provided for new sites with no prior monitoring are commonly derived from aerial imagery, habitat mapping, or previous vegetation surveys, so may not represent the logical best location for a site when you are on the ground. Based on the above considerations, there is scope to move new sites from the initial waypoint. Moderate moves (<500 m) from the waypoint that was provided do not require confirmation with the survey designer. Large moves (>500 m) require contact with the survey designer in order to confirm the move and discuss the best options.

Several scenarios are provided as a guide to making decisions when at establishing sites at existing fire plots or establishing sites at new locations. These scenarios are instances when a site may need to be moved from the waypoint provided, and demonstrate when communication with survey designer is required to confirm an intended move.

Scenario 1: Upon arrival at an existing fire plot, you find it is only 10 m off a vehicle track. A 100 m set back is required from all tracks, even from apparently disused tracks (they may see increased traffic in future). Waypoint the track and then walk through the fire plot and beyond to a distance of 100 m from the track. Mark this as the boundary of Plot 1 (i.e. 100 m away from the track but as close as possible to the fire plot) and, if possible, set Plot 2 on the opposite side of Plot 1 (i.e. even further away from track). Walk around the area to establish the lay of the land and orient the paired plots accordingly so they are within the desired habitat. No call to the survey designer or auxiliary person is required.

Scenario 2: Upon arrival at a new site (no fire plot) in wet rainforest, you find the entire area is under 1-2 feet of water. In this case a scouting trip is required to find a drier location that is still in the appropriate habitat. Use the printed copies of aerial imagery of the site and surrounding vegetation to guide your scouting trip. A walk along a 2 km stretch of the watercourse reveals there is no drier area of wet rainforest in the vicinity. In this situation, a call should be made to the survey designer or auxiliary person to discuss your options.

## GPS accuracy

All waypoints should be determined as precisely as possible by collecting from one to three averaged waypoints for each location using the waypoint averaging function in a handheld GPS. In flat exposed terrain, a single waypoint may be suitable, whereas under a dense canopy in undulating terrain, additional waypoints (up to a total of three) will improve accuracy. The collection of multiple waypoints - using waypoint averaging - should occur at different times of the same day, or on different days for improved accuracy. An error estimate of <6 m showing on the GPS display is desirable. Where this cannot be achieved, note the accuracy against the relevant waypoint on the datasheet.

# Fauna survey methods

## Monitoring records versus incidental and opportunistic records

There are three types of records: monitoring records, incidental records and opportunistic records. The differences are as follows:

Monitoring records include captures during live trapping, and detections of species 'on' site (i.e. within Plot 1 or 2) during formal surveys (active searches, spotlighting, and bird surveys).

Incidental records include detections of any species - including common and widespread species - that are 'on' site (i.e. within Plot 1 or 2) but are outside of formal timed surveys. Only record species as being incidental records if they have not already been recorded in previous monitoring records (i.e. formal timed surveys 'on' site). For those species that were initially recorded as incidental but that are subsequently detected 'on' site during monitoring surveys, delete the incidental record and replace it with an 'On survey' entry on the datasheet. Waypoints are not required for incidental records because they occur 'on' site; however, a waypoint should be taken if it is a species and location of interest (e.g. active Gouldian Finch nest site). Incidental records are to be recorded on the appropriate data sheet (bird survey or active search; Appendix 4, 5).

Opportunistic records include detections of threatened species, rare species, or species of interest (e.g. for which the record may be a range extension) 'off' site, including species observed during travel to and from sites. Avoid recording opportunistic records of common and widespread species. A waypoint should be collected with all opportunistic records, where possible. Opportunistic records should be recorded on the opportunistic datasheet (Appendix 2), not on the live trapping, bird survey, or active search data sheets.

## Sampling sites - paired plot design

The paired plot design involves setting up two 50 x 50 m trapping grids. These are nested centrally within two juxtaposed 100 x 100 m plots (Fig. 1).

If the site is that of an old fire plot, Plot 1 is typically placed to the left of the fire plot, but this is dependent on considerations in *'Locating and establishing sites'* section above. To position Plot 1, stand at the fire plot site marker and/or aerial location disc, and looking through the fire plot, place Point 2 of Plot 1 (refer to Fig. 1) at the left corner marker post of the fire plot, and use the existing post as the corner post (i.e. Point 2).

To capture the desired habitat in instances where a fire plot is in narrow linear habitat (e.g. riparian) or patchy and fragmented habitat (e.g. wet or dry rainforest), Plot 1 may be placed at one end (upstream or downstream) of the fire plot. Plot 2 is then located adjacent to Plot 1, in order to best capture the same habitat as Plot 1. Ideally, at least 50% of each plot should be in the desired habitat.

If the site is new (i.e. no fire plot), then Plot 1 is placed centrally around the waypoint and Plot 2 is placed adjacent to Plot 1, along whichever edge represents (to the greatest extent) the habitat of Plot 1 (dependant on considerations in '*Locating and establishing sites*' section above). In small patches of habitat (e.g. dry rainforest), the site should straddle the patch i.e. part of Plots 1 and 2 should be in the target habitat, with their outer edges extending into non-target habitat (e.g. Fig. 2a). In small patches of habitat or where habitat hugs a cliff or river, it may be necessary to move the 50 x 50 m trapping grid within the 100 x 100 m plot so that the trapping grid abuts one edge of the 100 x 100 m plot (e.g. Fig. 2a and b). Ideally, at least 50 % of each 100 x 100 m plot should be in the desired habitat.

In difficult fragmented habitats, Plots 1 and 2 may be established so they are only conjoined by part of one edge. However, any variations from Figure 1 must be described and drawn in detail for future record.

Any deviation from the standard layout (Fig. 1) will be reflected in the series of waypoints collected, but should also be described briefly on the site datasheet (including reasoning behind any deviation from the standard).

A mud map can be drawn to show the site layout, location of pit traps and camera traps, and any other pertinent information on site accessibility.

At each site, the corners of the 50 x 50 m trapping grids of Plots 1 and 2 should be recorded using GPS waypoint averaging and marked permanently using steel droppers (Fig. 1; see '*Locating and establishing sites*' section above).

The corners of the 100 x 100 m plots should be marked by flagging tape and flagging tape should also be placed at regular intervals along the edge at which the two plots are conjoined (Fig. 1). Note: flagging tape must be removed prior to leaving the site after completing the survey.

In instances of patchy habitat where 50 x 50 m trapping grids of Plot 1 and 2 are positioned to share an edge (i.e. not located centrally within the plot, e.g. Fig. 2), instillation of a single set of corner posts is adequate.

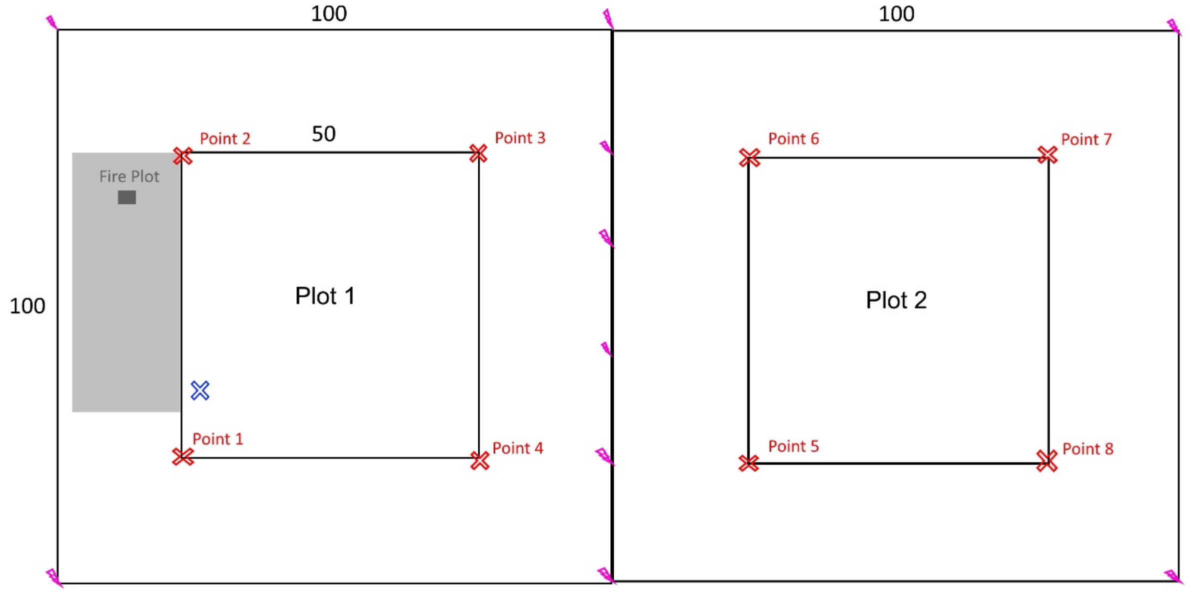



Figure 1. Standard site sampling unit, showing the location of Plot 1 relative to Plot 2, and the preferred location relative to fire plots (grey rectangle). The location of the fire plot site aerial location disc and/or numbered post is shown as a dark-grey rectangle inside the fire plot. Locations of eight permanent markers are denoted by red crosses, and labelled Points 1 – 8. The suggested location of the permanent marker for photo point alignment is denoted by a blue cross. Suggested locations of flagging tape (pink bolt) are also shown.


Figure 2. Examples of modifications to the paired plot design (i.e. modifications to the standard layout that may be required to effectively sample: A) patchy habitat (e.g. dry rainforest patch; patch boundary shown in red); and B) linear habitat (e.g. riparian woodland, with the river channel shown as a blue line). If required the 50 x 50 m trapping grid (inner black box) can be placed in different locations within the 100 x 100 m plot (outer black box).

## Live-trapping

### Layout

The survey area for live trapping is the 50 m x 50 m trapping grid of each plot.

*Plot 1*

Eight cage traps – one at each corner and one half way along each of the four sides (Fig. 3).

Sixteen Elliott traps – set around the perimeter, four on each side and located approximately 8 m (10 - 12 steps) apart (Fig. 3).

Three pit traps – within the 50 x 50 m grid and spaced as far apart from each other as possible, but not overlapping the edges of, or going outside of, the trapping grid. Each pit trap comprises a 20 L plastic bucket (smaller buckets or additional funnel traps [beyond the prescribed 12 funnels per plot] should not be used as a substitute for large pit traps) dug into the ground and 10 m of drift-fence set across it in order to channel small ground-dwelling fauna into the bucket. Pits should be positioned in different microhabitats within the trapping grid e.g. in open ground, in dense grass, close to trees, in rocky areas.

Permanent pits are to be installed at all dry sites; however, they are not to be installed in locations that are prone to lengthy periods of inundation (e.g. some riparian and wet rainforest sites).

Permanent pits are to be marked with a metal dropper.

Permanent pits must have small holes drilled in the bottom to allow water to drain out.

Remove bucket handle during installation.

Each pit trap should be clearly numbered (using flagging tape and by marking its number inside the bucket or on the dropper using a marker pen). All captures are to be recorded by pit trap number.

A waypoint should be taken for each pit trap, ensuring <5 m accuracy, and recorded on the datasheet (Fig. 4).

When three pit traps cannot be installed on the first day, they should be installed the following day and the date of installation noted on the datasheet against the pit trap number.

If it is not possible to set up all pit traps by end of day 3, then record the number of pits that were successfully established.

At the end of a trapping period, permanent pit traps should be filled with large rocks, covered by a lid and the lid then covered by soil. If large rocks are unavailable, fill a canvas bag with soil and place it inside the pits, cover with a lid and then cover the lid with soil.

In some situations, it may not be possible to install some or any pit traps (e.g. due to rocky terrain with very shallow soil) and, in some circumstances, some or all pit traps may flood or not stay in the ground (e.g. in instances of having waterlogged ground with a raised water table). In these instances, omit pits and install drift fences with two sets of paired funnel traps on their own (see below, Fig. 3). A metal dropper should be installed and a waypoint taken in the centre of the drift fence (where a pit trap normally goes).

Twelve funnel traps – should be used in total, with four funnels per drift fence, placed in pairs on either side of the drift fence at each terminal end of the drift fence.

*Plot 2*

This plot has three pit traps and 12 funnel traps that are placed following the procedure for Plot 1 for these trap types (Fig. 3).

Waypoint should be taken for each pit trap, and at each of the four plot corners and recorded on the datasheet (Fig. 4).

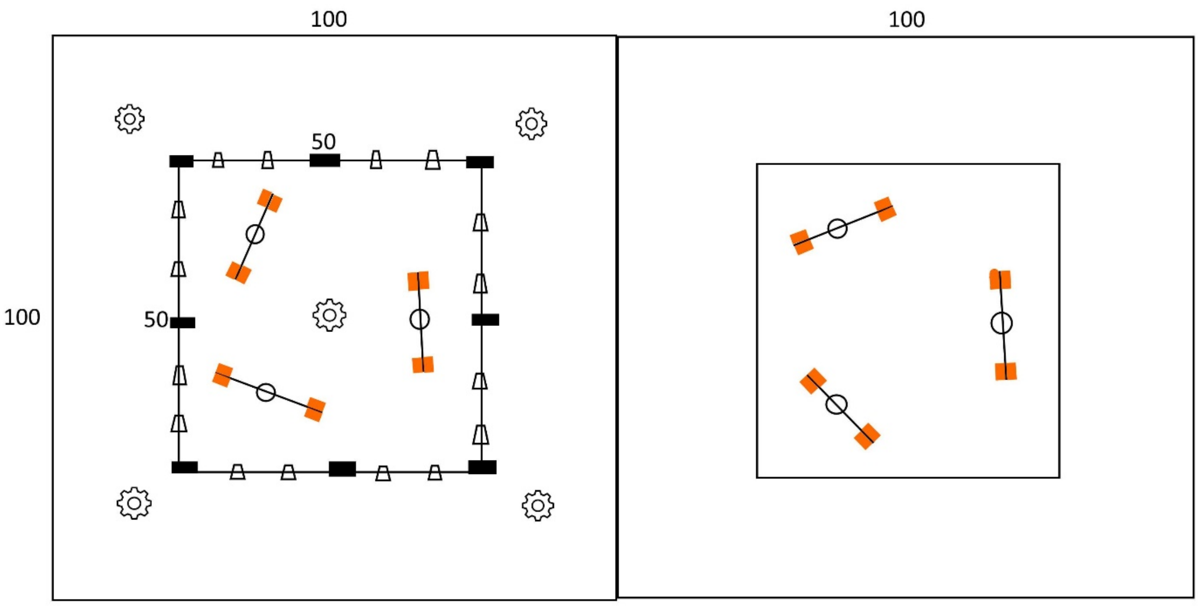



Figure 3. Live trapping configuration at a site showing the required locations for cameras (cog wheel symbols), and suggested locations for pit (circles with lines, which themselves represent 10 m drift fences) and funnel traps (orange rectangles). Plot 1 contains eight cages (at corners and at mid-point of each side), 16 Elliott (along edges between cages), three pit traps, 12 funnel and five camera traps. Plot 2 contains 3 pit and 12 funnel traps.

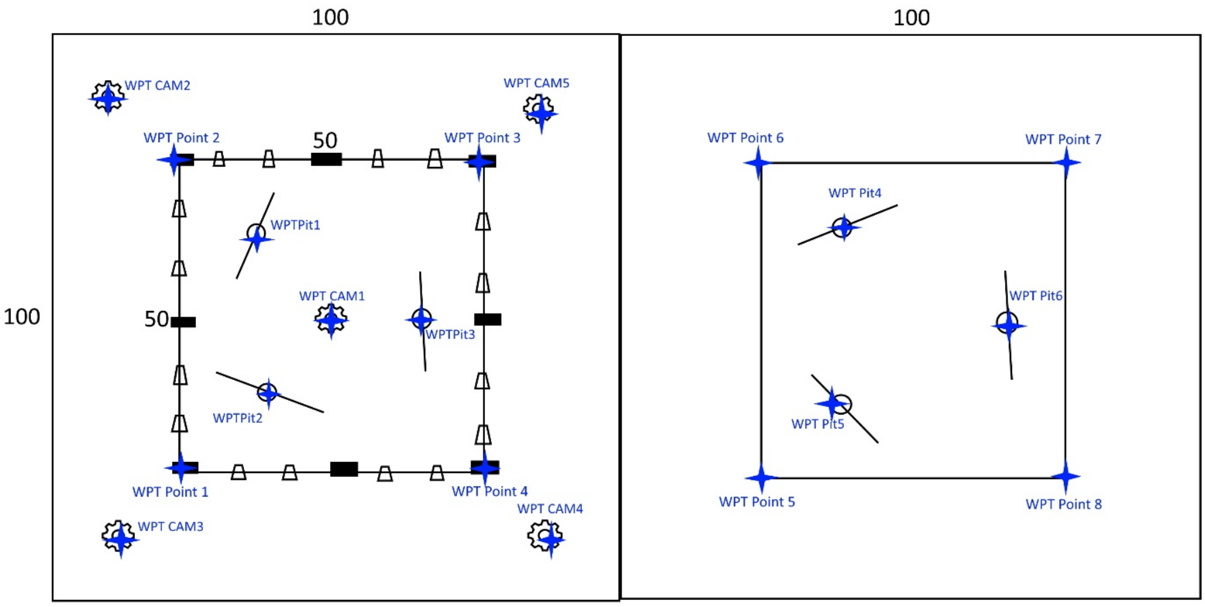



Figure 4: Waypoints (blue star) to be taken at each site of eight plot corner points (permanent steel posts), six pit traps, and five camera traps.

**Placement and installation**

The cage and Elliott traps along the 50 x 50 m trapping grid should be marked with flagging tape that is tied to a tree, shrub, grass, or log. Traps do not need to be directly underneath the flag, but can be positioned within 3 m of it.

Elliott and cage traps should be placed in microhabitats close to the 50 x 50 m perimeter line, where they are more likely to catch small mammals, on visible runways, outside burrows or openings to hollow logs and in situations where there is shelter from the sun. If putting a trap under a dense bush or grass, or anywhere else it is concealed then tie a second flag nearby so it can be easily relocated.

Ensure that Elliott and cage traps are well 'bedded' into the ground, in order to maximise their effectiveness. Prior to setting a trap, level the ground (with your boot) and remove any debris that could cause it to wobble.

When setting pit and funnel traps, align the drift fence to make use of the two vertical slits that have been cut into the rim of buckets. Also ensure that the drift fence is vertical over the pit trap (Fig. 5A and B) and well-buried along its entire length.

Level the soil around the rim of the buckets and create a clear runway along the drift fences and at the entrances to funnels.

Pit traps must contain at least 1 cm of dirt or sand and several large leaves or pieces of bark for shelter, as well as a Chux cloth and polystyrene float (See Fig. 5A for desired number of leaves and decent layer of dirt).

When installing pit traps, prop the bucket lid over the bucket to provide daytime shade. Balance the lid into place using two metal pegs (Fig. 5B).

When installing pit traps, spread a thin amount of Coopex (insecticide) in a circle just back from the rim of the bucket; this is to keep ants out. Use no more than ½ tsp per pit. To prevent vertebrate mortalities in situations where lots of meat ants are falling into the bucket, a small amount of Coopex can be placed in the bucket and at the ant nest entrance.

Funnels should be set in pairs at each terminal end of the drift fence, such that the funnels do not act to extend the length of the fence. Use two metal pegs per funnel to ensure that it is positioned snugly against the drift fence. The entrance of the funnel must be flat against the ground along one entire edge, and a decent amount of dirt should be used to build a ramp into the funnel. This will ensure that animals are funnelled into the trap rather than slipping under or behind it along the drift fence. All funnels must be well-shaded at all times; this should be done using a single sheet of roofing insulation that has been cut to size or, when this is unavailable, grass or leaves can be used. Ensure vegetation used for shading does not impede movement into the funnel.

A single photo of each pit trap is required at an appropriate angle and field of view (Fig 5C); this will enable scoring of the quality of trap set-up.

To maximise their effectiveness, care should be taken to install pit traps properly. Some issues that contribute to reduced trap effectiveness and that should be avoided are shown in Figure 5C.

Ensure that all traps are working correctly and are ‘tuned’. Fix any damage or fine-tune traps as required using a set of fine-nosed pliers. Set traps on a hair-trigger.

Replace any damaged traps with your spare traps and mark the damaged trap using pink flagging tape and a note. This will allow it to be fixed upon return to the office.

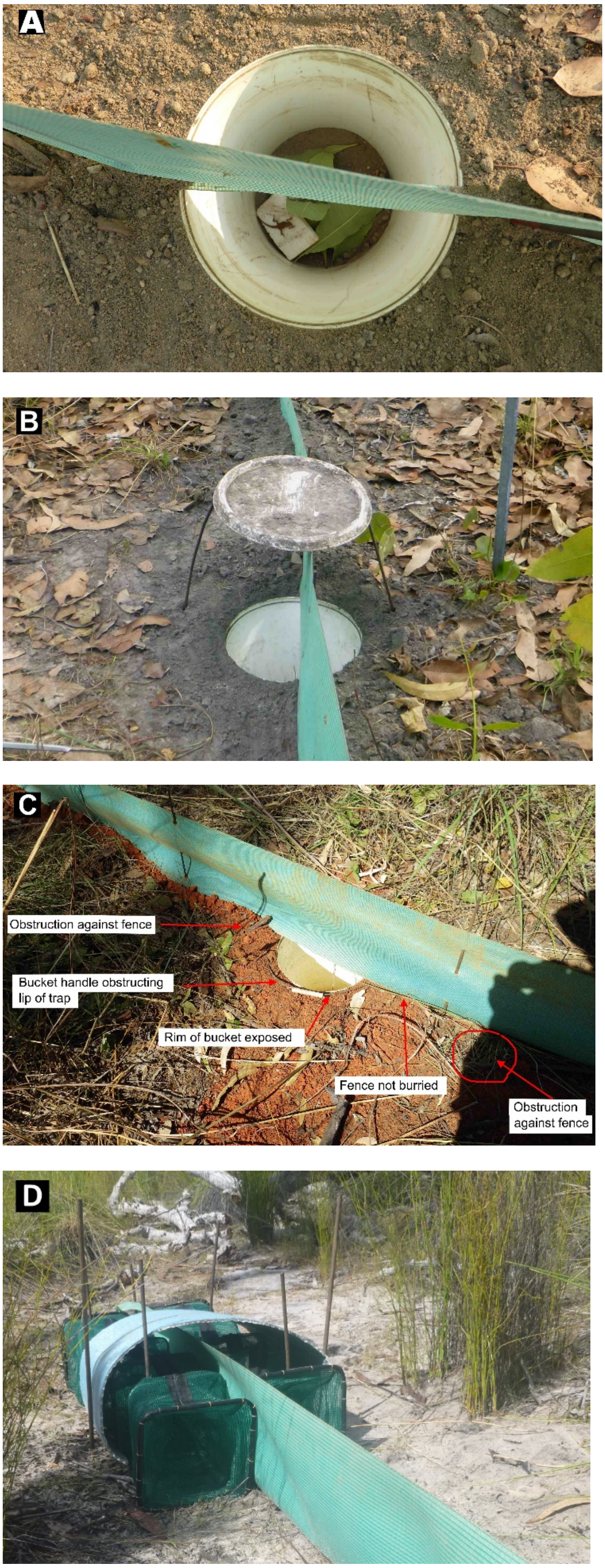



Figure 5. Photos of pit and funnel traps showing: A) the required addition of dirt, leaves, Chux cloth and polystyrene float in pit traps: B) bucket lid propped up with pins over the pit trap to provide shade; C) correct orientation and angle of photo to be taken at all pit traps

operated at a site, and several issues that reduce trap effectives - shown in red; and, D) correct instillation of paired funnel traps at each terminal end of drift fence.

**Operation**

Elliott and cage traps:

Baited with a mixture of oats, peanut butter and honey.

Baiting should occur as late in the day as possible to avoid catching small mammals before nightfall, ant infestations or disturbance by crows.

Operated for four consecutive nights.

All traps are to be checked early each morning, have bait removed and closed. They are to be kept closed throughout the day. All leftover bait should be collected and removed from the site to avoid ant invasions.

Pit and funnel traps:

Not baited, and operated both day and night for four consecutive nights.

Checked in the morning, and again in the late afternoon (when opening and baiting Elliott and cage traps). At exposed sites or during excessive heat, it may be necessary to recheck pit traps around midday. Pits must be kept damp throughout the day; this is done by adding some water.

First check pits using a long stick or tongs (to avoid bites or stings); then by removing all leaves, bark, Chux cloth and polystyrene float; then by sifting through sand/dirt to ensure there are no tiny animals.

Pit traps are numbered and captures are to be assigned to each individual pit.

For funnels, first check for snakes when the funnels are still are on the ground, then thoroughly inspect all ends of the trap for animals.

Trapped animals are to be identified to as low a taxonomic level as is possible (whilst retaining high confidence in the identification) and released near the capture point, or collected and retained for a short time for identification and/or genetics and/or measurements. Animals taken for identification are to be held individually in appropriately-sized calico bags (mammals and reptiles) or plastic bags with water (frogs).

For reptiles and mammals requiring genetic samples, consult the Standard Operating Procedure - Genetics Sampling and Vouchering of Terrestrial Vertebrate Specimens.

Note at the bottom of each column on the datasheet the number of traps that were unavailable for live trapping each night. This includes all Elliott and cage traps that were closed in the morning but that did not contain animals (all empty triggered traps are assumed to have been unavailable for the entire preceding night, despite not knowing when they were actually set off). If branches fall into pit traps or traps become flooded, this information should also be recorded as traps being unavailable since they were last checked/set. In exceptional cases, an entire trapping grid may not be operated for a night.

Make a note of weather conditions each night, recording noteworthy information such as full moon, no moon, heavy rain, high winds etc.

## Camera trapping

In addition to live trapping in Plot 1, a camera trap array is also installed (Fig. 3).

Five camera traps – arranged in the standard camera trap array with several modifications (see *Standard Operating Procedure for Camera Trapping*, Attachment 1):

Four outer RW (standard) cameras positioned off each corner of the live trapping grid (Fig. 3). Cameras must be installed in these locations, or as close as possible to these locations (i.e. dependent upon tree availability) relative to the layout of Plot 1. This means that, even in linear habitats, we do not change the shape of the camera trap array to fit within the desired habitat. All camera trap arrays must resemble a square (four cameras; one at each corner of the square; Fig. 3).

A waypoint should be taken for each camera trap, ensuring <5 m accuracy, and recorded on the datasheet (Fig. 4).

One RS (high sensitivity short focal length) camera is to be established in the centre of the plot. This is to have a drift fence and cork board set-up.

Briefly, all cameras are mounted on live trees that are greater than 20 cm in diameter; however, when no suitable trees are available, metal star steel stakes can be used. Four outer cameras are mounted at a height of 40 cm (to top of camera) above the ground, with the focal point to be at the base of a bait station that is set 1.5 m south (use compass) of the tree/star steel. The centre camera is mounted at 90 degrees and is 65 cm (to top of camera) off the ground, with the focal point to be at the centre of a corkboard that is 65 cm south of the tree/star steel. For full details of the required set up, see the *Standard Operating Procedure for Camera Trapping* (Attachment 1).

## Bird surveys

The survey areas for birds are the 100 x 100 m plots.

Nine 10 minute bird surveys are to be conducted in Plot 1, and a further nine in Plot 2. This totals 18 bird surveys across the site.

In all cases, the survey of Plot 1 should be immediately followed by the survey of Plot 2 or vice versa (so the results from two 10 minute 100 x 100 m surveys can be combined to provide a 20 minute 2 ha survey).

Ideally, the nine surveys of each plot will span 3 days, and occur at times of day that are optimal for bird detections.

When operating a single site, aim for three surveys of each plot on Day 2, 3 and 4 (Day 1 = set-up day): two in the morning between 7 and 11 am (with at least 20 minutes between repeat surveys of the same plot), and one in the afternoon between 4 and 6 pm, when birds are most active. Avoid the heat of the day between 11:30 am and 3 pm.

When operating two sites simultaneously, there may only be enough time for one survey in the morning per plot, instead of two. In this case, the remaining bird surveys should be completed on the pack-up day (Day 5).

In high winds or during moderate to heavy rainfall, bird surveys should be postponed to another time or day, as these conditions reduce the chances of detecting birds.

It is important to note the start time of each survey against the results, and be strict with the 10 minutes.

During the survey, it is important to actively walk around the plot, covering all areas and flushing any birds from the ground or from behind bushes.

Make a count of the minimum number of individual birds of each species confirmed on site (within 100 x 100 m plot) during the survey, recording as either ‘seen’ or ‘heard’.

Example 1: One willie wagtail is seen early in a 10 min survey then one willie wagtail is seen later in the same 10 min survey. This is a minimum count of 1 for this species, as the two observations are assumed to be of the same individual. The only instance that this minimum count does not apply is if the birds can be confirmed as being different individuals (e.g. clear distinguishing features such as male/female, adult/juvenile, and tail moult).

Example 2: two silver-crowned friarbirds are heard on plot, and then five silver-crowned friarbirds are seen on plot. This should be recorded as a minimum count of five for this species, as the figure of five birds exceeds the figure of two, but they cannot be confidently summed to being seven individuals (i.e. the two could be part of the five).

Example 3: one rufous whistler is seen, and at the same time, a call of the same species is heard with high level of confidence the call was made ‘on plot’ but at a different location. This is a minimum count of 2 for this species.

A record of ‘heard’ can be updated to ‘seen’ later within the survey period.

Unidentified birds in early surveys can be recorded as sp. 1, sp. 2 etc., with associated diagnostics; this will enable them to be assigned a species if/when they can be identified at a later date.

Birds seen flying overhead are only recorded as monitoring records if they are observed hunting overhead (e.g. raptors, wood-swallows).

Birds seen flying through a site and not stopping (e.g. lorikeets) are not to be recorded as they are not using the site.

Incidental records of species not already recorded in survey include:

Birds seen or heard inside the 100 x 100 m plot outside formal survey times, or birds seen flying overhead and actively hunting outside formal survey times.

Birds seen flying overhead or through the 100 x 100 m plot that are not hunting should not be recorded as incidentals; instead, they should be considered an opportunistic record (if the species meets the requirements of an opportunistic record; see section above).

Note: Birds seen during nocturnal spotlight surveys are to be recorded on the active search datasheet and not duplicated on the bird survey datasheet.

Observer's initials must be recorded against each survey.

## Diurnal active searches

Diurnal active searches focus on reptiles, although any predator scats that are seen should also be collected.

The survey areas are the 100 x 100 m plots.

Six 10 minute meander searches should be performed within Plot 1, and a further six searches in Plot 2, totalling 12 diurnal active searches across the site.

In all cases, the search of plot 1 should be immediately followed by the search of Plot 2 (or vice versa) so that the results from the two 10 minute 100 x 100 m searches can be combined to provide a 20 minute 2 ha search.

Ideally, one search in each 100 x 100 m plot is to be conducted in the morning, and one in the afternoon on each of Days 2, 3, and 4 (not on Day 1 = setup day). Preferred time windows for active searches are 10 – 11:30 am and 3:30 – 5:30 pm. Reptile activity may increase earlier in the day at some exposed or rocky sites; in this case, the time windows within which to perform searches may be adjusted to 9 – 11 am. Avoid the heat of the day from 11:30 am – 3 pm.

The search should cover the entire plot, targeting areas and features likely used by reptiles. Gloves should be worn.

Every effort should be made to detect species that are using the site. Move rocks and logs, rake through leaf litter and vegetation, and inspect rock crevices. Use crowbars to split logs and pull bark off trees to find reptiles. Put rocks and logs back in place as best as possible during the search.

The number of individuals of each species seen during each search is recorded. All animals observed within the plot during the search period must be recorded to the highest taxonomic level you are highly confident of. It is important not to make a guess of species ID. It is absolutely fine to record 'skink', or 'lizard' where there is uncertainty.

Record all diggings assignable to goannas and record and collect all owl pellets.

Scats are to be recorded if they can confidently be attributed to a species. The macropod scat identification key in the *Standard Operating Procedure for Scat Collection for DNA Analysis* (Attachment 2) should be used to accurately ID scats to species. If unsure, take photos of scats and include a reference object in the image as a gauge of size. Relatively fresh macropod scats (black and shiny, not grey or white) suspected to be from a species of rock-wallaby or Nabarlek should be collected. Scats considered to be from separate individuals should be collected using plastic gloves or a stick (to avoid contamination) and placed in sterile paper bags that are labelled with the location, date and collector's name.

Similarly, carnivore scats of any age, and owl pellets of any age should be collected for hair and e-DNA analysis. This should be done by using plastic gloves or a stick, and placing scats considered to be from different individuals in separate sterile paper bags labelled with the location, date and collector's name.

Observer’s initials must be recorded against each survey.

## Nocturnal active searches

The survey area for nocturnal active searches are the 100 m x 100 m plots.

Four 10 minute spotlight searches are to be conducted in Plot 1, and a further four 10 minute spotlight searches in Plot 2, totalling eight nocturnal active searches across the site.

In all cases, the search of Plot 1 should be immediately followed by the search of Plot 2 (or vice versa) so the results from two 10 minute 100 x 100 m surveys can be combined to provide a 20 minute 2 ha survey.

Spotlighting should involve a two person team walking a lap around the 50 x 50 m perimeter as a baseline and moving away from the baseline to search interesting features within the 100 x 100 m plot.

Animals seen or heard outside the 100 x 100 m plot during the search, or outside the 10 minute search period, should be recorded as incidental (only if they are species not already recorded in previous searches at the plot).

The number of individuals of each species seen or heard during each search should be recorded.

If frogs are calling but cannot be identified, their call should be recorded on a smart phone or other recording device for later identification.

## Hold and release of animals for identification

All animals captured in traps should be released near their point of capture. It may not be possible to identity some animals at the point of capture (e.g. small skinks, small rodents, blind snakes) and these should be put into suitable individual calico, or wetted plastic (for frogs) bags and taken off-plot for processing.

Each bag is to be labelled with the site number and time of capture, and the capture is to be recorded on the datasheet but using a term (e.g. ‘unknown rodent’) that can later be supplanted by the species’ taxonomic identification.

Bags containing captured animals should be placed in a marked box or bucket to avoid crush injuries or misplacement, and placed in a shaded and well-ventilated space to avoid overheating.

Unidentified animals should be identified as soon as possible using the identification resources at hand.

If required, animals may also be processed as voucher specimens (animals euthanised and kept), genetic samples obtained and/ or measurements taken (animals released).

Diurnal animals should be released at the time of the next visit to their capture site. Nocturnal animals should be released in the evening or during spotlighting into shelters that provide them with safety and orientation.

It is important to note that rodents and small Dasyurids have fast metabolisms and may require a small amount of bait if they are held for the day.

## Genetic samples

Genetic samples are to be collected following the *Standard Operating Procedure for Genetic Sampling and Vouchering of Vertebrate Specimens* (Attachment 3).

## Voucher specimens

Guidelines for collecting voucher specimens and the use of Lethabarb solution are outlined in the *Standard Operating Procedure for Genetic Sampling and Vouchering of Vertebrate Specimens* (Attachment 3).

## Injured wildlife

Injured wildlife may be encountered while travelling to sites or as a result of the trapping process. Information for developing contingency plans for injured wildlife is available at Charles Darwin University's animal ethics website.

In remote locations where access to either a veterinarian or a permitted wildlife carer is not possible (islands, day travel to station, town centre) the following actions are recommended:

Animals with more serious injuries may be kept in a quiet, cool location for further observation and release or euthanasia. If injured animals are encountered on the final days of fieldwork, they may be transported to either a veterinarian or a permitted wildlife carer.

Seriously injured animals may be euthanised using recommended techniques outlined in the *Standard Operating Procedure for Genetic Sampling and Vouchering of Vertebrate Specimens* (Attachment 3), which includes the use of Lethabarb solution.

## Pouch young

In order to reduce the chance of a female ejecting pouch young a number of techniques will be used depending on three different circumstances:

The female does not appear excessively stressed and young are secure inside pouch or secure with natural method of attachment (e.g. possums on the mothers back) – in this case the animal is released after processing. Release procedure - take the animal away from the processing area to a shaded location with cover, near where the animal was caught, place the unsecure (untied) bag on the ground so that the animal can get out unaided, researchers depart the area and the animal is left to exit the bag of their own accord.

Female and young are separated within the bag during processing or in the trap when the young are small, unfurred and highly dependent on female – female will be handled within the bag and pouch will be exposed, young are placed in position where they can re-attach to the teat, in most cases they re-attach immediately, the pouch is then taped closed with wide tape that can be easily removed by the female (such as packing tape). The next step depends upon the state of the female, either the release technique from i) is followed or if the female is obviously agitated the animals are left in the bag with the bag tied in a sheltered safe place for a period of time up to one hour, the bag is then un-tied and the release procedure from i) is followed.

Female and young are separated, female is stressed or agitated and young are furred (or at an age where they can be off the teat) - female is to be separated from the young for processing (to reduce the likelihood of the female injuring young) – then returned to the bag with the young – the bag is to be left tied up in a sheltered, quiet secure place and left for a period of time up to one hour, after this time the bag is then un-tied and the release procedure from i) is followed.

### Data recording

Each capture and detection of an animal during surveys must be recorded on a paper datasheet (see Appendix 3 - 5).

These data are to be recorded against the day or night of each encounter, allowing for additional analyses (e.g. species accumulation curves, occupancy modelling).

Any deaths for voucher specimens or unplanned deaths are also to be recorded on the datasheet; this information will be used for reporting to the Animal Ethics Committee. Unplanned deaths must be accompanied by a brief explanation and trap type (if applicable).

Notable weather conditions that may influence animal activity or detectability should be recorded in the relevant location on datasheets.

Any departure from the standard survey effort must be recorded in the relevant location on the datasheets. This includes noting if any traps were 'unavailable' for capturing animals the previous night. Examples include cage and Elliott traps closed but empty in the morning when checked, and instances when a branch may have fallen into a pit trap.

Use neat writing to ensure your data are transcribed into the database correctly.

## Habitat survey methods

A habitat assessment of each site is to be completed during each 4 day survey period. The habitat assessment will focus on collecting data related to vegetation structure that can be used to track changes in habitat structure through time. A full floristic survey of all new non-fire plot sites will be undertaken independently at some time in the future.

### Habitat survey design

Habitat structure data are to be collected from eight transects that are set along the edges of the 50 x 50 m trapping grids, as shown in Figure 6.

Habitat assessment along the four parallel transects (T1, T3, T5, T7; Fig. 6) involves point intercept sampling, feral herbivore quadrats, log measurement, and mid-layer and tree-layer assessments of shrubs and trees.

Habitat assessment along the four other transects (T2, T4, T6, T8; Fig. 6) involves point intercept sampling only. The results from each survey transect are to be entered on separate datasheets.

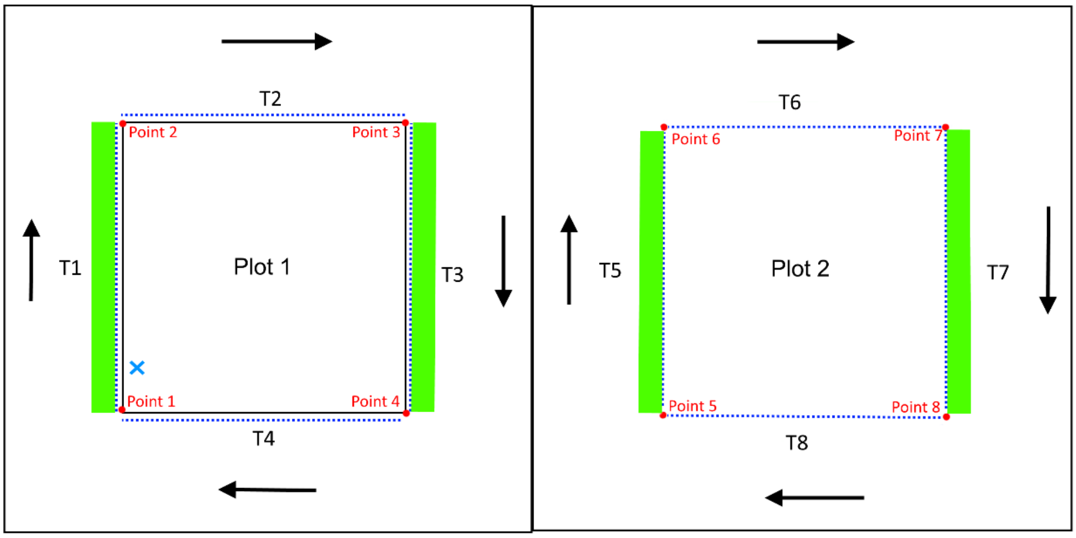



Figure 6. Layout of habitat surveys showing: eight 50 m transects (T1 – T8; blue dotted lines) for point intercept (see offset details in text); four 50 m transects (T1, T3, T5, T7) for herbivore quadrats; four 5 m x 50 m strip transects (T1, T3, T5, T7; thick green lines) for tree-layer method; and four 2 m x 50 m strip transects (T1, T3, T5, T7) Black arrows show the direction of data collected along each transect. Blue cross is the preferred location of the photo alignment marker.

## Site photo point

A photograph should be taken at each site using a method that ensures that future visits to the same survey site will yield photographs that capture the same view. The photo number (specific to the camera used by the survey team) is to be recorded on the datasheet.

On the initial site visit, select a corner post that provides a good view of the site to take the photo from (e.g. Point 1, Fig. 6). Hammer this post in so that the above ground portion is 1 m high. Set the camera to its widest angle and hold it in a fixed position on top of the post facing into the site. While viewing the camera screen, get your survey partner to walk slowly in an arc at a distance of 2 m in front of you with a sighting dropper suspended vertically. When the sighting dropper is aligned with the left hand edge of the camera's field of view, hammer the dropper in (blue 'X' on Fig. 6).

Taking a photo on the initial site visit and subsequent sites visits:

Set the camera to its widest angle

Place the camera on top of the corner post.

Turn the camera to the point where the **base** of the sighting dropper appears in the bottom left hand corner of the viewing screen.

Take a photo (Fig. 7). Check the photo and make sure it is in focus.

Record on the datasheet in the space provided the sequence number assigned to that photo by the camera used. This will aid in re-labelling the photo when back in office.

Figure 7. Correct alignment of a sighting dropper for a site photo – its base in the bottom left hand corner of the field of view.

## Point intercept

Data are to be collected from along eight 50 m transects and entered into the habitat datasheet (Appendix 7).

On Plot 1, each transect is to be offset 2 m from the baseline (trapping grid) in the direction that is away from the 50 x 50 m plot area (Fig. 6). Lie out the 50 m measuring tape between two fixed transect markers, parallel with the baseline (Fig. 6).

On Plot 2, no offset from the baseline is required, so lie out the 50 m measuring tape between the two fixed transect markers.

Point intercepts are to be recorded at 1 m intervals along the transect using a pole that is mounted with a laser pointing down from 1.6 m and densitometer pointing up from 1.6 m.

The 50 m tape may fall a little short or beyond the transect markers, depending on the terrain but the tape should always be used to guide the location of point intercepts.

The start point is along Transect 1 from the corner that is assigned Point 1, and data must be collected in a clockwise direction along each transect around each plot (Fig. 6). Start collecting point intercepts from the correct end of each 50 m transect that is needed to follow the preferred survey directions; this will then provide consistency between surveys (direction of data collection shown in Fig. 6). For sites that do not follow the standard design (Fig. 1 and 6), the collection of waypoints for corner numbers 1 – 8, and accurate naming of transects 1 – 8 in a clockwise direction around plots, are essential for repeat surveys.

Collecting point intercepts – starting at 0 m, place the pole precisely at each 1 m intercept s and hold the pole vertically, using the levels as a guide to the same. Identify the first thing the laser beam touches that is below 1.5 m; this will be either vegetation or substrate. If the laser hits vegetation, record the type of growth form and its height class at point of interception with the laser – either 0-20 m (1), 20-50 cm (2), or 50-150 cm (3). Growth form types are as follows:

Grass. If first intercept of the laser beam is grass, record one of:

Perennial: More firmly rooted in the ground and mostly forms distinct tussocks

Annual: Can easily be pulled out and has very short root systems

Hummock grass: *Triodia* spp. (spinifex grass).

Sedge: like a grass but generally have a leathery, smooth texture with brown at the base.

Forb/herb: non-woody plants that are neither grasses nor sedges, with broader leaves and, when present, distinct flowers.

Weed: write as ‘weed’ and record species ID in column on datasheet (see photo guide of common weeds; Appendix 8) or take a specimen and record the identification of the specimen on the datasheet against that point intercept record.

Shrub. If first intercept of the laser beam is a woody-stemmed plant (shrub, palm, cycad, etc.) record it as:

Shrub

Weed: score as weed. Also record species ID or sample photo ID, or specimen ID on datasheet against that point intercept record.

If the laser hits the ground or a ground-like substrate, record one of the following:

Bare ground

Litter

Rock: 2 - 20 cm

Rock: 20+ cm

Bedrock

Log (wood > 5 cm diameter)

Water

At every point intercept, record if the ground is burnt (i.e. tick the ‘**FIRE**’ column) if there is any evidence of fire since the last wet season.

Measure the projected foliage cover of the mid layer by rechecking the level of the pole and looking through the densitometer. Assess whether the cross-hairs intercept foliage/branch/twig above 1.6 m, up to a maximum height of 6 m (use a clinometer if necessary to accurately gauge 6 m). Do not record intercept type, just a ‘yes’ or ‘no’ for presence of one of these.

Upon completion of each point intercept (before moving on to next point intercept), also monitor along the appropriate transects for feral sign using the ground quadrat method (see below).

## Ground quadrats

Along the four parallel 50 m transects (T1, 3, 5, & 7; Fig. 6) (laid for point intercept method), record the presence within a 1 m quadrat of any **sign** or damage from feral herbivores. If sign is present, identify it to species level if possible, and record the information on the datasheet.

1 m quadrats should be considered as the 1 x 1 m area immediately in front of the pole used for the point intercept method (i.e. 0 – 1 m, 1 – 2 m etc.).

## Logs

Along the four parallel 50 m transects (T1, 3, 5, & 7; Fig. 6), record all logs that intercept the transect (i.e. tape measure laid out for point intercept) up to a maximum height of 1.5 m off the ground, if the logs are >5 cm diameter at the point of intersection. For the latter logs, record the length of log that is >5 cm diameter, up to a maximum height of 1.5 m off the ground, and measure the log’s diameter at its mid-length.

If a fallen tree with multiple branches that cross the transect is still attached to the tree, then only record one measurement (i.e. only one measurement for that tree, despite multiple intercepts). Measure the combined length of the primary branch (thickest branch) and trunk to the root collar of any trunk that is >5 cm diameter.

Any branches >5 cm diameter that have broken free of a main log and that are crossing the transect are to be considered separate logs and must be measured separately.

At sites where the 50 x 50 m trapping grids are not positioned centrally within Plot 1 and 2 but are co-joined (e.g. patchy habitats such as wet/dry rainforest) and hence share an edge, both Transect 3 and 5 still require survey. In this situation, the 2 m offset of the point intercept line that is applied to Transect 3 should also be applied to Transect 5 to avoid the trapping line.

## Mid-layer – stem circumferences

Along the four parallel 50 m transects (T1, 3, 5, & 7; Fig. 6), measure circumference of all dead and alive stems >3 cm and <31 cm circumference at 1.3 m height, up to 2 m from the point intercept in the direction away from the 50 x 50 m plot area. Only measure the first 50 stems on each transect. At the 50$^{th}$ measured stem, record distance along the 50 m transect.

For multi-stemmed shrubs that have more than one stem > 3 cm circumference, only record the circumference of the single largest stem but then also record the number of stems in that same shrub that are > 3 cm circumference. Denote the number of stems >3 cm in brackets on datasheet alongside the single circumference measure.

Identify each stem to genus and note phenology (fruiting, flowering).

### Tree-layer – trunk circumferences

Along each of the four parallel 50 m transects (T1, 3, 5 & 7), at 1.3 m height, measure circumference of dead and alive stems >31 cm circumference, up to 5 m from the point intercept transect in the direction away from the 50 x 50 m plot area. Only measure the first 50 trees on each transect. At the 50$^{th}$ tree, record distance along the 50 m transect.

Identify each stem to species, and note phenology (fruiting, flowering). For multi-stemmed trees, record the circumference of each stem that is >10 cm diameter. Place measurements for the same tree in the same row on the data sheet, separated by commas.

### Weeds

In addition to the weeds recorded with point intercept method, record the presence of any key weeds in the broader 100 x 200 m site. For a photo guide of a suite of common weeds, see Appendix 8.

## Equipment

Eight 1 m aluminium stakes with fluoro spray on end, to permanently mark each end of the 4 transect

Laser pointer and densitometer mounted on pole with height classes.

50-100 m tape measure - laid out along transect (between two fixed markers/stakes) for 1 m point intercepts, log intercepts, and to use as a baseline for DBH strip transects.

5 m builders' tape measure - to indicate width of strip transect for mid (2 m) and tree layer (5 m) assessment (also required for camera set up).

3 m tailors' tape measure - for DBH measurements and log measurements.

1 m PVC pipe - for perennial grass quadrat assessment.

Plant press.

Camera to take photos of trees, flowers/fruit, and trunk/bark of unidentified trees.

Trapping equip: 16 Elliott, 8 cage traps, 6 x drift fences for pit traps, 2 x funnel traps, bait, flagging tape

Bird surveys: binoculars

Safety equipment – satellite phone, EPIRB, 10 L of water /person/day

Night searches: high lumen head torch

Camera – setup: 5 x cameras, bait station

Vouchering/genetics/Lethabarb kits

## Priorities and proposed schedules

### Single sites (predominantly helicopter access sites)

When setting up a single site, instances may arise when there is not enough time on the set-up day to install the full complement of traps. Ensure that at least all high priority tasks are completed on the set-up day (Day 1), with other tasks able to be deferred to the following day/s.

Tasks, listed in order of priority for Day 1, are:

Measuring and flagging out Plot 1 and Plot 2 of the site.

Installation of all cage and Elliott traps

Installation of all drift fences and funnel traps

Installation of as many pit traps as possible

Lower-priority tasks that can be deferred till Day 2 include:

Installation of remainder of pit traps

Installation of metal stakes

Collection of waypoints

Note: Camera trap installation and habitat surveys should not occur on Day 1.

Any change from the full complement of traps on Night 1 at a site should be recorded on the datasheet in the appropriate place. Any pit traps not installed and operational by Day 2 should not be installed.

A proposed schedule of survey activities when operating a single site is presented in Table 2. This schedule can be used as a guide to the sequence of survey activities on Days 2, 3 and 4 of the survey. However, it's important to note there is a degree of flexibility in the timing of bird surveys, active searches, and spotlighting, and the days on which these activities occur. Delays in site set up or inclement weather may mean surveys need to occur on different days.

Instances may arise when it is not possible to perform the required number of surveys (e.g. delays in set-up, bad weather, an injured staff member). Lower-priority surveys that can be omitted from the survey, in order of lowest priority (i.e. first thing to drop), are:

Point intercepts 101 – 200 on either or both of Plot 1 and Plot 2

One to four bird surveys on either or both of Plot 1 and Plot 2

One to three active searches on either or both of Plot 1 and Plot 2

One to two spotlight surveys on either or both of Plot 1 and Plot 2

Tree and shrub survey on Transect 3 and/or Transect 7

Table 2. Proposed daily schedule of activities for Days 2, 3 and 4 when operating a single site. Preferred window for active searches is 10 – 11:30 am and 3:30 – 5:30 pm, and for bird surveys, 7 – 10 am and 4 – 6 pm. The heat of the day from 12 – 3 pm should be avoided.

| Time | Duration | Daily activity |
|---|---|---|
| 6:15 | 0:45 | Check/close traps |
| 7:00 | 0:10 | Bird survey Plot 1 |
| 7:10 | 0:10 | Bird survey Plot 2 |
| 7:20 | 0:20 | Check and water pits |
| 7:40 | 0:10 | Bird survey Plot 1 |
| 7:50 | 0:10 | Bird survey Plot 2 |
| 8:00 | 2:00 | One-off tasks e.g. camera installation, habitat survey |
| 10:00 | 0:30 | Break/rest |
| 10:30 | 0:10 | Diurnal active search Plot 1 |
| 10:40 | 0:10 | Diurnal active search Plot 2 |
| 10:50 | 1:10 | One-off tasks e.g. camera installation, habitat survey |
| 12:00 | 2:00 | Break/rest/lunch/process herps |
| 14:00 | 0:20 | Check and water pits |
| 14:20 | 1:50 | One-off tasks e.g. camera installation, habitat survey |
| 16:10 | 0:10 | Diurnal active search Plot 1 |
| 16:20 | 0:10 | Diurnal active search Plot 2 |
| 16:30 | 0:30 | Break/rest |

| | | |
|---|---|---|
| 17:00 | 0:10 | Bird survey Plot 1 |
| 17:10 | 0:10 | Bird survey Plot 2 |
| 17:20 | 0:20 | Check and water pits |
| 17:40 | 0:20 | Open/bait traps |
| 18:00 | 1:00 | Break/rest/dinner |
| 19:00 | 0:10 | Nocturnal active search Plot 1 |
| 19:10 | 0:10 | Nocturnal active search Plot 2 |

## Paired sites - vehicle access

When setting up paired sites, it is imperative to complete the instillation of all live traps (cage, Elliott, pit and funnel traps) at one site before moving to the second site. Instances may arise when there is not enough time on the set-up day to install all live traps at the second site. Highest-priority tasks for completion at the second site on the set-up day (Day 1) are the same as listed for a single site (see above). Ensure at least all high-priority tasks are completed, with other tasks able to be deferred to the following day. NB: any change from the full complement of traps at a site should be recorded on the datasheet in the appropriate place. Note: any pit traps not installed and operational by Day 2 should not be installed.

When travel time between paired sites exceeds 50 minutes, there will not be enough time in the day to complete all survey activities. If there is not enough time for a complete survey of both sites, then survey effort at one site can be sacrificed in order to enable complete survey at the other site. Sacrificed surveys at one site should follow the list of low-priority surveys provided (see above).

When operating paired sites, allow the entirety of Day 5 to complete any unfinished surveys (e.g. bird surveys, active searches, habitat surveys). However, instances may arise when it is not possible to perform the required number of surveys (e.g. delays in setup, bad weather, an injured staff member). Lower-priority surveys that can be omitted from the survey are provided (see above).

A proposed schedule of survey activities for paired sites is presented below to assist in workflow of surveys and other activities (Table 3).

Table 3. Proposed daily schedule of activities on Days 2, 3 and 4 when operating two sites. Schedule based on 10 minutes transit time from camp to Site 1 and 50 minutes transit time from Site 1 to Site 2. Site 1 activities are coloured green; site 2 are coloured yellow. Preferred window for active searches is 10 – 11:30 am and 3:30 – 5:30 pm, and for bird surveys, 7 – 10 am and 4 – 6 pm. The heat of the day from 12 – 3 pm should be avoided.

Note: based on this schedule, an additional day (Day 5) would be required to complete bird surveys.

| Location | Time | Duration | Daily activity | Assistant activity |
|---|---|---|---|---|
| Transit | 6:00 | 0:10 | Drive/walk camp to site | |
| Site 1 | 6:10 | 0:20 | Check/close traps | |
| Transit | 6:30 | 0:50 | Walk/drive/walk between sites | |
| Site 2 | 7:20 | 0:10 | Bird survey plot 1 | Check/close traps |
| | 7:30 | 0:10 | Bird survey plot 2 | Check/close traps |
| Transit | 7:40 | 0:50 | Walk/drive/walk between sites | |
| Site 1 | 8:30 | 0:10 | Bird survey plot 1 | |
| | 8:40 | 0:10 | Bird survey plot 2 | |
| | 8:50 | 1:10 | One-off tasks (cameras, habitat, etc.) | |
| | 10:00 | 0:10 | Active search plot 1 | Check traps and water pits |
| | 10:10 | 0:10 | Active search plot 2 | Check traps and water pits |
| Transit | 10:20 | 0:50 | Walk/drive between sites | |
| Site 2 | 11:10 | 0:10 | Active search plot 1 | Check and water pits |
| | 11:20 | 0:10 | Active search plot 2 | Check and water pits |
| | 11:30 | 2:00 | Lunch/rest/process herps | |
| Site 2 | 13:30 | 2:00 | One-off tasks (cameras, habitat, etc.) | |
| | 15:30 | 0:10 | Active search plot 1 | |
| | 15:40 | 0:10 | Active search plot 2 | |
| | 15:50 | 0:10 | Bird survey plot 1 | |
| | 16:00 | 0:10 | Bird survey plot 2 | |

| | | | | |
|---|---|---|---|---|
| | 16:10 | 0:10 | Check and water pits | |
| | 16:20 | 0:10 | Open/bait traps | |
| Transit | 16:30 | 0:50 | Walk/drive between sites | |
| Site 1 | 17:20 | 0:10 | Active search plot 1 | Check and water pits |
| | 17:30 | 0:10 | Active search plot 2 | Check and water pits |
| | 17:40 | 0:10 | Bird survey plot 1 | Open/bait traps |
| | 17:50 | 0:10 | Bird survey plot 2 | Open/bait traps |
| Transit | 18:00 | 0:10 | Walk/drive site to camp | |
| | 18:10 | 1:00 | Dinner/rest | |
| Transit | 19:10 | 0:10 | Drive/walk camp to site | |
| Site 1 | 19:20 | 0:10 | Spotlight search plot 1 | |
| | 19:30 | 0:10 | Spotlight search plot 2 | |
| Transit | 19:40 | 0:50 | Walk/drive/walk between sites | |
| Site 2 | 20:30 | 0:10 | Spotlight search plot 1 | |
| | 20:40 | 0:10 | Spotlight search plot 2 | |
| Transit | 20:50 | 0:50 | Walk/drive to camp | |

## Site pack up and departure

Upon completion of the survey and prior to departure, is imperative that pit traps are closed effectively. All soil/litter must be removed from the pit and the bucket must be filled with suitably-sized rocks or a canvas bag filled with soil before it is closed. Ensure the lid is on tightly, and shovel a minimum of 20 cm of soil on top of the lid for protection from sun and fire. If available, rocks can also be piled on top of the soil; these will help to prevent trampling damage by ungulates. Collect and remove all flagging tape from the site.

## Post-survey

A series of tasks must be completed post survey to ensure appropriate handling and storage of data and samples.

Genetic samples must be transferred to the genetics fridge and datasheets passed to the Technical Officer, Terrestrial Ecosystems, following the *Standard Operation Procedure - Genetics Sampling and Vouchering of Terrestrial Vertebrate Specimens* (Attachment 3).

Voucher specimens must be stored and processed appropriately and datasheets passed to the Technical Officer Terrestrial Ecosystems, following the *Standard Operation Procedure - Genetics Sampling and Vouchering of Terrestrial Vertebrate Specimens* (Attachment 3).

All survey data should be promptly entered into purpose-built electronic databases, and all datasheets provided to the survey lead, or archived in an ordered fashion in an accessible location.

Site photographs should be stored digitally with a filename or number linked to the site description.

# Appendices

## Appendix 1. Useful References and Field Guides

Brock J (2001) *Native plants of northern Australia*. Reed New Holland, Sydney.

Brocklehurst P, Lewis D., Napier D, Lynch D. (2007) *Northern Territory guidelines and field methodology for vegetation survey and mapping*. Technical Report No. 02/2007D, Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory.

Churchill S (2008) *Australian bats. Second edition*. Jacana Books, Crows Nest, Australia.

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Cowie ID, Short PS & Madsen MO (2000) *Floodplain flora: a flora of the coastal floodplains of the Northern Territory, Australia*. Flora of Australia Supplementary Series Number 10. ABRS, Canberra & PWCNT Darwin.

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Jessop J (1981) *Flora of central Australia*. Reed Books, Sydney.

McDonald RC, Isbell RF, Speight JG, Walker J & Hopkins MS (1998) *Australian soil and land survey handbook*. Second edition.

Menkhorst P & Knight F (2001) *A field guide to the mammals of Australia*. Oxford University Press, Australia.

Pizzey G & Knight F (2007) *The field guide to the birds of Australia*. Harper Collins Australia.

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Tyler MJ & Davies M (1986) *Frogs of the Northern Territory*. Conservation Commission of the Northern Territory, Darwin.

Van Dyke S & Strahan R (2008) *The mammals of Australia*. *Third edition*. Reed New Holland, Sydney.

Wheeler JR, Rye BL, Koch BL & Wilson AJG (1992) *Flora of the Kimberley Region*. Department of Conservation and Land Management, Western Australia.

Wilson S & Swan G (2008) *A complete guide to reptiles of Australia. Second edition*. New Holland, Sydney

Woinarski J, Pavey C, Kerrigan R, Cowie I & Ward S (eds) (2007) *Lost from our landscape: threatened species of the Northern Territory*. Northern Territory Department of Natural Resources, Environment and the Arts, Darwin.

## Appendix 2. Opportunistic records datasheet (sample only, print original for field work)

OPPORTUNISTIC RECORDS TOP END ECOLOGICAL MONITORING PROGRAM, DENR Flora & Fauna Division 89955000

Page 1/2

Park:

| SPECIES | DATE | OBSERVER | LAT | LONG | COMMENTS |
|---|---|---|---|---|---|
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# Appendix 3. Live trapping datasheet (sample only, print original for field work)

**LIVE TRAPPING** - **TOP END ECOLOGICAL MONITORING PROGRAM, DENR, Flora and Fauna Division, 0889955000**

*Page 1/2*

| | | | | |
|---|---|---|---|---|
| **Park:** | **Site:** | **PLOT1** | **Start Date:** | **Obs(s):** |
| PLOT 1 Live trapping 50x50m grid 4 nights: 8 cages; 16 Elliott's; 3 pits; 12 funnels. | | | Pit start day (if not D1): P1 P2 P3 | |
| Any modifications to standard survey effort? | | | | |
| WAYPOINTS (Decimal Degrees, GDA94) | | | | |
| Corner 1, Lat: | Long: | Pit/Funnel 1, Lat: | Long: | |
| Corner 2, Lat: | Long: | Pit/Funnel 2, Lat: | Long: | |
| Corner 3, Lat: | Long: | Pit/Funnel 3, Lat: | Long: | |
| Corner 4, Lat: | Long: | Pit removed? (Yes): P1 | P2 | P3 |

| SPECIES | Record number of individuals captured in: C = Cage; E = Elliott; P1 = Pit1, P2 = Pit2, P3 = Pit3; F1 (i.e., either funnel on P1), F2, F3. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY/NIGHT | D1 | N1 | D2 | N2 | D3 | N3 | D4 | N4 | D5 | Sample ID (scat, genetics, voucher) |
| DATE | | | | | | | | | | |
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| TRAPS NOT AVAILABLE (closed) | | | | | | | | | | |
| WEATHER, IF NOTEWORTHY | | | | | | | | | | |

| ANIMAL DEATH | REASON FOR DEATH |
|---|---|
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|---|---|---|
| **PLOT 2** | **Start Date:** | **Obs(s):** |
| PLOT 2 Live trapping 50x50m grid 4 nights: 3 pits; 12 funnels. | | Pit start day (if not D1): P4 P5 P6 |
| Any modifications to standard survey effort? | | |
| WAYPOINTS (Decimal Degrees, GDA94) | | |

| | | | |
|---|---|---|---|
| Corner 5, Lat: | Long: | Pit/Funnel 4, Lat: | Long: |
| Corner 6, Lat: | Long: | Pit/Funnel 5, Lat: | Long: |
| Corner 7, Lat: | Long: | Pit/Funnel 6, Lat: | Long: |
| Corner 8, Lat: | Long: | Pit removed? (Yes): P4 P5 P6 | |

| SPECIES | Record number of individuals captured in: P4 = Pit4, P5 = Pit5, P6 = Pit6; F4 (i.e., either funnel on P4), F5, F6 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY/NIGHT | D1 | N1 | D2 | N2 | D3 | N3 | D4 | N4 | D5 | Sample ID (scat, genetics, voucher) |
| DATE | | | | | | | | | | |
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| TRAPS NOT AVAILABLE (closed) | | | | | | | | | | |
| WEATHER, IF NOTEWORTHY | | | | | | | | | | |

| ANIMAL DEATH | REASON FOR DEATH |
|---|---|
| | |
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# Appendix 4. Active search datasheet (sample only, print original for field work)

**ACTIVE SEARCH** **TOP END ECOLOGICAL MONITORING PROGRAM, DENR, Flora & Fauna Division. 0889955000**

*Page 1/2*

**Park:** **Site:** **PLOT 1** **Start Date:** **Obs(s):**

Enter count of individuals observed, or enter S for Scat, or D for Digging

| SPECIES | Diurnal Active Search | | | | | | Nocturnal Spotlighting | | | | INC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | |
| OBSERVER (initials) | | | | | | | | | | | |
| DATE | | | | | | | | | | | |
| TIME (24 hour) | | | | | | | | | | | |
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| WEATHER (IF NOTEWORTHY) | | | | | | | | | | | |

**<u>PLOT 2</u>** **Start Date:** **Obs(s):**

Enter count of individuals observed, or enter S for Scat, or D for Digging

| SPECIES | Diurnal Active Search | | | | | | Nocturnal Spotlighting | | | | INC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | |
| OBSERVER (initials) | | | | | | | | | | | |
| DATE | | | | | | | | | | | |
| TIME (24 hour) | | | | | | | | | | | |
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| WEATHER (IF NOTEWORTHY) | | | | | | | | | | | |

## Appendix 5. Bird survey datasheet (sample only, print original for field work)

**BIRD SURVEY** TOP END ECOLOGICAL MONITORING PROGRAM, DENR Flora and Fauna Division, 08 89955000 *Page 1/2*

| Park: | Site: | PLOT 1 | Start Date: | Obs(s): |
|---|---|---|---|---|

| BIRDS (common name) | Diurnal Searches 1-9. Enter count of individuals and whether they were Seen (S) or Heard (H) | | | | | | | | | INC |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| OBSERVER (initials) | | | | | | | | | | |
| DATE | | | | | | | | | | |
| TIME (24 hour) | | | | | | | | | | |
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| WEATHER (IF NOTEWORTHY) | | | | | | | | | | |

**PLOT 2** **Start Date:** **Obs(s):** *Page 2/2*

| BIRDS (common name) | Diurnal Searches 1-9. Enter count of individuals and whether they were Seen (S) or Heard (H) | | | | | | | | | INC |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| OBSERVER (initials) | | | | | | | | | | |
| DATE | | | | | | | | | | |
| TIME (24 hour) | | | | | | | | | | |
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| WEATHER (IF NOTEWORTHY) | | | | | | | | | | |

# Appendix 6. Camera trapping datasheet (sample only; print original for field work)

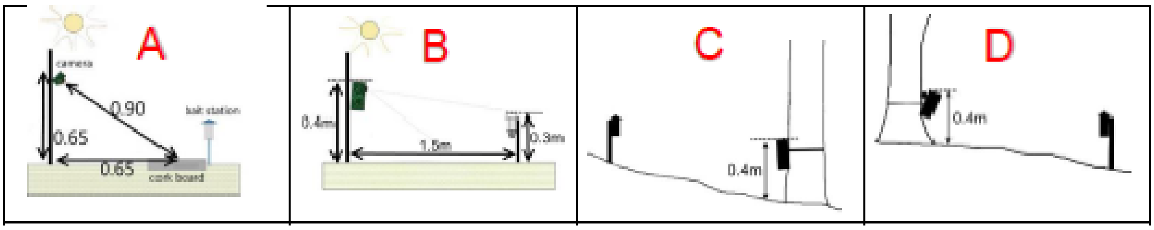
**CAMERA TRAPPING** **TOP END ECOLOGICAL MONITORING PROGRAM, DENR Flora and Fauna Division, 0889955000**

| | | |
|---|---|---|
| Park: | | Site ID: |
| Camera Deployment | Set out : / / <br> Retrieved : / / | Observers: |

| Cam No. | Waypoint ID | Lat (E) | Long (N) | Distance (m) | Camera ID | SD Card No. |
|---|---|---|---|---|---|---|
| C1 | _____Centre | | | 0.65 | RS _____ | |
| C2 | | | | 1.5 | RW _____ | |
| C3 | | | | 1.5 | RW _____ | |
| C4 | | | | 1.5 | RW _____ | |
| C5 | | | | 1.5 | RW _____ | |

**Quick Guide (not to replace SOP)**

- C1 is always an RS (high sensitivity short focal length) camera at the centre of the 5-camera array, with focal point at the centre of a corkboard 65 cm south of the tree/star steel (A).
- The four outer cameras are RW (standard) cameras with the focal point at the base of the bait station set at 1.5 m south of the tree/star steel (B)
- Only attach cameras to live trees greater than 20 cm in diameter at chest height (no dead trees!). If no suitable trees attach cameras to star steel pickets.
- Set cameras facing south using a compass, unless there is a rock wall/ledge entirely shading the camera from the sun.
- Bait stations must have a rain hood, and are to be secured to a stake with a cable tie, so that the top of the rain hood is 30 cm above the ground.
- Sprinkle Coopex powder lightly around the base of the bait station stake to deter ants.
- **RS CAMERA** (A) Mount at 90 degrees so LED globes are on left hand side and the PIR sensor on the right hand side (when facing the front of camera), at a height of 65 cm (use a tape measure) to the top of the camera housing.
- **RW CAMERAS** (B) On flat ground the top of the camera housing is at 40 cm height (use a tape measure). LED globes are on top and the PIR sensor on the bottom. On sloping ground the height stays the same but camera angle will vary (C and D) to align with the base of the bait station.
- Aim the camera so the focal point (C1, middle of corkboard, C2 – 5 base of bait station) is in the centre of the camera field of view. Angle cameras appropriately (downward on flat ground) by adjusting the backing screws on the RS camera (C1); or, using short sticks or rocks wedged behind the camera (RW cameras, C2 - 5). Ensure wedges do not extend beyond the camera housing.
- Test that the camera is positioned correctly by triggering the camera and checking the image by transferring SD card to, and playing back images on a hand-held digital camera with a target circle on the LCD display. The focal point must be in the target circle.
- Arm camera and ensure latch is firmly closed
- **DOUBLE CHECK** camera has SD card, is armed, closed, the right way up, and positioned correctly.



## Appendix 7. Habitat survey datasheet (sample only; print original for field work)

**HABITAT SURVEY** – TOP END ECOLOGICAL MONITORING PROGRAM - DENR, Flora and Fauna Division, 0889955000

*Page 1/9*

**SITE OVERVIEW**

| | |
|---|---|
| Park: | Site Description: |
| Site ID: | Photopoint Photo #: |
| Weed species present (*additional to point intercept records*): | |

**LOGS**

Site:____.1 Date:_____/_____/____ Observers:________________________

| Transect 1 (50 m) all logs > 5 cm diameter where intersecting the transect line within 1.5m above ground | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) |
| 1 | | | 7 | | | 13 | | |
| 2 | | | 8 | | | 14 | | |
| 3 | | | 9 | | | 15 | | |
| 4 | | | 10 | | | 16 | | |
| 5 | | | 11 | | | 17 | | |
| 6 | | | 12 | | | 18 | | |

Site:____.1 Date:_____/_____/____ Observers:________________________

| Transect 3 (50 m) all logs > 5 cm diameter where intersecting the transect line within 1.5m above ground | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) |
| 1 | | | 7 | | | 13 | | |
| 2 | | | 8 | | | 14 | | |
| 3 | | | 9 | | | 15 | | |
| 4 | | | 10 | | | 16 | | |
| 5 | | | 11 | | | 17 | | |
| 6 | | | 12 | | | 18 | | |

Site:____.2 Date:_____/_____/____ Observers:________________________

| Transect 5 (50 m) all logs > 5 cm diameter where intersecting the transect line within 1.5m above ground | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) |
| 1 | | | 7 | | | 13 | | |
| 2 | | | 8 | | | 14 | | |
| 3 | | | 9 | | | 15 | | |
| 4 | | | 10 | | | 16 | | |
| 5 | | | 11 | | | 17 | | |
| 6 | | | 12 | | | 18 | | |

Site:____.2 Date:_____/_____/____ Observers:________________________

| Transect 7 (50 m) all logs > 5 cm diameter where intersecting the transect line within 1.5m above ground | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) | | Length (cm) | Mid-point diam (cm) |
| 1 | | | 7 | | | 13 | | |
| 2 | | | 8 | | | 14 | | |
| 3 | | | 9 | | | 15 | | |
| 4 | | | 10 | | | 16 | | |
| 5 | | | 11 | | | 17 | | |
| 6 | | | 12 | | | 18 | | |

**TREES AND SHRUBS**



Site:________.1 Date:_____/______/______ Observers:______________________________

| Transect 1 (50m) – Trees; having one stem >=31 cm circumference @ 1.3 m; measure all stems (inc. dead) >=31 cm at 1.3 m high. Shrubs: plants with >3 cm and < 31 cm stem circumferences @ 1.3 m; measure circumference of thickest stem and record total count for multi-stemmed shrubs in brackets. PH (phenology): fl = flowering, fr=fruiting | | | | | |
|---|---|---|---|---|---|
| Tree Species (in 5 m strip) | Circumference (s) | PH | Shrub Species (in 2 m strip) | Circumference (+count) | PH |
| Example: Euc miniata | 31, 45, 62 | fl | Acacia oncinocarpa | 15 (8) | flfr |
| 1 | | | 1 | | |
| 2 | | | 2 | | |
| 3 | | | 3 | | |
| 4 | | | 4 | | |
| 5 | | | 5 | | |
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| 49 | | | 49 | | |
| 50 | | | 50 | | |
| Dist at 50th stem: | | | Dist at 50th stem: | | |

## TREES AND SHRUBS

Site:__________.1

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| **Transect 3 (50 m)** – Trees; having one stem >=31 cm circumference @ 1.3 m; measure all stems (inc. dead) >=31 cm at 1.3 m high. Shrubs: plants with >3 cm and < 31 cm stem circumferences @ 1.3 m; measure circumference of thickest stem and record total count for multi-stemmed shrubs in brackets. PH (phenology): fl = flowering, fr=fruiting | | | | | |
| Tree Species (in 5 m strip) | Circumference (s) | PH | Shrub Species (in 2 m strip) | Circumference (+count) | PH |
| Example: Euc miniata | 31, 45, 62 | fl | Acacia oncinocarpa | 15 (8) | flfr |
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| Dist at 50th stem: | | | Dist at 50th stem: | | |

**TREES AND SHRUBS**



Park:_______________Site:________.2 Date:_____/______/______

Observers:________________________________

**Transcect 5 (50 m)** – Trees; having one stem >=31 cm circumference @ 1.3 m; measure all stems (inc. dead) >=31 cm at 1.3 m high.
Shrubs: plants with >3 cm and < 31 cm stem circumferences @ 1.3 m; measure circumference of thickest stem and record total count for multi-stemmed shrubs in brackets. PH (phenology): fl = flowering, fr=fruiting

| Tree Species (in 5 m strip) | Circumference (s) | PH | Shrub Species (in 2 m strip) | Circumference (+count) | PH |
|---|---|---|---|---|---|
| Example: Euc miniata | 31, 45, 62 | fl | Acacia oncinocarpa | 15 (8) | flfr |
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| Dist at 50th stem: | | | Dist at 50th stem: | | |

Site:__________2

| Transcect 7 (50m) – Trees; having one stem >=31 cm circumference @ 1.3 m; measure all stems (inc. dead) >=31 cm at 1.3 m high. Shrubs: plants with >3 cm and < 31 cm stem circumferences @ 1.3 m; measure circumference of thickest stem and record total count for multi-stemmed shrubs in brackets. PH (phenology): fl = flowering, fr=fruiting | | | | | |
|---|---|---|---|---|---|
| Tree Species (in 5m strip) | Circumference (s) | PH | Shrub Species (in 2m strip) | Circumference (+count) | PH |
| Example: Euc miniata | 31, 45, 62 | fl | Acacia oncinocarpa | 15 (8) | flfr |
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| Dist at 50th stem: | | | Dist at 50th stem: | | |

## POINT INTERCEPTS



Site ________.1 Date: ____/____/____ Observers:_________________

Point intercept type codes (Hit type <1.5m): **AG**=Annual Grass, **PG**=Perennial Grass, **HG**=Hummock Grass, **SE**=Sedge, **FO**=Forb, **WE**=Weed, **SH**=Shrub, **Log**=Log >5cm diam, **O**=Bare Ground, **Lit**=Litter, **RS**=Rock small 2-20cm, **RL**=Rock large >20cm, **BR**=Bedrock. Height intercept cats (Height cat): **1**=0-20cm, **2**=20-40cm, **3**=40cm-1.5m

| Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire | Feral 1 x 1 m quadrat | Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire |
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## POINT INTERCEPTS



Point intercept type codes (Hit type <1.5 m):**AG**=Annual Grass, **PG**=Perennial Grass, **HG**=Hummock Grass, **SE**=Sedge, **FO**=Forb, **WE**=Weed, **SH**=Shrub, **Log**=Log >5cm diam, **O**=Bare Ground, **Lit**=Litter, **RS**=Rock small 2-20cm, **RL**=Rock large >20cm, **BR**=Bedrock. Height intercept cats (Height cat): **1**=0-20cm, **2**=20-40cm, 3=40cm-1.5m

| Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire | Feral 1 x 1 m quadrat | Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire |
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**POINT INTERCEPTS** 

Site ________.2 Date: ____/____/____ Observers:____________________

Point intercept type codes (Hit type <1.5 m):**AG**=Annual Grass, **PG**=Perennial Grass, **HG**=Hummock Grass, **SE**=Sedge, **FO**=Forb, **WE**=Weed, **SH**=Shrub, **Log**=Log >5cm diam, **O**=Bare Ground, **Lit**=Litter, **RS**=Rock small 2-20cm, **RL**=Rock large >20cm, **BR**=Bedrock. Height intercept cats (Height cat): **1**=0-20cm, **2**=20-40cm, 3=40cm-1.5m

| Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire | Feral 1 x 1 m quadrat | Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire |
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## POINT INTERCEPTS



Point intercept type codes (Hit type <1.5 m):**AG**=Annual Grass, **PG**=Perennial Grass, **HG**=Hummock Grass, **SE**=Sedge, **FO**=Forb**, WE**=Weed, **SH**=Shrub, **Log**=Log >5cm diam, **O**=Bare Ground**, Lit**=Litter, **RS**=Rock small 2-20cm, **RL**=Rock large >20cm, **BR**=Bedrock. Height intercept cats (Height cat): **1**=0-20cm, **2**=20-40cm, **3**=40cm-1.5m

| Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire | Feral 1 x 1 m quadrat | Point | Hit type <1.5m | Height cat | For Weeds (WE) identify to species | Hit 1.6-6 m | Fire |
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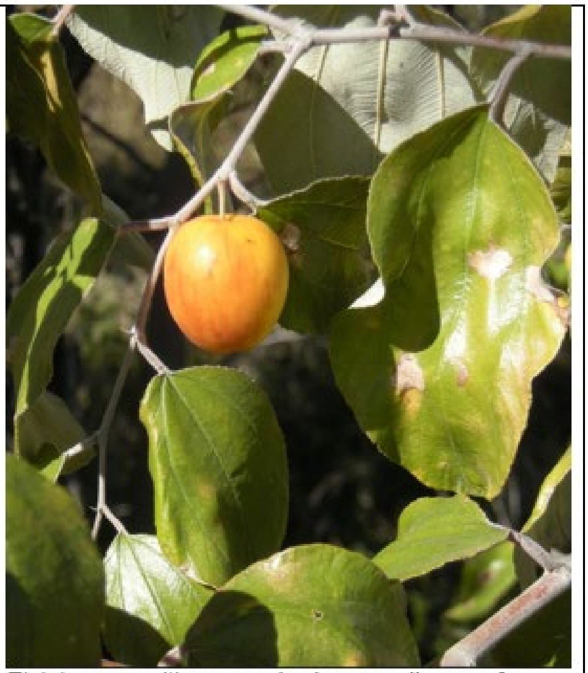
## Appendix 8. Weed Photo Guide

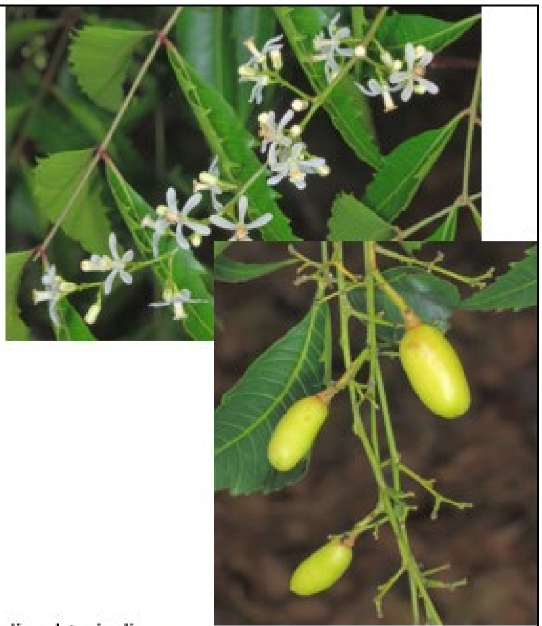
Compiled by Kym Brennan

*Jatropha gossypifolia* – a shrub, 3-lobed leaves, margins of leaves with distinct stalked hairs



*Ziziphus mauritiana* – a shrub or small tree, often with paired spines along the branches, leaves white below, 2 other native species quite similar but their leaves not, or not so white below.

*Calotropis procera* – shrub or small tree, copious milky sap



*Azadirachta indica*
Neem – a small to medium tree, leaves compound pinnate, toothed.

*Ricinus communis* Caster Oil Plant – a robust shrub, usually riparian

*Grewia asiatica* – a robust spreading shrub

*Leucaena leucocephala* –tall shrub / small tree, hard smooth bark. The bipinnate leaves and flowers resemble several native *Vachellia*'s (ex Acacia) but they usually have deep fissured corky bark

*Mimosa pigra* Giant Sensitive Plant – a shrub, very thorny with touch sensitive foliage

| | |
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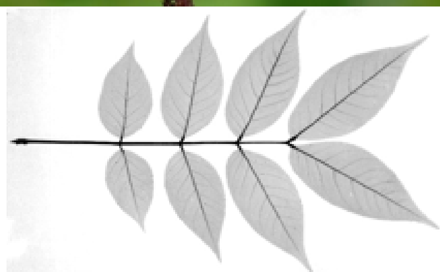
| <br>*Parkinsonia aculeata* – spiny shrub / small tree, leaves congested bipinnate or pinnate, leaflets tiny on a broad rachis | <br>*Senna alata* Candle Bush – spreading shrub, leaves pinnate with oblong medial leaflets. Inflorescence unlike anything else |

| | |
|---|---|
| <br>*Senna obtusifolia* – often a sparse shrub, leaves pinnate wth the medial leaflets widest in the distal half | <br><br>*Senna occidentalis* Coffee Senna – shrubby, leaves pinnate, leaflets widest in the basal half, tapering to a narrow tip |

*Hyptis suaveolens* – mostly herbaceous, sometimes shrubby, strongly aromatic foliage when crushed

*Xanthium sumatranum* – shrubby, fruit covered by distinctive hooked setae

*Martynia annua* – a robust herb or shrub, leaves and stems densely hairy, slimy to touch, malodourous is crushed. Friut with paired recurved spines

*Sesamum orientale* – mostly herbaceous, leaves malodourous when  crushed

*Hibiscus sabdariffa* Rosella – slender spreading shrub, stems deep red

*Gossypium hirsutum* Cottton – shrubby, leaves distinctively black speckles when held to light

*Crotalaria goreensis* – herbaceous, leaves 3-foliate with a relatively long petiole

*Stylosanthes hamata* –
leaves 3-foliate, having a distinctive membranous sheath around the stem below the petiole, Several other species, all weeds. S.humils is the only other one with leaflets of this shape

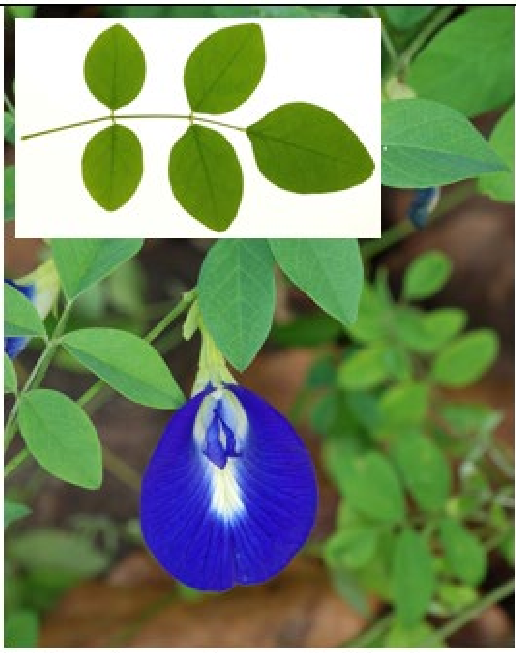
*Chamaecrista rotundifolia* – sprawling herbaceous, distinctive paired leaflets

*Stachytarfetta* spp. –

Several species, all look similar with distinctive long spikes of mauve flowers

*Lantana camera* – shrubby, distinctive clustered flowers orange or mauve

*Cryptostegia grandiflora* – aggressive climbing vine, copoius milky sap – not yet established in NT but slowly spreading W through western Qld, could turn up in Limmen one day



*Clitoria ternatea* – a vigorous climbing vine

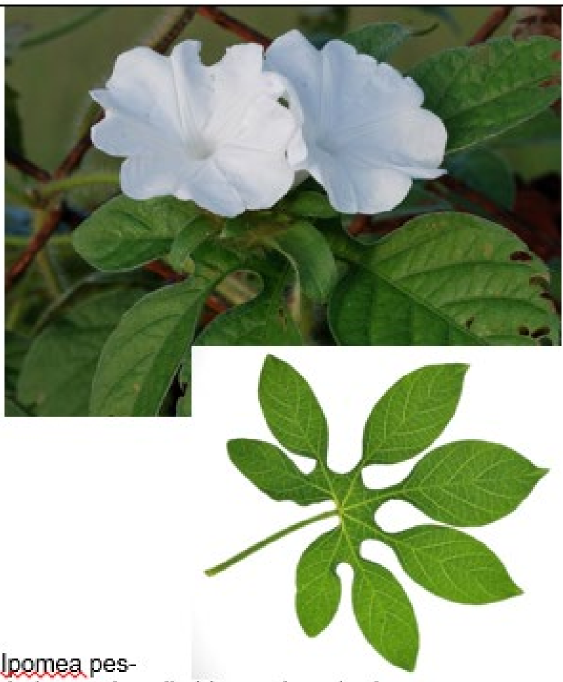
*Centrosema molle* – a vigorous climbing vine

*Passiflora foetida* – a vigorous climbing vine

*Passiflora suberosa* – a vine

Macroptilium atropurpureum – a vine,  ground-running or climbing on low shrubs

Macroptilium lathyroides – usually an erect herb, occasionally a weak climber on low vegetation



Ipomea pes-tigris – a vine climbing on low shrubs

Ipomoea quamoclit – vine, climbing into midstorey vegetation

*Merremia aegyptia* – an aggressive vine in low to mid-level vegetation

Merremia dissecta – an aggressive vine in low to mid-level vegetation

*Calopogonium mucinoides* Calopo Vine – a vigourous ground cover vine

*Andropogon gayanus* Gamba Grass– an aggressive tall perennial grass

*Megathyrsus maximus* Guinea Grass – a moderately tall perennial grass, a couple of native species look a bit similar

*Cenchrus pedicellatus* – Annual Mission Grass – a tall grass with whitish heads

*Cenchrus polystachyus* – Mission Grass – an aggressive tall perennial with greenish heads

| | |
|---|---|
| <br>*Urochloa humidicola* Creeping Signal Grass – a vigorous perennial usually < 1m spreading by stolons. Rich green erect foliage | <br>*Urochloa mosambicensis* Sabi Grass – a low creeping perennial, difficult to distinguish from several other native species |

| | |
|---|---|
| <br>Themeda quadrivalvis – a perennial around 1m high, similar to the native Themeda triandra but has heads that look more congested | |

# Attachments

## Attachment 1. Standard Operating Procedure - Camera trapping for the Top End Ecological Monitoring Program

Last updated: April 2018, G. Gillespie, B. Hill, D. Stokeld, K. Buckley

## Task

Reconyx Hyperfire camera traps are used to detect species as a part of the Top End Long Term Monitoring Program. In particular, camera trapping is useful to record the presence of mammals and some bird species that may not be otherwise detected due to their cryptic or trap-shy nature, or rarity. Data obtained from camera traps can be used to examine spatial and temporal patterns of species distribution, including occupancy, population density estimation and assemblage composition studies. This standard operating procedure for camera trap use is intended to be used in conjunction with the SOP for the Top End Long Term Monitoring Program.

## Camera bookings

The status and availability of Reconyx Hyperfire cameras are listed in the Camera Trap Asset List, found at the following location:

\\Ccs-bas10\Spatial\Working\Biodiversity\Survey\Camera_Traps_Management_NO NERP DATA

Following approval from the Director Terrestrial Ecosystems, camera bookings are to be entered on the Field Planner found at:

\\Ccs-bas10\BAS_DATA\Biodiversity\Survey & Fieldwork Files\Field Trips

The Research Assistant Terrestrial Ecosystems will assist with camera management from that point including maintenance of the Camera Trap Asset List.

## Pre-survey requirements

Prior to any survey work it is imperative that personnel are familiar with the operation of Reconyx Hyperfire cameras. Cameras are also to be loaded with batteries and SD cards. The cameras must have the most recent firmware updates and it must be ensured that settings are configured to the specific requirements of the project, which may vary from project to project. The handheld digital camera used in the field must be prepared with targets for locating bait stations (developed to maximise detections of small species).

### Equipment

Reconyx Hyperfire cameras

Recently charged NiMH (nickel metal hydride) AA batteries

SD cards

Firmware update (available at http://www.reconyx.com/page/firmware)

Lumix handheld digital cameras. Note, Nikon cameras do not consistently display images from camera trap SD cards so Lumix cameras are to be used for this purpose.

Label maker with clear adhesive

**Reconyx Hyperfire camera preparation**

Open the camera housing. Install recently charged batteries and an empty SD card.

On the right hand side of the door there is an ‘on/off’ switch. Flip the switch to the ‘on’ position. Watch the screen, check that batteries charge is greater than 80%, that battery type is set to NiMH, that the SD card is empty, and the date and time are correct. Wait for ‘ARM CAMERA’ to be displayed.

If there is some doubt that the camera is operational Press the ‘<’ button to return to ‘ARM CAMERA’. Press the ‘OK’ button. A countdown timer will start (from 10 seconds).

Check that the rubber seal is clean before closing the unit ensuring a water proof seal.

Move in front of the unit to trigger a photo, and then check that an image has been stored on the camera. The image can be viewed by inserting the SD card into a Lumix handheld digital camera and playing back the images.

**Firmware Update**

Navigate to the SUPPORT tab on the Reconyx website to locate the most recent firmware update. Updates occur on an approximately annual basis.

Check the camera model for the appropriate update – we currently have

HC500, HC550, HC600 and PC850 models which all have the same update.

Upload firmware update onto an SD card then insert SD card into each camera.

Switch on the camera and updates will automatically occur. NOTE previous updates have reset camera settings to default but the 2016 update maintained current camera settings. CHECK or SET camera settings AFTER firmware updates.

**Camera Trap Settings**

Use the Quickset advanced option to check that the camera trigger settings are properly programmed as outlined below. The quickset function provides three pre-programmed trigger configurations in all Reconyx models and an advanced setting which overrides other settings and allows setting manual combinations (Fig. 1).

Check that the sensor sensitivity is set to High.

Set the Picture Interval to “Rapidfire”

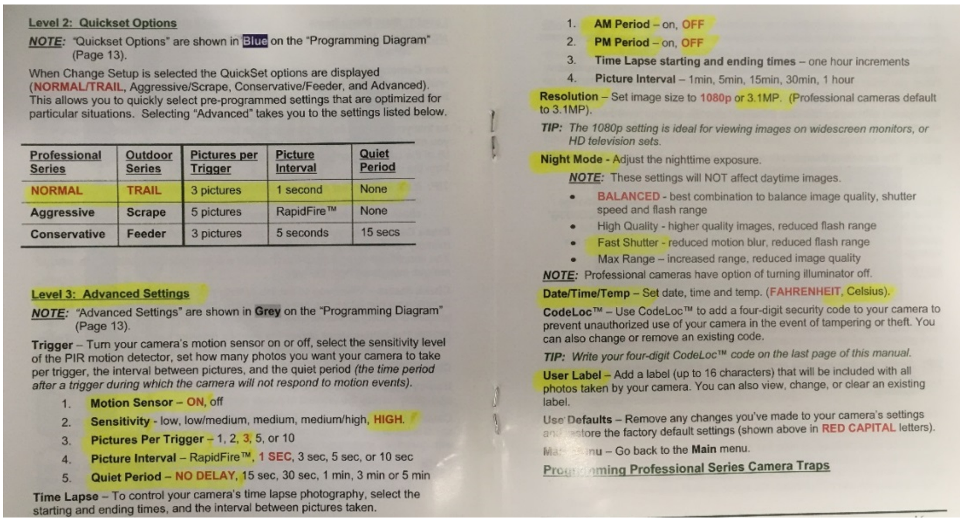
Check that the image resolution is set to 3.1 mega pixels (avoid 1080 pixels as this reduces the area captured in the image).

Set the shutter speed in Night Mode to “Fast Shutter”

Ensure that the Date/Time/Temp are correct and unit of temperature is Celsius.

Ensure that the user label represents the camera code or the site code.

Ensure that the battery type is set to NiMH



**Level 2: Quickset Options**

***NOTE:*** “Quickset Options” are shown in **Blue** on the “Programming Diagram” (Page 13).

When Change Setup is selected the QuickSet options are displayed (NORMAL/TRAIL, Aggressive/Scrape, Conservative/Feeder, and Advanced). This allows you to quickly select pre-programmed settings that are optimized for particular situations. Selecting “Advanced” takes you to the settings listed below.

| Professional Series | Outdoor Series | Pictures per Trigger | Picture Interval | Quiet Period |
|---|---|---|---|---|
| NORMAL | TRAIL | 3 pictures | 1 second | None |
| Aggressive | Scrape | 5 pictures | RapidFire™ | None |
| Conservative | Feeder | 3 pictures | 5 seconds | 15 secs |

**Level 3: Advanced Settings**

***NOTE:*** “Advanced Settings” are shown in **Grey** on the “Programming Diagram” (Page 13).

**Trigger** – Turn your camera’s motion sensor on or off, select the sensitivity level of the PIR motion detector, set how many photos you want your camera to take per trigger, the interval between pictures, and the quiet period *(the time period after a trigger during which the camera will not respond to motion events).*

1. **Motion Sensor** – ON, off
2. **Sensitivity** - low, low/medium, medium, medium/high, HIGH.
3. **Pictures Per Trigger** – 1, 2, 3, 5, or 10
4. **Picture Interval** – RapidFire™, 1 SEC, 3 sec, 5 sec, or 10 sec
5. **Quiet Period** – NO DELAY, 15 sec, 30 sec, 1 min, 3 min or 5 min

**Time Lapse** – To control your camera’s time lapse photography, select the starting and ending times, and the interval between pictures taken.

1. **AM Period** – on, OFF
2. **PM Period** – on, OFF
3. **Time Lapse starting and ending times** – one hour increments
4. **Picture Interval** – 1min, 5min, 15min, 30min, 1 hour

**Resolution** – Set image size to 1080p or 3.1MP. (Professional cameras default to 3.1MP).

***TIP:*** *The 1080p setting is ideal for viewing images on widescreen monitors, or HD television sets.*

**Night Mode** - Adjust the nighttime exposure.

***NOTE:*** These settings will NOT affect daytime images.

- BALANCED - best combination to balance image quality, shutter speed and flash range
- High Quality - higher quality images, reduced flash range
- Fast Shutter - reduced motion blur, reduced flash range
- Max Range – increased range, reduced image quality

***NOTE:*** Professional cameras have option of turning illuminator off.

**Date/Time/Temp** – Set date, time and temp. (FAHRENHEIT, Celsius).

**CodeLoc™** – Use CodeLoc™ to add a four-digit security code to your camera to prevent unauthorized use of your camera in the event of tampering or theft. You can also change or remove an existing code.

***TIP:*** *Write your four-digit CodeLoc™ code on the last page of this manual.*

**User Label** – Add a label (up to 16 characters) that will be included with all photos taken by your camera. You can also view, change, or clear an existing label.

**Use Defaults** – Remove any changes you’ve made to your camera’s settings and restore the factory default settings (shown above in RED CAPITAL letters).

**Main Menu** – Go back to the **Main** menu.

**Programming Professional Series Camera Traps**

Figure 1. Reconyx Hyperfire Quickset and Advanced settings with SOP options highlighted

**Lumix Digital Camera with target for locating bait station**

Prepare a hand held digital camera with a transparent film printed with a small target circle placed on the viewing screen. This is used to correctly aim the Reconyx Hyperfire camera at the bait station (Fig. 2). The position of the black circle is determined pre-survey by using an image known to be centered correctly.

Print a label of capital ‘o’ and 7 spaces (font size 4) - using a label maker and transparent adhesive strip. The spaces allow length to centre the adhesive strip (Fig. 2).

Save an image known to be centred correctly (measured centre on both vertical and horizontal axes) to an SD card.

Load this to the digital camera.

Place the adhesive transparent strip on the screen of each digital camera so that the base of the bait station stake is in the circle.

Mark the camera appropriately and provide spare adhesive strips so that strips may be replaced in the field if required.


Figure 2. Digital camera with label placed on viewing screen (L) and camera trap image showing (R) the positioning of the base of the bait station within the optimal (black circle) location. This may vary for camera models so test each camera with a reference model in order to attach the transparent label correctly.

## Transportation in the field

Reconyx Hyperfire cameras are to be transported in sealed containers and stored in a safe and secure location in the field to prevent damage or theft.

### Equipment

Nally bins with lids and foam padding.

Space cases

Pelican cases

Secure location

### Procedure

Store camera traps in **closed** nally bins, space cases or pelican cases to minimise exposure to dust.

Pack cameras tightly and use foam padding to avoid rubbing and damage to PIR sensor and other screens. This is especially important if vehicles will be traveling on rough roads.

If risk of theft is high then lock camera traps in vehicle.

## Field equipment requirements

| Equipment | Notes |
|---|---|
| **Reconyx Hyperfire cameras** | The Flora and Fauna Division only uses Reconyx Hyperfire cameras and it is recommended that other practitioners use these for data consistency and comparability. For Top End Ecological Monitoring Program only standard white light (RW) and short focal length high sensitivity (RS) cameras are used. |
| **Nally bins with lids and foam padding, space cases and pelican cases** | For safe and secure transport of Reconyx cameras. |
| **Digital memory cards** | 8 GB SDHC cards. |
| **Charged AA batteries** | Each Reconyx Hyperfire camera to be loaded with 12 recently charged AA batteries prior to departure. Additional recently charged batteries for GPS units, and spares for camera traps, should also be packed. |
| **Battery chargers with 12 V (vehicle) and 240 V power cables** | To recharge batteries as required in field. |
| **Camera mounting straps, mounting boards and bolts, and mounting posts** | Camera mounting straps may be bungee straps or cable lock straps in high risk areas. Mounting posts (usually star pickets) are only necessary when trees may not be available. |
| **Compass, GPS or PDA (CyberTracker) and tape measure** | Used for determining and recording site and Reconyx Hyperfire camera locations; and for measuring the height that cameras are set. |
| **Flagging or gaffer tape, aluminium tree tags with nails, and permanent markers.** | To mark camera trap locations. |
| **Lumix handheld digital camera and battery charger** | Used to ensure that the bait station is located correctly and Reconyx Hyperfire camera is operational. Nikon cameras do not consistently display images from camera trap SD cards. |
| **Bait stations, stakes, hammer, cable ties.** | Bait stations are ~80 mm (length) x 55 mm (diameter) PVC pipe with a ventilated end caps to allow scent to escape. The top cap has an |

| | |
|---|---|
| | overhanging cover to reduce bait degradation due to environmental conditions. Bait stations are fixed using cable ties to a metal stake hammered into the ground. 5 metal star steel stakes should be taken into each site in case there are no suitable for attaching cameras. |
| **Marine ply backing for RS camera with drift fences** | The marine ply backing (23 x 12 cm) is attached to the back of the camera allowing it to be deployed with the long edge horizontal. Make a hole in the centre of the board to allow attachment of the camera using a bolt (size ¼” x 15 mm mushroom head). Make two additional holes in the top corners allowing the octopus strap to be threaded through. Make a final hole in the centre of the top edge to fit the bolt (M8 x 120 mm hex head) that will allow adjustment of the camera. Attach two nuts to the bolt, one on each side of the ply, allowing easy adjustments of the camera. |
| **Corkboard and tent pegs** | For RS camera setup specifically targeting reptiles and small mammals, a 30 x 30 cm cork board is used. Drill holes in each corner of the cork board and ply to allow tent pegs through to secure the board in the field. |
| **Drift fences (4 metres) and pegs** | Two drift fences are used for each RS camera set in the middle of the 5 camera array. |
| **Bait, bait mixing and storage containers.** | Standard small mammal bait mix (i.e. peanut butter, rolled oats and honey) should be used for general surveys. If alterative baits or lures are used for specific projects or target species, record on the data sheet which type of bait or lure was used at deployment. |
| **Ant granules** | A small circle of granulated ant poison is placed around the base of each bait station to deter ants and increase the longevity of bait effectiveness. |
| **Leather gloves, shovel and or fire rake, secateurs** | For clearing the camera trap site of any vegetation that may move and cause false triggers. |
| **Camera Trap Deployment Form** | See Appendix 6 |

| | |
|---|---|
| **Camera Trap Retrieval Form** | Generated after the initial deployment of cameras, containing a range of relevant fields (see details within this SOP) |
| **Field note book, pencils, data sheets and folders** | For data recording. |
| **Waypoints of camera sites** | Subsequent to the establishment of sites in the initial round of the Top End Ecological Monitoring Program, a list of camera waypoints should be taken to the site to locate the tree used in previous rounds of monitoring. |
| **Camera trap asset database or spreadsheet** | To record camera number, SD card number, condition, damage or faults. |

## Sampling methodology

These camera trap guidelines have been developed for use in conjunction with the Northern Territory Flora and Fauna Top End Ecological Monitoring Program fauna sampling methods. Five camera traps (comprised of four standard white light (RW) cameras and one short focal length high sensitivity (RS) camera) are deployed for a minimum of five weeks to maximise detection of both native mammals (including dingoes) and feral mammals (including cats). Camera trap deployments at monitoring sites should occur at the time other fauna sampling is undertaken.

The four RW cameras will be set up with a bait station, and the central RS camera will be set up with drift fences and a cork board platform in the centre of the field of view. The cork board creates a more homogenous temperature zone, and therefore more temperature contrast, to improve detection of small mammals in hot savanna environments. The drift fences help to direct mammals to the camera detection zone.

The location of each camera trap at monitoring sites is determined by the 50 x 50 m fauna trapping quadrat (see SOP for Top End Parks Monitoring Program). The RS camera is placed in the centre of the quadrat and the four remaining standard RW cameras are placed in a diamond configuration surrounding the quadrat, each being 50 m from the centre camera (Fig. 3). If logistical constraints prevent this (for example due to a lack of suitable tree supports), the cameras are placed as close as possible to 50 m from the centre camera, with a minimum separation distance of 30 m. In instances where there are no suitable trees a metal start steel stake can be used. GPS is used to measure the distances between cameras creating a total area of coverage as close as possible to 0.5 ha.

Camera traps should be placed in a variety of different micro-habitats within the sampling site to maximise the probability of capturing a variety of species. For example, camera traps may be placed adjacent to animal paths, rock ledges or creek beds; or in areas with contrasting vegetation structures. Avoid deploying camera traps in areas where there is a risk of inundation by flooding during the deployment period.

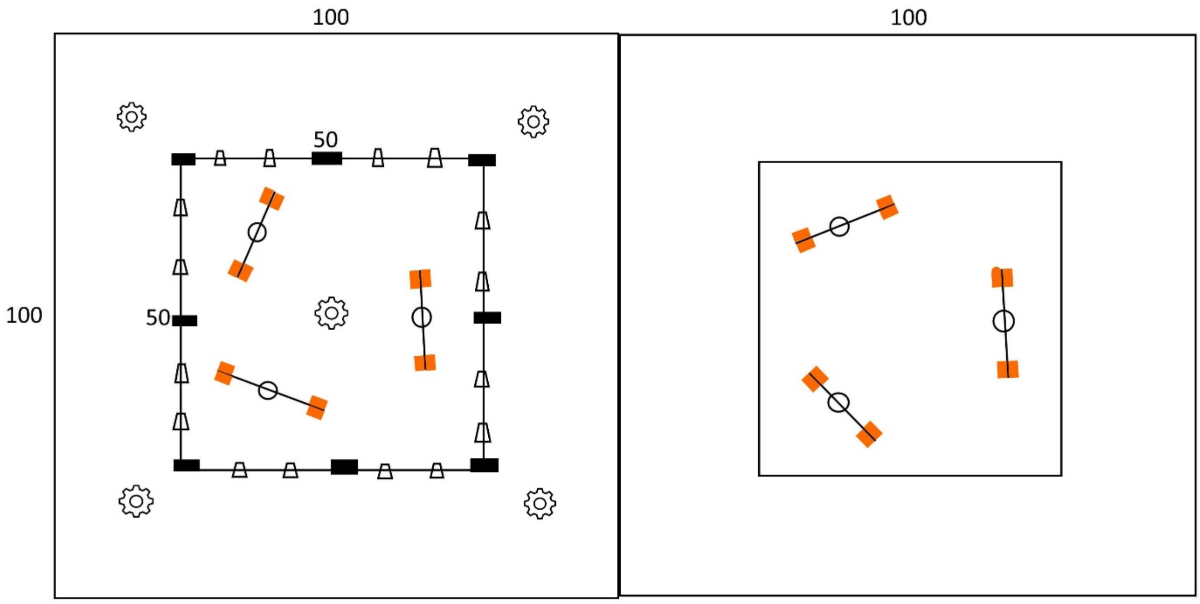


Figure 3. Arrangement of five-camera set up in relation to the Top End Ecological Monitoring Program paired 100 x 100 m plots. 50 x 50 m mammal trapping grid located within the LHS plot, and consists of 3 pits (circles with lines representing 10 meter drift fences), 12 funnels (orange rectangles), 8 cages (at corners and mid pint of each side), 16 Elliott's (along edges between cages), and 5 cameras (cog wheel symbols). The centre camera is a RS and the four outer cameras are RW cameras.

## Field deployment

**Site preparation**

Careful site clearing is important to minimise false triggers, maximise identification of animals and to reduce fire risk to equipment.

Clear all vegetation between the camera and the bait station, and at least 1 m behind the bait station and 1 m surrounding the camera tree. Use a shovel or fire rake and secateurs to remove any low hanging vegetation, grass, sticks, leaves etc. (Fig. 4).

Consider the field of view of the sensor and ensure that vegetation is cleared at least 1.5 m to either side of the bait station.

Remove any other vegetation outside this area may cause false triggers, such as over-hanging branches, or plants that may grow into the sensor field during the deployment period.

If deployment will extend over the period September to May dig out perennial grass and shrub bases of the cleared area.

Avoid piling cleared material right next to the camera station area as this may just blow across the field of vision, triggering false images or impede animal access.

When installing cameras with drift fences, also clear an approximately ten metre strip perpendicular to the camera/bait station orientation (generally east to west) for the drift fence.

Check the camera field of view to verify effective vegetation clearing by triggering the camera and checking photos on the SD card with a digital camera.

Figure 4. Properly prepared site with all grass, shrubs and leaf litter cleared around a camera and bait station. Flagging tape is visible and not obstructing camera trap. Note that clearing for RS cameras includes a strip for the drift fence.

**Bait station installation**

Bait containers are 80 mm PVC pipes with a ventilated end cap on each end to allow scent to escape. An overhanging cover is used to reduce water diluting the bait. A bait ball (mixture of peanut butter, oats and honey which should have a wet and oily consistency) is placed within the bait container and should be the size of a golf ball, no smaller.

Secure each bait station to the fence dropper with a cable tie and knock it into the ground 1.5 m from the camera. The top of the bait station is approximately 30 cm above the ground.

Sprinkle ant granules around the base of the fence dropper.

**Reconyx camera setup**

Select an appropriate camera mounting tree, greater than 20 cm in diameter at chest height, as smaller trees move in the wind causing false triggers. Avoid dead trees. Where there are no suitable trees use a metal star steel stake.

Record the location of the tree with a GPS by selecting ‘Mark’ and entering the site number and corresponding camera number. Do not forget to select ‘Done’ to enter the ID and ‘Done’ again to save the location.

Record the coordinates and the waypoint name on the Camera Trap Deployment Form.

Record the camera number, SD card number, date and time on the Camera Trap Deployment Form (Appendix 6).

Set cameras facing south using a compass. This will prevent sun damage to the camera lens and sensor, glare in the photos and false triggers during sunrise and sunset. This requirement can be relaxed where there is a rock wall or ledge blocking sun interference.

***RS CAMERA SETUP***

Secure the camera to a wooden mounting board.

Mount at 90 degrees so LED globes are on left hand side and the PIR sensor on the right hand side (when facing the camera), so that the latch is on the top of the camera housing at a height of 65 cm. For precision and consistency all distances should be determined by tape measure.

Place the cork board 65 cm from the base of the tree and secure with four tent pegs. This arrangement creates a 90 cm distance from the lens to the middle of the corkboard (Fig. 5).

Angle the camera downward approximately 45° by adjusting the backing screw. Aim the camera so the middle of corkboard is in the centre of the camera field of view – use a small object placed on the centre of the corkboard as a target (Fig. 6).

To install the bait station, secure it to the bait stake with a cable tie and knock it into the ground in the centre of the far edge of the cork board. The top of the bait station is approximately 30 cm above the ground. Sprinkle ant granules around the base of the bait stake.

Using the shovel clear a path for two 4 m drift-fences extending each side the cork board (Fig. 5). Unroll the fence and place the first stake closest to the cork board then pull it tight, secure the end stake and lastly the middle stake. The entire lip of the each fence should be facing the same way. Put excess dirt along the base of the fence so there are no gaps or easy exits (Fig. 6, 7).

Pay attention to the fences being consistently erect along their lengths and ensure there are no obstructions to animal movement along either side of the drift fences.

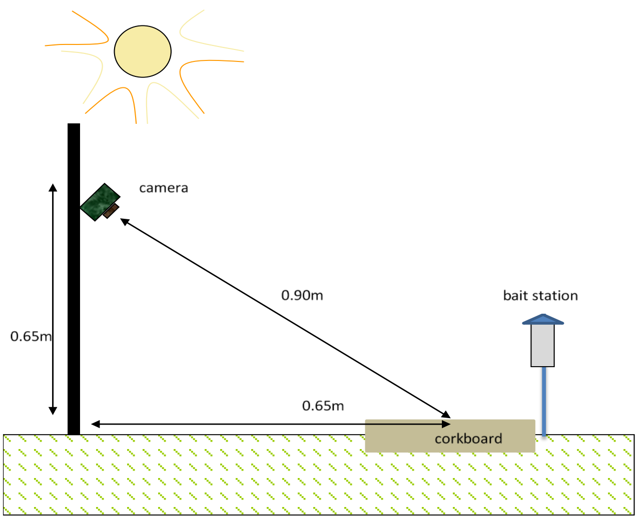



Figure 5. Correct camera deployment arrangement for RS cameras.

Figure 6. Bungee strap and mounting screw used to angle camera to focal point at centre of the corkboard.

Figure 7. Correct drift fence, bait station and camera deployment arrangement for RS cameras.

***RW CAMERA SETUP***

Position the top of the camera housing 40 cm above the ground (Fig. 8). Ensure that the camera is the right way up, with the LED globes on top and the PIR sensor on the bottom.

Angle the camera slightly downward so the base of the bait station stake is within the target circle. Use short sticks or rocks wedged behind the camera to adjust the camera angle. Ensure these wedges do not extend beyond the camera housing to prevent interference by animals at a later date.

Bait stations for all four RW cameras should be installed 1.5 m from the base of the tree. For precision and consistency all distances should be determined by tape measure. Secure each bait station to the stake with cable ties so that the top of the bait station is approximately 30 cm above the ground.

Record the distance that each camera is set from its bait station on the Camera Trap Deployment Form (Appendix 6).

Sprinkle ant granules around the base of the star picket (Fig. 9).

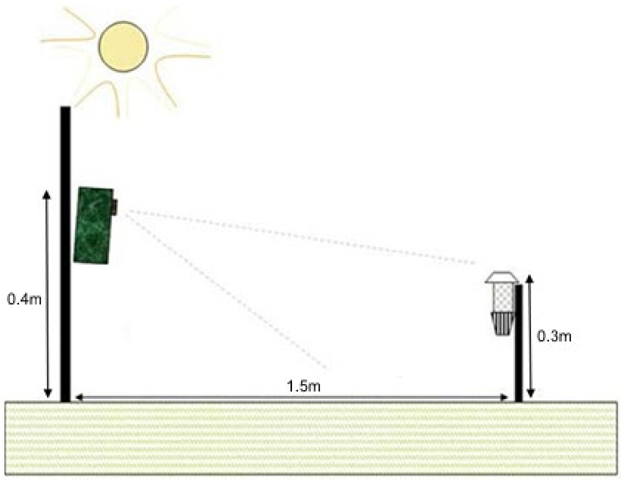



Figure 8. Correct camera deployment arrangement for RW cameras.


Figure 9. Bait station secured to stake with a cable tie (left). Ant granules are visible around the base of the bait station (right).

### Checking and arming cameras

Test that the camera is positioned correctly. Arm the camera. Trigger the camera and check images on the SD card with a hand-held digital camera and target to ensure camera is angled correctly (Fig. 10). Ensure the focal point is within the black circle on the handheld camera to ensure a consistent field of detection. Re-insert the SD card in the camera trap, delete the images, adjust the camera position and repeat the exercise as necessary. This is an essential step as it is known that variations in camera position to bait station have an effect on the detection of animals.

Before leaving the camera trap site: double check that the camera is switched on and that the SD card contains a limited number of setup photos for verification of deployment date. Ensure that the sensor screen and camera lens are clean. Check that there are no obstacles in front of the sensor, flash unit or camera lens, such as branches, straps or flagging tape.

Secure flagging tape above each camera to enable easy relocation of camera trap sites. Ensure flagging tape is long enough to see from a distance but not likely to slip or wave in front of the camera causing false triggers. Avoid flagging if proximity to a road will make the camera vulnerable to theft or vandalism.


Figure 10. Correct camera and bait station positioning (left) compared to incorrect positioning (right).

## Camera trap retrieval

Generate a Camera Trap Retrieval Form for use in the field. The form should list all deployed camera ID’s, SD card numbers, latitude and longitude, date of retrieval, date SD card filled, and have a generous column for comments.

Approach the camera from the front and remove bait station FIRST to trigger the camera trap.

When opening the camera check display screen for trigger event. If screen is blank press the OK button.

If the camera is currently operating it will display the number of images it has recorded.

If the SD card is full it will display “card full” and the date it became full.

If the screen is blank the camera may not working due to battery or camera fail. Check if the camera is working.

Make note of when the SD card became full or if the camera is not working.

Record any site details that may have caused camera failure (fallen camera, camera left off etc.).

## Post-survey requirements

### Equipment

Labelled containers for used and charged batteries

Labelled containers for SD cards

Labelled containers for accessories

Battery chargers

Camera trap asset database or spreadsheet

Cotton buds

Cloths

Soft brushes

Nally bins (open tubs to facilitate airflow)

### Returning cameras

Remove cameras from field storage containers (Nally bins, space and pelican cases) ASAP to prevent exposure to excess condensation through humidity.

Check cameras for condensation moisture, with affected cameras to be dried outside.

Remove batteries and place in appropriate tray for charging.

Remove SD cards and cross check with field metadata to prevent discrepancies.

Upload and clear data from SD cards and store with other blank SD cards in labelled container in camera room.

Once cameras are cleaned and ready for storage or redeployment, cameras must be entered as “returned” on the camera asset spreadsheet/database and the field planner.

Clean all Nally bins, space and pelican cases and ensure they are free of any dust and aired dry. Store in air-conditioned camera room.

### Camera cleaning

Check cameras for any damage to the PIR sensor film, flash screen, camera window, case or latch.

Check cameras inside and out for any plant matter, dust, insect homes or spider webs, particularly under the latch and along the camera seal.

Check camera windows for any dust, condensation, scratches or smudging.

Clean cameras so they are completely free of any foreign material and smudges on seal, body and windows (cleaning equipment is in the grey shelves in the camera storage room).

Place aside for testing any cameras that may have suffered significant damage or any issues that could affect future deployments and note these issues in the camera asset spreadsheet/database.

Alert Research Assistant Terrestrial Ecosystems to any issues.

**Camera storage**

ALWAYS store with Reconyx camera housing doors open (to allow moisture to escape housing) in Nally bins in the air-conditioned camera storage room to allow ventilation and any hidden moisture to escape.

Store camera traps in Nally bins two layers deep with no foam or other divider between layers - to allow air flow.

Ensure the timer fan in storage room is left running after hours and weekends when the air conditioning is not operating, to prevent humidity build up around cameras.

**Bait station cleaning and storage**

Check mounting straps (bungee cords) for damage, loosely tie in bundles of 5 and store in a Nally bin.

Scrub bait stakes free of dirt and store in the shed.

Empty residual bait from all bait stations and notify the Technical Officer – Terrestrial Ecosystems of damage that may affect their subsequent operation.

Soak bait stations, then wash, rinse and dry. Store in the shed.

## Attachment 2. Standard Operation Procedure - Scat collection for DNA analysis for the Top End Ecological Monitoring Program

Last updated: March 2018, L. Einoder, B. Hill, K, Buckley

Scat identification is an important method for use at monitoring sites, providing an opportunity to increase the detection of a range of vertebrates not detected using other standard survey methods of the Top End Ecological Monitoring Program. Scats from a range of species can be identified with confidence, such as echidnas, emus, dogs, cats, pigs, and macropods. Collection of scats of some animal groups is necessary for species identification (e.g. Nabarlek and Wilkins' Rock-wallaby), or for e-DNA and dietary analysis. For these reasons, identification of scats is required, and collection of relevant scats is required.

To maximise value from scat collection, it is important that correct equipment is used in the field, samples are appropriately selected for collection, and all associated data and photos are recorded and stored appropriately. On return to Flora and Fauna, it is vital that the data and photos are entered into corporate databases, and that the samples are stored or transferred to the appropriate museum or research group. This standard operating procedure outlines the steps involved for this process to occur successfully.

### General requirements

Scats detected during a range of surveys methods (e.g. active searches) are to be recorded where they can confidently be attributed to a species (e.g. echidna, emu, dog, cat, pigs).

Attempts should be made to identify macropod scats using the macropod scat identification key.

Nabarlek and Wilkins' Rock-wallaby must be collected using the methods detailed herein.

Carnivore scats should be identified to species and recorded on datasheets, and collected using the methods detailed herein.

Owl pellets are also of value and should be collected using the methods detailed herein.

### Macropod Scat Identification Key

The Field Guide 'Tracks, Scats and Other Traces' by Barbara Triggs is a valuable resource and should be used in the field to aid in the identification of mammal scats. Figures and Tables below are from: Telfer, W.R., Griffiths A.D., and Bowman, D.M.J.S (2006) Scats can reveal the presence and habitat use of cryptic rock-dwellings macropods. Australian Journal of Zoology. 54:325-334.

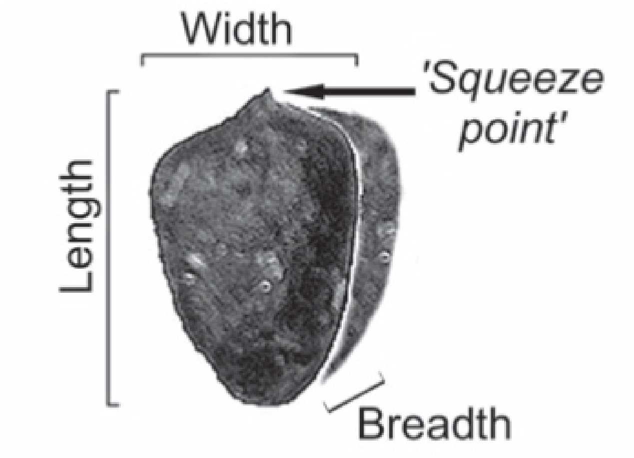



**Fig. 1.** Characteristics of scats measured for the scat-identification key.

**Table 1. Size characteristics and collection locations of the scats of the seven macropod species and the rock ringtail possum (*Petropseudes dahli*) in the monsoon tropics of the Northern Territory**

| Species | No. scats measured | Length (mm) Mean | Length (mm) Range | Width (mm) Mean | Width (mm) Range | Breadth (mm) Mean | Breadth (mm) Range |
|---|---|---|---|---|---|---|---|
| *Macropus agilis* | 500 | 22.7 | 11.5–41.8 | 15.9 | 10.7–25.8 | 12.4 | 8.7–21.1 |
| *M. antilopinus* | 180 | 24.9 | 11.1–41.5 | 20.1 | 11.5–28.3 | 15.7 | 10.5–22.4 |
| *M. bernardus* | 300 | 24.7 | 13.4–38.6 | 19.9 | 11.9–28.5 | 14.5 | 7.8–20.9 |
| *M. robustus* | 140 | 24.2 | 14.5–35.9 | 22.9 | 12.5–30.5 | 16.1 | 10.0–19.8 |
| *Petrogale brachyotis* | 500 | 17.1 | 7.0–32.4 | 10.5 | 5.5–14.5 | 8.6 | 4.2–17.8 |
| *P. concinna* | 100 | 10.3 | 6.9–14.3 | 8.7 | 6.1–12.0 | 7.1 | 4.4–9.7 |
| *Onychogalea unguifera* | 35 | 20.4 | 11.1–37.3 | 12.3 | 7.0–19.0 | 10.4 | 5.8–14.5 |
| *Petropseudes dahli* | 120 | 18.0 | 13.5–25.8 | 7.0 | 5.4–8.9 | 6.6 | 3.8–8.5 |

**Table 2. Categories of scat condition used in measurement of persistence and decay of *Petrogale brachyotis* scats in experiments at Litchfield National Park**

| Category | Description |
|---|---|
| 1 | Shiny black or dark brown, dried mucous coating still present, pellets firm and no signs of breakdown; sand particles may be adhering to pellets |
| 2 | Matte black/brown, pellets firm and no signs of cracking or breakdown |
| 3 | Dull black/brown, 0–25% light-coloured fibres showing, cracking |
| 4 | Dull black/brown, 25–50% light-coloured fibres showing, cracking |
| 5 | Patchy dull black to grey, 50–75% light-coloured fibres showing, weathered appearance |
| 6 | Generally dull grey, 75–100% light-coloured fibres showing, weathered appearance and often crumbly to touch |
| 7 | Signs of insect damage visible, or half eaten |

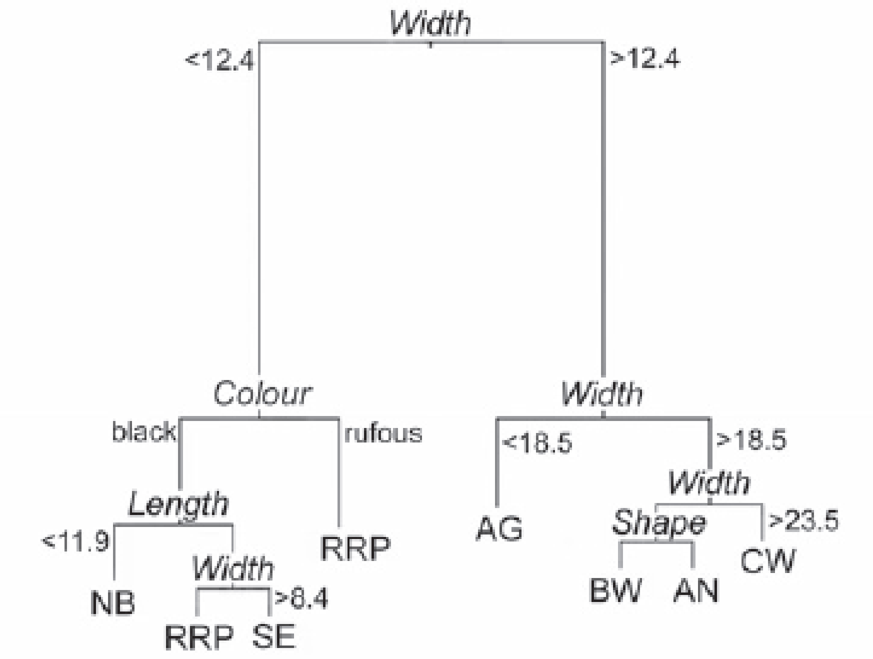



**Fig. 2.** Classification tree model of the scats of the macropods and associated species of the monsoon tropics of the Northern Territory. AG, agile wallaby (*Macropus agilis*); AN, antilopine wallaroo (*M. antilopinus*); BW, black wallaroo (*M. bernardus*); CW, common wallaroo (*M. robustus*); NB, nabarlek (*Petrogale concinna*); RRP, rock ringtail possum (*Petropseudes dahli*); SE, short-eared rock-wallaby (*Petrogale brachyotis*). Scat measurements are in millimetres.

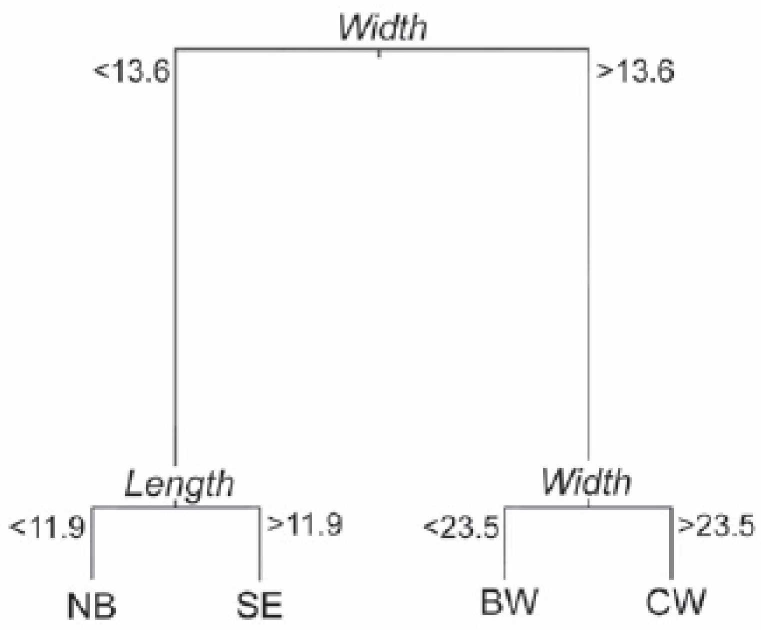



**Fig. 3.** Classification tree model of the scats of the rock-dwelling macropods of the monsoon tropics of the Northern Territory. BW, black wallaroo (*Macropus bernardus*); CW, common wallaroo (*M. robustus*); NB, nabarlek (*Petrogale concinna*); SE, short-eared rock-wallaby (*Petrogale brachyotis*). Scat measurements are in millimetres.

## Scat Collection for DNA analysis

### *For Nabarlek and rock-wallaby*

ONLY collect scats in the relevant size range. Not bigger than your little fingernail —see key (over) for details

Only collect where the majority of the scats are small —so it is unlikely that they are from a juvenile rock wallaby with adults.

Scats from a single location are likely to be from the same individual, so collect only 1—2 per site

Choose the freshest scats they will be black and glossy. Do not collect old grey ones.

Collect into paper envelopes —you have some supplied. Plastic makes them sweat and go mouldy.

ONE sample per envelope to limit cross-contamination—if you collected >1 from a site make sure that is clear on the collection envelope (i.e. sample 1 of 2 and provide same site name)

DO NOT handle scats with bare hands. Human DNA can cause cross-contamination resulting in false analyses. Use fresh latex gloves or tweezers to put scats into envelopes.

Fill in ALL of the relevant details on the envelope.

### *For predator scats and owl pellets*

Collect into paper envelopes —you have some supplied. Plastic makes them sweat and go mouldy

ONE sample per envelope to limit cross-contamination—if you collected >1 from a site make sure that is clear on the collection envelope (i.e. sample 1 of 2 and provide same site name)

DO NOT handle scats with bare hands. Human DNA can cause cross-contamination resulting in false analyses. Use fresh latex gloves or tweezers to put scats into envelopes

Fill in ALL of the relevant details on the envelope.

## Filling in the Label

SITE— If close to a survey site please use site name and N1, N2 to indicate scat collection number (eg LNP001_N1)

DATE—date sample collected

LAT and LONG—use coordinates for actual collection site

SAMPLE ___ of _____ - indicate how many samples

LOCATION— optional description of where scats were collected so someone could find it again

DETAILS—this is for the details of the scat dump. Include details such as approx. number of scats present and proportion that were small.

When you return to the office ensure that Brydie or Kate are aware of the samples and are arranging for them to be sent to the museum for analysis.

**Reference Photo, when ID cannot be established**

If unsure of macropod species ID take a photo of scats with a reference object for size in image.

**Storage of specimens and data management**

DNA degrades quickly so it’s important the samples are processed as soon as possible.

If possible store them in a freezer. If not somewhere they will not sweat or get wet

When you return to the office ensure that Brydie or Kate are aware of the samples and are arranging for them to be sent to the museum for analysis.

**Equipment**

Paper envelopes

Callipers

Camera with macro mode

Forceps

Labels

Pencils

## Attachment 3. Standard Operation Procedure - Genetics Sampling and Vouchering of Terrestrial Vertebrate Specimens

Last updated: October 2017, D. Stokeld, K. Buckley

Historically, morphometric characters have been used to identify species and highlight phylogenetic relationships. However, with the development of molecular techniques and population genetic statistics, new species have been described from organisms that don't present obvious morphological differences. Cryptic diversity, defined as two or more distinct species that were classified as a single species due to morphological similarity, is believed to be a potentially important factor influencing future conservation decisions.

For these reasons, the Flora and Fauna Division requires genetic samples from a range of vertebrate species from across the Northern Territory, collected alongside morphological data. As a general rule, up to five samples from a species within a locally-defined trapping/study area is a good sample size, but for some species more samples may be required to answer specific management or research questions.

To maximise value from sample collection, it is important that correct equipment and resources are used in the field, samples and specimens are appropriately selected for collection, and all associated data and photos are recorded and stored appropriately. On return to Flora and Fauna, it is vital that the data and photos are entered into corporate databases, and that the samples and specimens are stored or transferred to the appropriate museum or research group. This standard operating procedure outlines the steps involved for this process to occur successfully.

**General requirements**

All specimen handling and vouchering be undertaken in association with appropriate AEC approvals and permits

AEC approval conditions may place additional conditions/restrictions beyond this Standard Operation Procedure.

Personnel undertaking genetics sampling must be a Flora and Fauna Divisional staff member ("staff member"), or operating under the direct supervision of a staff member.

Personnel undertaking genetics sampling require experience in animal handling techniques.

Personnel undertaking genetics sampling are to be trained in tissue sampling techniques.

Personnel undertaking vouchering of specimens must be a staff member authorised to possess and use a Schedule 4 substance by Medicines and Poisons Control ("authorised staff"). See Standard Operating Procedure for Lethabarb: *\\Ccs-bas10\bas_data\Biodiversity\Survey & Fieldwork Files\SOPs\Drugs*

**Preparation of sampling equipment in the laboratory**

Genetic sampling. Colour coded (or otherwise marked) Cryovials of RNALater or analytical grade absolute ethanol are to be prepared in the laboratory prior to fieldwork. The use of ethanol must be recorded in the ethanol log book. Field sample numbers are to be inserted into vials, with vials stored in a labelled box. Sample numbers are to be laser printed on goatskin parchment and baked at 170 °C for 1 min to set the ink. Corresponding printed sticky labels are to be used for data sheets and the outside of vials or voucher containers to facilitate processing or archiving. Field sample numbers can be obtained from the Technical Officer – Terrestrial Ecosystems.

RNALater is a preserving medium that enables a larger amount of genetic information to be extracted from samples than those stored in ethanol.

Goatskin parchment is archival grade paper made without the use of formaldehyde.

Absolute ethanol (analytical grade) is not denatured with additives that can interfere with genetic extractions.

Vouchering. Voucher sampling kits are to be prepared in the laboratory (see Appendix 1). Authorised staff are also to check and prepare their Lethabarb kits for fieldwork as per the Standard Operating Procedure for Lethabarb: *\\Ccs-bas10\bas_data\Biodiversity\Survey & Fieldwork Files\SOPs\Drugs*

Formalin solution: preparation of 100 ml of 34.5 % concentrated formaldehyde diluted with water to 1 L. Strong formalin contains about 40 % formaldehyde gas, so this 1 in 10 dilution contains about 4% of the gas. The diluted solution is referred to as 10 % formalin or 4% formaldehyde.

Field kits are to be checked and prepared in the laboratory prior to fieldwork. It is the responsibility of individual staff to decontaminate equipment and appropriately store all chemicals as per the relevant Material Safety Data Sheets (located in the laboratory or via the internet).

**Data collection**

A Flora and Fauna (FF ####) field sample number is to be assigned to each tissue sample and voucher specimen. All data will be stored against this number. These numbers are to be inserted into Cryovials in the laboratory (see *Preparation of sampling equipment in the laboratory*).

Data are to be recorded as per the Flora and Fauna Terrestrial Group Genetics Datasheet and all relevant fields are to be completed. Datasheet is stored at: *\\Ccs-bas10\bas_data\Biodiversity\Survey & Fieldwork Files\Genetic samples and voucher specimens*

Take good photos of dorsal and lateral view of animals sampled to show colour and patterns; this is particularly important where there is no voucher specimen.

Reduce data errors by including the specimen number in the photo and noting the SD card or camera number.

Photographs of gecko lamellae (pads under toes) may be useful for diagnostic purposes.

**Genetics samples**

Take a maximum of 5 samples per species per site.

Due to the risk of an animal escaping whilst processing, obtaining a genetic sample should be undertaken prior to obtaining morphometric measurements or photographs. Prepare sampling equipment (sharp stainless steel scissors or lab mouse ear punch) by cleaning with an alcohol swab or RNase AWAY wipes (NOT bleach as this destroys DNA). Prepare animal surface by wiping with an alcohol swab and use one cut to obtain the sample (see Table 1).

If an animal has escaped but a tissue sample was obtained, keep the sample and document the loss on the Genetics Datasheet.

Place the tissue sample in a colour coded Cryovial of RNALater or absolute ethanol (analytical grade).

Photograph the animal and then take all morphometric measurements.

Record all details on the Genetics Datasheet.

Release animals as soon as possible at the point of capture.

Table 1. Tissue samples required from vertebrate animal groups for genetics.

| Animal Group | Tissue sample Required |
|---|---|
| Small mammals | Ear clip |
| Limbed lizards | Tail clip (1-2 mm, BUT adjust to size of animal) |
| Snakes/legless lizards | Tail clip, or 1-2 ventral scale clips |
| Frogs | Toe clip at $1^{st}$ or $2^{nd}$ joint of long toe on hind foot or from finger (2-4 mm, not from thumbs) |
| Blind snakes | Voucher only: remove liver material from voucher specimens prior to fixing |

## Voucher specimens

Animals to voucher may include: any animal found dead in Elliott, cage and pit traps that is still intact (not half eaten by ants), not desiccated or decomposing; road kill (especially snakes, lizards and small mammals); and taxa with high taxonomic uncertainty (Table 2).

If there is no opportunity to immediately take a tissue sample and formalin-fix specimens then they can be refrigerated or frozen.

Carefully photograph the animal (live if possible) and then take all morphometric measurements.

Take a genetic and/or liver sample and record all details on the Genetics Datasheet.

Your voucher specimen number is the same as the genetic sample number.

Euthanise animal using acceptable methods (only by those with training and authorisation).

Table 2. Taxa with high taxonomic uncertainty that may be collected as voucher specimens.

| Common name | Scientific name |
|---|---|
| Small dasyurids | *Dasyuridae* |
| Blind snakes | *Typhlopidae* |
| Children's pythons | *Antaresia* |
| Elapid snakes | Elapidae |
| Agamid lizards | *Diporiphora* |
| Geckos | *Crenadactylus, Gehyra, Heteronotia, Lucasium, Oedura, Strophurus* |
| Skinks | *Cryptoblepharus, Ctenotus* |

**Euthanasia and vouchering methods**

Staff administering Lethabarb must be authorised as per the Standard Operating Procedure for Lethabarb: *\\Ccs-bas10\bas_data\Biodiversity\Survey & Fieldwork Files\SOPs\Drugs*

**Reptiles**: an acceptable euthanasia method is barbiturate overdose (Lethabarb). Intraperitoneal route - enter the abdominal cavity anterior (in front) of a hind leg.

Intra-cardiac – inject directly into the heart, this should only be performed on unconscious animals

Intravenous route– injection into the dorsal tail vein, dorsal midline of the tail (large reptiles only). *Should only be performed by experienced people

**Frogs**: an acceptable euthanasia method is barbiturate overdose (Oral-eze)

Subcutaneous absorption – place 1 drop on the ventral surface of small frogs, 2 or more drops for larger frogs until death is achieved

**Mammals**: an acceptable euthanasia method is barbiturate overdose (Lethabarb)

Intravenous route

Intra-peritoneal or intra-cardiac route after sedation

After euthanasia check for signs of death: absence of respiration and heart beat and loss of corneal reflex (no response when the eye is touched - only applicable to animals with moveable eyelids, not snakes or lizards with spectacles).

OPTIONAL: Sample the liver (remove gall bladder), or take a snip from a larger liver, and store in the same Cryovial as the genetic sample. Larger liver samples should be cut into several pieces (1-2 $mm^3$) before placing in the vial.

After processing the animal, use cotton to attach a label with the specimen number to the body (tie around the mid-body between front and hind legs, or around a hind leg for larger animals). Your voucher specimen number is the same as the genetic sample number.

Inject body cavities with formalin solution. Medium to large species with heavy muscle or fat (such as gecko tails) need to have these areas injected with formalin. All specimens should be lightly pricked with a needle tip to allow better absorption of formalin into tissue.

Place a layer of Chux or hand paper towelling on the formalin tray base, between each layer of animals and on top. Moisten each Chux with formalin solution. Ensure surface is moist, but animals should not be 'swimming' in formalin (Figure 1). ALWAYS WEAR gloves when using formalin and work in a well-ventilated area.

Use a fine probe or forceps to arrange limbs and toes naturally, separating and straightening toes so they do not overlap. This allows taxonomists to accurately examine and measure the specimen. Do not bulk-drum reptile and frog specimens, as this will result in curled toes and limbs, and potential loss of important morphological characteristics.

Snakes can be coiled flat in the tray with the head on the inside of the coil. Larger snakes may need to be coiled in a jar and covered with formalin (Figure 2).

Lizards and geckos should be placed belly down with the limbs, tail and toes extended (Figure 2).

Frogs should be placed belly-down with the limbs extended and the fingers and toes separated and extended (Figure 3).

Figure 1. Example of a formalin tray and layering of voucher specimens.

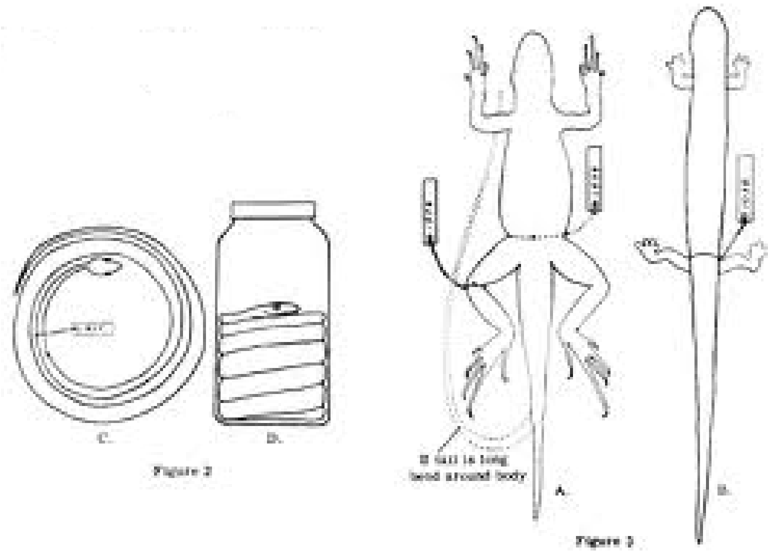



Figure 2. Preservation positions for snakes, lizards and geckos.

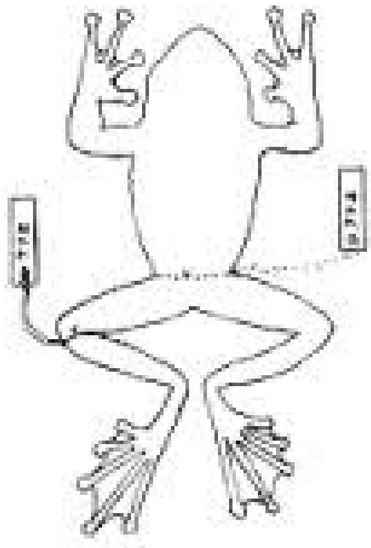



Figure 3. Preservation position for frogs.

**Storage of specimens and data management**

**Genetic samples** - On return to the office/lab, samples stored in RNALater are to be placed in the laboratory freezer. Samples stored in absolute ethanol can be stored in the ventilation hood or the laboratory fridge. *SAMPLES MUST NOT BE LEFT IN FIELD KITS OR OFFICES.*

**Voucher Specimens** - On return to the office/lab, it is the responsibility of individual staff to transfer collected specimens into 70% denatured ethanol after rinsing in water. Specimens require fixing in formalin for varying lengths of time dependent on the taxonomic group, prior to transfer into ethanol (Table 3). Specimens are then to be stored in the ventilation hood.

Wear gloves and always work in a well-ventilated area (outside) or a functional and well maintained fume hood. Use appropriate procedures outlined in MSDS.

**Data sheets** - are to be given to the person responsible for data management ("responsible person"), who is to enter all data into the Genetics and Voucher Specimen Data spreadsheet and store photographs in the same location. Responsible person for Berrimah is the Technical Officer – Terrestrial Ecosystems. The Genetics and Voucher Specimen Data spreadsheet is located at: \\Ccs-bas10\bas_data\Biodiversity\Survey & Fieldwork Files\Genetic samples and voucher specimens

**Photographs** - are to be given to the responsible person, who is to store photographs in the same location as the Genetics and Voucher Specimen Data spreadsheet. Photos of animals must be coded with the Specimen Number so that they match the recorded data. Identify multiple photos for an animal as follows FF0296a, FF0296b, FF0296c, etc.

The responsible person is to forward all genetic samples and voucher specimens and associated data for analysis or long term storage as follows;

Individual researchers as current requirements dictate.

Museum and Art Gallery of the Northern Territory (MAGNT) for voucher specimens. MAGNT will accept specimens formalin-fixed and stored in 70% denatured ethanol. Some frozen specimens may be accepted.

South Australian Museum (SAM) for genetic samples Exception: Glider samples may be sent to Teigan Cremona, CDU.

MAGNT and SAM are to provide the responsible person with museum accession numbers, who will then record accession numbers on the Genetics and Voucher Specimen Data spreadsheet.

Table 3. Fixation time in 4% formaldehyde required for different taxonomic groups. Table sourced from SOP No 8.1 Vouchering vertebrate fauna specimens, DEC Nature Conservation Service.

| Taxonomic Group | Preservation Method |
|---|---|
| Mammals | Frozen or fixed in formalin solution for 7 days, rinsed in water and transferred to 70% denatured ethanol |
| Birds | Frozen or fixed in formalin solution for 7 days, rinsed in water and transferred to 70% denatured ethanol |
| Reptiles (small) | Frozen or fixed in formalin solution for 2-3 days, rinsed in water and transferred to 70% denatured ethanol |
| Reptiles (large) | Frozen or fixed in formalin solution for 7 days, rinsed in water and transferred to 70% denatured ethanol |
| Frogs | Fixed in formalin solution for 1 day, rinsed in water and transferred to 70% denatured ethanol. Do not freeze. |

### Samples and specimens not collected according to protocol

If a specimen has been preserved in ethanol *before* obtaining a tissue sample in RNALater, then subsequent tissue samples obtained from the specimen should be stored in absolute ethanol (analytical grade). Any vial with ethanol preserved genetic samples should be labelled as such so that it is clear that it is not RNALater.

Tissue samples cannot be obtained from any specimen that has been fixed in formalin. Obtain tissue samples prior to formalin fixing.

Specimens that have been frozen before tissue samples have been obtained should be sampled and the tissue stored in RNALater. However, ideally tissues should be collected before the specimen is defrosted as the cells will lyse, followed rapidly by DNA degradation, once the tissues are defrosted.

**Equipment**

Ziplock bags for holding skinks and frogs

Calico specimen bags for holding lizards and mammals

Callipers

Camera with macro mode

Lab mouse ear punches

Fine forceps

Sharp scissors

Alcohol swabs

Cryovials prepared with RNALater or absolute ethanol and storage box

Data sheets or PDA with software

Pencils for data recording

Camera

Forceps for dissection

Small sharp tipped scissors for dissection

Needles 25G, 27G

Syringes 1 ml, 3 ml

Sharps container

Lethabarb kit

Oral-eze (with 1 ml syringe)

Nitrile gloves

Formalin solution (with dedicated syringe and needle)

70% denatured ethanol

Museum tags (voucher labels)

Chux cloths

Formalin trays (rectangular leak-proof plastic container).

# Appendix II. List of mammal species detected by habitat type

Species listed under the EPBC Act or NT Territory Parks and Wildlife Act (TPWCA): VU – Vulnerable, EN – Endangered, CR – Critically Endangered. Number of sites occupied (OCC); Habitat types: LW – Lowland Woodland, RW – Riparian Woodland, RSW/H – Rugged Sandstone Woodland/heathland, SW – Sandstone Woodland, ALLO – Allosyncarpia, WR – Wet Rainforest, DR – Dry Rainforest. Asterix indicates introduced species.

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agile wallaby | *Notamacropus agilis* | | | 27 | + | + | | + | | + | + |
| Antilopine wallaroo | *Osphranter antilopinus* | | | 8 | + | | + | | + | | + |
| Arnhem rock-rat | *Zyzomys maini* | VU | | 9 | | | + | | + | | + |
| Black wallaroo | *Osphranter bernardus* | | | 19 | + | + | + | + | + | | + |
| Black-footed tree-rat | *Mesembriomys gouldii gouldii* | EN | | 4 | + | + | | | | | |
| Northern brushtail possum | *Trichosurus vulpecula arnhemensis* | VU | | 8 | + | + | | | | | |
| Common rock-rat | *Zyzomys argurus* | | | 12 | | + | + | + | + | | + |
| Common wallaroo | *Osphranter robustus* | | | 12 | + | + | + | + | + | | |
| Delicate mouse | *Pseudomys delicatulus* | | | 2 | + | | | | | | + |
| Dingo | *Canis familiaris* | | | 30 | + | + | + | + | + | + | + |
| Fawn antechinus | *Antechinus bellus* | VU | EN | 2 | + | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Grassland melomys | *Melomys burtoni* | | | 13 | | + | + | + | | + | |
| Kakadu pebble-mouse | *Pseudomys calabyi* | | | 1 | | | | + | | | |
| Northern brown bandicoot | *Isoodon macrourus* | | | 11 | + | + | + | | + | | |
| Northern quoll | *Dasyurus hallucatus* | EN | R | 7 | + | + | + | | | | |
| Pale field-rat | *Rattus tunneyi* | | VU | 6 | + | + | + | + | | | |
| Red-cheeked dunnart | *Sminthopsis virginiae* | | | 1 | | | | + | | | |
| Rock ringtail | *Petropseudes dahli* | | | 2 | | | | | + | | + |
| Sandstone pseudantechinus | *Pseudantechinus bilarni* | | | 8 | | | + | | + | | + |
| Savanna glider | *Petaurus ariel* | | | 8 | + | + | + | + | + | | + |
| Short-beaked echidna | *Tachyglossus aculeatus* | | | 13 | + | + | + | + | + | | + |
| Water rat | *Hydromys chrysogaster* | | | 9 | | + | | | | + | |
| Western chestnut mouse | *Pseudomys nanus* | | | 1 | | | | + | | | |
| Wilkins' rock-wallaby | *Petrogale wilkinsi* | | | 7 | | | + | + | + | | + |
| Planigale | *Planigale* | | | 5 | | | + | | | | + |
| Black rat | * *Rattus rattus* | | | 26 | + | + | + | + | + | + | + |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cat | * *Felis catus* | 32 | + | + | + | + | + | + | + |
| Cattle | * *Bos taurus* | 10 | + | + | | | | + | |
| Donkey | * *Equus asinus* | 5 | + | + | | | | + | |
| Horse | * *Equus caballus* | 3 | + | + | | + | | | |
| Pig | * *Sus scrofa* | 23 | + | + | | | + | + | + |
| Swamp buffalo | * *Bubalus bubalis* | 12 | + | + | | | | + | + |

## Appendix III. List of bird species detected by habitat type.

Species listed under the EPBC Act or NT Territory Parks and Wildlife Act (TPWCA): VU – Vulnerable, EN – Endangered, CR – Critically Endangered. Number of sites occupied (OCC); Habitat types: LW – Lowland Woodland, RW – Riparian Woodland, RSW/H – Rugged Sandstone Woodland/heathland, SW – Sandstone Woodland, ALLO – Allosyncarpia, WR – Wet Rainforest, DR – Dry Rainforest.

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arafura fantail | *Rhipidura dryas* | | | 2 | | + | | | | + | |
| Australasian figbird | *Sphecotheres vieilloti* | | | 2 | | + | | | + | | |
| Australian boobook | *Ninox boobook* | | | 6 | + | + | + | + | | | |
| Australian bustard | *Ardeotis australis* | | | 1 | | + | | | | | |
| Australian owlet-nightjar | *Aegotheles cristatus* | | | 11 | + | + | | | + | + | + |
| Australian white ibis | *Threskiornis molucca* | | | 3 | | + | | | | + | |
| Azure kingfisher | *Ceyx azureus* | | | 1 | | | | | | + | |
| Banded honeyeater | *Cissomela pectoralis* | | | 15 | + | + | + | + | + | | |
| Bar-breasted honeyeater | *Ramsayornis fasciatus* | | | 2 | | + | | | | | |
| Barking owl | *Ninox connivens* | | | 4 | | + | | | | + | |
| Bar-shouldered dove | *Geopelia humeralis* | | | 32 | + | + | + | + | + | + | + |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Black kite | *Milvus migrans* | | | 4 | + | | | | | + | |
| Black-banded fruit-dove | *Ptilinopus alligator* | | | 7 | | + | + | | + | | + |
| Black-faced cuckoo-shrike | *Coracina novaehollandiae* | | | 15 | + | + | + | + | + | + | |
| Black-faced woodswallow | *Artamus cinereus* | | | 1 | | + | | | | | |
| Black-necked stork | *Ephippiorhynchus asiaticus* | | | 2 | | + | | | | | |
| Black-shouldered kite | *Elanus axillaris* | | | 1 | | | | + | | | |
| Black-tailed treecreeper | *Climacteris melanura* | | | 8 | + | | | | | | |
| Blue-faced honeyeater | *Entomyzon cyanotis* | | | 5 | + | | | | | + | |
| Blue-winged kookaburra | *Dacelo leachii* | | | 25 | + | + | + | | + | + | |
| Brolga | *Antigone rubicunda* | | | 3 | | | + | + | + | | |
| Brown falcon | *Falco berigora* | | | 7 | + | + | + | | + | | + |
| Brown goshawk | *Accipiter fasciatus* | | | 12 | | + | + | + | + | + | |
| Brown honeyeater | *Lichmera indistincta* | | | 33 | + | + | + | + | + | + | + |
| Brown quail | *Coturnix ypsilophora* | | | 5 | + | + | + | + | | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brush cuckoo | *Cacomantis variolosus* | | | 1 | | + | | | | | |
| Buff-sided robin | *Poecilodryas cerviniventris* | | | 1 | | + | | | | | |
| Bush stone-curlew | *Burhinus grallarius* | | | 2 | + | + | | | | | |
| Channel-billed cuckoo | *Scythrops novaehollandiae* | | | 2 | | + | + | | | | |
| Chestnut-backed button-quail | *Turnix castanotus* | | | 2 | + | | | | | | |
| Chestnut-quilled rock-pigeon | *Petrophassa rufipennis* | | | 7 | | | + | | + | | |
| Cicadabird | *Coracina tenuirostris* | | | 1 | | | + | | | | |
| Collared sparrowhawk | *Accipiter cirrocephalus* | | | 5 | + | + | + | | | + | |
| Common bronzewing | *Phaps chalcoptera* | | | 5 | + | + | + | | | | |
| Crimson finch | *Neochmia phaeton* | | | 3 | + | | | | | + | |
| Diamond dove | *Geopelia cuneata* | | | 6 | + | + | + | + | | | |
| Dollarbird | *Eurystomus orientalis* | | | 2 | | + | | | + | | |
| Double-barred finch | *Taeniopygia bichenovii* | | | 3 | | + | + | | | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dusky honeyeater | *Myzomela obscura* | | | 21 | + | + | + | + | + | + | |
| Fairy martin | *Petrochelidon ariel* | | | 1 | + | | | | | | |
| Forest kingfisher | *Todiramphus macleayii* | | | 11 | + | + | | | + | + | |
| Fork-tailed swift | *Apus pacificus* | | | 5 | + | | + | + | + | | + |
| Galah | *Eolophus roseicapilla* | | | 4 | + | | | | | + | |
| Golden-headed cisticola | *Cisticola exilis* | | | 2 | + | + | | | | | |
| Great bowerbird | *Ptilonorhynchus nuchalis* | | | 22 | + | + | + | + | + | + | + |
| Great egret | *Ardea modesta* | | | 1 | | + | | | | | |
| Green-backed gerygone | *Gerygone chloronota* | | | 9 | | + | | | + | + | |
| Green Oriole | *Oriolus flavocinctus* | | | 11 | | + | + | | + | + | |
| Grey fantail | *Rhipidura albiscapa* | | | 2 | + | + | | | | | |
| Grey goshawk | *Accipiter novaehollandiae* | | | 1 | | | | | | + | |
| Grey shrike-thrush | *Colluricincla harmonica* | | | 8 | + | + | | | + | | |
| Grey-crowned babbler | *Pomatostomus temporalis* | | | 4 | + | | | | + | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Grey-headed honeyeater | *Lichenostomus keartlandi* | | | 2 | | | + | + | | | |
| Helmeted friarbird | *Philemon buceroides* | | | 16 | + | + | + | | + | + | |
| Intermediate egret | *Ardea intermedia* | | | 1 | + | | | | | | |
| Jacky winter | *Microeca fascinans* | | | 1 | | + | | | | | |
| Large-tailed nightjar | *Caprimulgus macrurus* | | | 1 | | | | + | | | |
| Leaden flycatcher | *Myiagra rubecula* | | | 15 | + | + | + | | + | + | |
| Lemon-bellied flycatcher | *Microeca flavigaster* | | | 8 | + | + | | | | + | |
| Little bronze-cuckoo | *Chalcites minutillus* | | | 1 | | | | | | + | |
| Little corella | *Cacatua sanguinea* | | | 5 | + | + | + | | | | |
| Little friarbird | *Philemon citreogularis* | | | 22 | + | + | + | + | + | + | + |
| Little shrike-thrush | *Colluricincla megarhyncha* | | | 11 | + | + | + | | + | + | |
| Little woodswallow | *Artamus minor* | | | 7 | + | + | + | + | | | |
| Long-tailed finch | *Poephila acuticauda* | | | 1 | + | | | | | | |
| Magpie-lark | *Grallina cyanoleuca* | | | 4 | + | + | + | | | + | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Masked finch | *Poephila personata* | | | 4 | + | + | + | | | | |
| Masked woodswallow | *Artamus personatus* | | | 1 | | | + | | | | |
| Mistletoebird | *Dicaeum hirundinaceum* | | | 19 | + | + | + | + | + | | + |
| Nankeen kestrel | *Falco cenchroides* | | | 3 | | | + | | | | |
| Nankeen night-heron | *Nycticorax caledonicus* | | | 4 | + | + | | | | + | |
| Northern fantail | *Rhipidura rufiventris* | | | 19 | + | + | + | + | + | + | |
| Northern rosella | *Platycercus venustus* | | | 10 | + | + | + | + | + | + | |
| Olive-backed oriole | *Oriolus sagittatus* | | | 4 | + | + | | | + | | |
| Orange-footed scrubfowl | *Megapodius reinwardt* | | | 10 | | + | + | | + | + | |
| Pacific baza | *Aviceda subcristata* | | | 2 | + | | + | | | | |
| Pacific emerald dove | *Chalcophaps longirostris* | | | 11 | | + | + | + | + | + | |
| Pallid cuckoo | *Cacomantis pallidus* | | | 1 | | + | | | | | |
| Partridge pigeon | *Geophaps smithii smithii* | VU | VU | 2 | + | | | | | + | |
| Peaceful dove | *Geopelia placida* | | | 38 | + | + | + | + | + | + | + |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Peregrine falcon | *Falco peregrinus* | | | 1 | | | + | | | | |
| Pheasant coucal | *Centropus phasianinus* | | | 11 | + | + | + | + | + | + | |
| Pied butcherbird | *Cracticus nigrogularis* | | | 12 | + | | + | + | + | | |
| Pied cormorant | *Phalacrocorax varius* | | | 1 | | | | | | + | |
| Radjah shelduck | *Radjah radjah* | | | 2 | | + | | | | | |
| Rainbow bee-eater | *Merops ornatus* | | | 35 | + | + | + | + | + | + | + |
| Rainbow pitta | *Pitta iris* | | | 9 | | + | | | + | + | |
| Red goshawk | *Erythrotriorchis radiatus* | VU | VU | 1 | | | | | | + | |
| Red-backed fairy-wren | *Malurus melanocephalus* | | | 1 | | + | | | | | |
| Red-backed kingfisher | *Todiramphus pyrrhopygius* | | | 2 | + | | | + | | | |
| Red-browed pardalote | *Pardalotus rubricatus* | | | 1 | | | + | | | | |
| Red-collared lorikeet | *Trichoglossus rubritorquis* | | | 32 | + | + | + | + | + | + | + |
| Red-tailed black-cockatoo | *Calyptorhynchus banksii* | | | 11 | + | | | + | | + | |
| Red-winged parrot | *Aprosmictus erythropterus* | | | 21 | + | + | + | + | + | + | + |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Restless flycatcher | *Myiagra nana* | | | 7 | | + | + | | + | | |
| Rose-crowned fruit-dove | *Ptilinopus regina* | | | 1 | | + | | | | | |
| Rufous whistler | *Pachycephala rufiventris* | | | 32 | + | + | + | + | + | + | |
| Rufous-banded honeyeater | *Conopophila albogularis* | | | 3 | + | + | | | | | |
| Rufous-throated honeyeater | *Conopophila rufogularis* | | | 7 | + | + | + | | + | | |
| Sacred kingfisher | *Todiramphus sanctus* | | | 4 | | + | + | + | | + | |
| Sandstone shrike-thrush | *Colluricincla woodwardi* | | | 8 | | | + | | + | | |
| Shining flycatcher | *Myiagra alecto* | | | 5 | | + | | | | + | |
| Silver-backed butcherbird | *Cracticus argenteus* | | | 1 | + | | | | | | |
| Silver-crowned friarbird | *Philemon argenticeps* | | | 27 | + | + | + | + | + | + | |
| Singing honeyeater | *Gavicalis virescens* | | | 1 | | + | | | | | |
| Spangled drongo | *Dicrurus bracteatus* | | | 20 | + | + | + | | + | + | + |
| Spotted nightjar | *Eurostopodus argus* | | | 1 | | | + | | | | |
| Straw-necked ibis | *Threskiornis spinicollis* | | | 3 | + | + | | | | + | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Striated pardalote | *Pardalotus striatus* | | | 22 | + | + | + | + | + | | + |
| Sulphur-crested cockatoo | *Cacatua galerita* | | | 23 | + | + | + | + | + | + | |
| Tawny frogmouth | *Podargus strigoides* | | | 12 | + | + | + | + | + | | |
| Torresian crow | *Corvus orru* | | | 38 | + | + | + | + | + | + | + |
| Torresian imperial pigeon | *Ducula spilorrhoa* | | | 1 | | | | + | | | |
| Varied lorikeet | *Psitteuteles versicolor* | | | 12 | + | + | + | + | | + | + |
| Varied triller | *Lalage leucomela* | | | 12 | + | + | | | + | + | |
| Variegated fairy-wren | *Malurus lamberti* | | | 4 | + | | + | | | | |
| Weebill | *Smicrornis brevirostris* | | | 12 | + | + | | | + | | |
| Whistling kite | *Haliastur sphenurus* | | | 17 | + | + | + | + | + | + | |
| White-backed swallow | *Cheramoeca leucosterna* | | | 1 | | | | + | | | |
| White-bellied cuckoo-shrike | *Coracina papuensis* | | | 26 | + | + | + | | + | + | |
| White-bellied sea-eagle | *Haliaeetus leucogaster* | | | 3 | | + | + | | | | |
| White-breasted woodswallow | *Artamus leucorynchus* | | | 1 | | + | | | | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| White-browed woodswallow | *Artamus superciliosus* | | | 1 | | | | | + | | |
| White-faced heron | *Egretta novaehollandiae* | | | 1 | | + | | | | | |
| White-gaped honeyeater | *Stomiopera unicolor* | | | 11 | + | + | | | + | + | |
| White-lined honeyeater | *Meliphaga albilineata* | | | 2 | | + | + | | | | |
| White-throated gerygone | *Gerygone olivacea* | | | 1 | + | | | | | | |
| White-throated grasswren | *Amytornis woodwardi* | VU | VU | 1 | | | + | | | | |
| White-throated honeyeater | *Melithreptus albogularis* | | | 22 | + | + | | + | + | + | |
| White-winged triller | *Lalage sueurii* | | | 8 | + | | + | + | | + | |
| Willie wagtail | *Rhipidura leucophrys* | | | 20 | + | + | + | + | + | + | |
| Yellow-tinted honeyeater | *Ptilotula flavescens* | | | 2 | | + | + | | | | |

# Appendix IV. List of reptile species detected by habitat type

Species listed under the EPBC Act or NT Territory Parks and Wildlife Act (TPWCA): VU – Vulnerable, EN – Endangered, CR – Critically Endangered. Number of sites occupied (OCC); Habitat types: LW – Lowland Woodland, RW – Riparian Woodland, RSW/H – Rugged Sandstone Woodland/heathland, SW – Sandstone Woodland, ALLO – Allosyncarpia, WR – Wet Rainforest, DR – Dry Rainforest.

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Two-spined rainbow-skink | *Carlia amax* | | | 32 | + | + | + | + | + | | + |
| Slender rainbow-skink | *Carlia gracilis* | | | 12 | + | + | | | | + | + |
| Shaded-litter rainbow-skink | *Carlia munda* | | | 8 | + | + | | | | | |
| Red-sided rainbow-skink | *Carlia rufilatus* | | | 2 | | | | | + | | + |
| Desert rainbow-skink | *Carlia triacantha* | | | 3 | | + | | | | | |
| Wall skinks | *Cryptoblepharus spp.* | | | 28 | + | + | + | + | | + | + |
| Jabiluka ctenotus | *Ctenotus arnhemensis* | | | 3 | + | + | | | + | | |
| White-faced ctenotus | *Ctenotus borealis* | | | 9 | + | + | + | + | + | | |
| Brown-backed ctenotus | *Ctenotus coggeri* | | | 5 | | | + | + | | | |
| Ten-lined ctenotus | *Ctenotus decaneurus* | | | 1 | | | + | | | | |
| Lowlands plain-backed ctenotus | *Ctenotus essingtonii* | | | 16 | + | + | + | | | | + |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Magela ctenotus | *Ctenotus gagudju* | | | 2 | + | | | | | | |
| Top End lowlands ctenotus | *Ctenotus hilli* | | | 1 | + | | | | | | |
| Bar-shouldered ctenotus | *Ctenotus inornatus* | | | 10 | + | + | + | | + | + | + |
| Kurnbudj ctenotus | *Ctenotus kurnbudj* | | | 1 | + | | | | | | |
| Straight-browed ctenotus | *Ctenotus spaldingi* | | | 2 | | | + | | + | | |
| Storr's ctenotus | *Ctenotus storri* | | | 3 | + | | | | | | |
| Sharp-browed ctenotus | *Ctenotus superciliaris* | | | 7 | + | | + | | | | + |
| Scant-striped ctenotus | *Ctenotus vertebralis* | | | 9 | | | + | + | + | | |
| Orange-sided bar-lipped skink | *Eremiascincus douglasi* | | | 1 | | + | | | | | |
| Northern bar-lipped skink | *Eremiascincus isolepis* | | | 12 | + | + | + | + | + | + | + |
| Northern mulch-skink | *Glaphyromorphus darwiniensis* | | | 12 | + | + | | | + | + | + |
| Lesser robust fine-lined slider | *Lerista karlschmidti* | | | 2 | + | | | | | + | |
| North-eastern orange-tailed slider | *Lerista orientalis* | | | 2 | + | | | | | | |
| Arnhem Coast fine-lined slider | *Lerista stylis* | | | 1 | | | | | + | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jabiluka dwarf skink | *Menetia concinna* | | | 3 | + | | | | | | |
| Common dwarf skink | *Menetia greyii* | | | 3 | + | | + | | | | |
| Northern dwarf skink | *Menetia maini* | | | 2 | + | | + | | | | |
| Lined fire-tailed skink | *Morethia ruficauda* | | | 8 | + | | + | | + | | + |
| Northern fire-tailed skink | *Morethia storri* | | | 10 | + | + | + | + | | | + |
| Ornate soil-crevice skink | *Notoscincus ornatus* | | | 5 | + | | | | + | | + |
| Northern soil-crevice skink | *Proablepharus tenuis* | | | 5 | + | | + | | + | | |
| Northern blue-tongue | *Tiliqua scincoides intermedia* | | | 1 | | | | | | | + |
| Zig-zag gecko | *Amalosia rhombifer* | | | 13 | + | + | + | + | + | | |
| Northern dtella | *Gehyra australis* | | | 18 | + | + | + | + | + | | |
| Northern spotted rock dtella | *Gehyra nana* | | | 16 | + | + | + | + | + | | + |
| Arnhem Land watercourse dtella | *Gehyra pamela* | | | 10 | + | | + | + | + | | + |
| Bynoe's gecko | *Heteronotia binoei* | | | 27 | + | + | + | + | + | | + |
| North-west prickly gecko | *Heteronotia planiceps* | | | 5 | | | + | | + | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pale-striped ground gecko | *Lucasium immaculatum* | | | 1 | | | | + | | | |
| Yellow-snouted ground gecko | *Lucasium occultum* | EN | VU | 2 | + | | | | | | |
| Northern knob-tailed gecko | *Nephrurus sheai* | | | 4 | | | + | | + | | + |
| Dotted velvet gecko | *Oedura gemmate* | | | 11 | | + | + | + | + | | + |
| Marbled velvet gecko | *Oedura marmorata* | | | 2 | + | | | | | | + |
| Northern giant cave gecko | *Pseudothecadactylus lindneri* | | | 6 | | | + | | + | | + |
| Rusty-topped delma | *Delma borea* | | | 5 | + | | | + | | | |
| Burton's legless lizard | *Lialis burtonis* | | | 3 | | | + | | + | | |
| Northern hooded scaly-foot | *Pygopus steelescotti* | | | 2 | + | | | + | | | |
| Frilled lizard | *Chlamydosaurus kingii* | | | 3 | + | | | + | | | |
| Slater’s ring-tail dragon | *Ctenophorus slateri* | | | 2 | | | + | | | | |
| White-lipped dragon | *Diporiphora albilabris* | | | 1 | + | | | | | | |
| Arnhem Land two-lined dragon | *Diporiphora arnhemica* | | | 1 | | | | | + | | |
| Two-lined dragon | *Diporiphora bilineata* | | | 20 | + | | + | + | + | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Northern savannah two-pored dragon | *Diporiphora sobria* | | | 1 | + | | | | | | |
| Water dragon spp. | *Gowidon/Lophognathus* | | | 1 | | + | | | | | |
| Ridge-tailed monitor | *Varanus acanthurus* | | | 2 | | | + | | + | | |
| Black-spotted spiny-tailed monitor | *Varanus baritji* | | | 5 | | + | + | + | | | + |
| Kimberley rock monitor | *Varanus glauerti* | | | 3 | | | | | + | | + |
| Black-palmed monitor | *Varanus glebopalma* | | | 8 | | + | + | + | + | | |
| Sand goanna | *Varanus gouldii* | | | 1 | + | | | | | | |
| Mertens' water monitor | *Varanus mertensi* | | VU | 3 | | + | | | | + | |
| Mitchell's water monitor | *Varanus mitchelli* | | VU | 2 | | + | | | | | |
| Yellow-spotted monitor | *Varanus panoptes* | | VU | 4 | | + | | | | | + |
| Northern ridge-tailed monitor | *Varanus primordius* | | | 1 | | | | | | | + |
| Spotted tree monitor | *Varanus scalaris* | | | 13 | + | + | + | + | + | | |
| Black-headed monitor | *Varanus tristis* | | | 10 | + | | + | + | + | | |
| Northern blind snake | *Anilios diversus* | | | 1 | | | | + | | | |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Darwin blind snake | *Anilios tovelli* | | | 1 | + | | | | | | |
| Children's python | *Antaresia children* | | | 4 | + | | + | | | | |
| Black-headed python | *Aspidites melanocephalus* | | | 2 | | | | | + | | |
| Water python | *Liasis fuscus* | | | 1 | | + | | | | | |
| Olive python | *Liasis olivaceus* | | | 1 | | | + | | | | |
| Carpet python | *Morelia spilota* | | | 1 | + | | | | | | |
| Oenpelli python | *Nyctophilopython oenpelliensis* | | VU | 1 | | | | + | | | |
| Brown tree snake | *Boiga irregularis* | | | 2 | | + | | | | | |
| Common tree snake | *Dendrelaphis punctulatus* | | | 3 | | + | | | | | |
| Slaty-grey snake | *Stegonotus cucullatus* | | | 5 | | + | | | | + | + |
| Keelback | *Tropidonophis mairii* | | | 3 | | + | | | | | |
| Rough-scaled death adder | *Acanthophis rugosus* | | | 3 | | + | | | + | + | |
| Northern shovel-nosed snake | *Brachyurophis roperi* | | | 6 | + | + | | | | | |
| Northern small-eyed snake | *Cryptophis pallidiceps* | | | 5 | | + | + | | | | + |

| Common name | Scientific name | EPBC | TPWCA | OCC | LW | RW | RSW/H | SW | ALLO | WR | DR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Olive whipsnake | *Demansia olivacea* | | | 1 | + | | | | | | |
| Greater black whipsnake | *Demansia papuensis* | | | 8 | + | + | | | + | + | |
| Sombre whipsnake | *Demansia quaesitor* | | | 1 | | | | + | | | |
| Black whipsnake | *Demansia vestigiata* | | | 3 | | + | | | | + | |
| Orange-naped snake | *Furina ornata* | | | 7 | + | + | + | | + | | |
| Coastal taipan | *Oxyuranus scutellatus* | | | 1 | | + | | | | | |
| Western pygmy mulga snake | *Pseudechis weigeli* | | | 2 | | | + | | + | | |
| Northern brown snake | *Pseudonaja nuchalis* | | | 4 | + | + | + | | | | |
| Little spotted snake | *Suta punctata* | | | 1 | | | | + | | | |
| Intermediate bandy-bandy | *Vermicella intermedia* | | | 1 | + | | | | | | |

# Appendix V. Kakadu fauna that can be monitored effectively with current program

List of vertebrate species found in Kakadu National Park for which the revised Top End Ecological Monitoring Program is expected to be capable of detecting trends with relatively high sensitivity or confidence. These species have high estimates of detection probability using the revised monitoring methods, and the proposed set of sampling locations adequately sample their known habitat. * Introduced species

| Common Name | Species Name | Monitoring Objective |
|---|---|---|
| **Threatened Species** | | |
| Arnhem Rock-rat | *Zyzomys maini* | Change/Decline |
| Black-footed Tree-rat | *Mesembriomys gouldii* | Recovery |
| Common Brushtail Possum | *Trichosurus vulpecula arnhemensis* | Recovery |
| Fawn Antechinus | *Antechinus bellus* | Recovery |
| Nabarlek | *Petrogale concinna* | Recovery |
| Northern Quoll | *Dasyurus hallucatus* | Recovery |
| Pale Field-rat | *Rattus tunneyi* | Recovery |
| Partridge Pigeon | *Geophaps smithii* | Recovery |
| **Mammals** | | |
| Agile Wallaby | *Macropus agilis* | Change/Decline |

| | | |
|---|---|---|
| Antilopine Wallaroo | *Macropus antilopinus* | Change/Decline |
| Black Rat | * *Rattus rattus* | Management |
| Black Wallaroo | *Macropus bernardus* | Change/Decline |
| Cat | * *Felis catus* | Management |
| Cattle | * *Bos taurus* | Management |
| Common Rock-rat | *Zyzomys argurus* | Change/Decline |
| Common Wallaroo | *Macropus robustus* | Change/Decline |
| Delicate Mouse | *Pseudomys delicatulus* | Recovery |
| Dingo | *Canis lupus* | Management |
| Grassland Melomys | *Melomys burtoni* | Change/Decline |
| Kakadu Dunnart | *Sminthopsis bindi* | Recovery |
| Northern Brown Bandicoot | *Isoodon macrourus* | Recovery |
| Pig | * *Sus scrofa* | Management |
| Red-cheeked Dunnart | *Sminthopsis virginiae* | Recovery |
| Sandstone Antechinus | *Pseudantechinus bilarni* | Recovery |

| | | |
|---|---|---|
| Short-beaked Echidna | *Tachyglossus aculeatus* | Change/Decline |
| Western Chestnut Mouse | *Pseudomys nanus* | Recovery |
| Wilkins' Rock-wallaby | *Petrogale wilkinsi* | Recovery |
| **Birds** | | |
| Banded Honeyeater | *Cissomela pectoralis* | Change/Decline |
| Bar-shouldered Dove | *Geopelia humeralis* | Change/Decline |
| Black-faced Cuckoo-shrike | *Coracina novaehollandiae* | Change/Decline |
| Black-tailed Treecreeper | *Climacteris melanura* | Change/Decline |
| Brown Falcon | *Falco berigora* | Change/Decline |
| Brown Goshawk | *Accipiter fasciatus* | Change/Decline |
| Brown Honeyeater | *Lichmera indistincta* | Change/Decline |
| Chestnut-quilled Rock-Pigeon | *Petrophassa rufipennis* | Change/Decline |
| Diamond Dove | *Geopelia cuneata* | Change/Decline |
| Dusky Honeyeater | *Myzomela obscura* | Change/Decline |
| Forest Kingfisher | *Todiramphus macleayii* | Change/Decline |

| | | |
|---|---|---|
| Great Bowerbird | *Ptilonorhynchus nuchalis* | Change/Decline |
| Grey Shrike-thrush | *Colluricincla harmonica* | Change/Decline |
| Helmeted Friarbird | *Philemon buceroides* | Change/Decline |
| Leaden Flycatcher | *Myiagra rubecula* | Change/Decline |
| Little Friarbird | *Philemon citreogularis* | Change/Decline |
| Little Shrike-thrush | *Colluricincla megarhyncha* | Change/Decline |
| Long-tailed Finch | *Poephila acuticauda* | Recovery |
| Masked Finch | *Poephila personata* | Recovery |
| Mistletoebird | *Dicaeum hirundinaceum* | Change/Decline |
| Northern Fantail | *Rhipidura rufiventris* | Change/Decline |
| Northern Rosella | *Platycercus venustus* | Change/Decline |
| Orange-footed Scrubfowl | *Megapodius reinwardt* | Change/Decline |
| Peaceful Dove | *Geopelia striata* | Change/Decline |
| Pheasant Coucal | *Centropus phasianinus* | Change/Decline |
| Pied Butcherbird | *Cracticus nigrogularis* | Change/Decline |

| | | |
|---|---|---|
| Rainbow Bee-eater | *Merops ornatus* | Change/Decline |
| Red-collared Lorikeet | *Trichoglossus haematodus* | Change/Decline |
| Red-tailed Black-cockatoo | *Calyptorhynchus banksii macrorhynchus* | Change/Decline |
| Red-winged Parrot | *Aprosmictus erythropterus* | Change/Decline |
| Rufous Whistler | *Pachycephala rufiventris* | Change/Decline |
| Rufous-throated Honeyeater | *Conopophila rufogularis* | Change/Decline |
| Silver-crowned Friarbird | *Philemon argenticeps* | Change/Decline |
| Southern Boobook | *Ninox novaeseelandiae* | Change/Decline |
| Spangled Drongo | *Dicrurus bracteatus* | Change/Decline |
| Striated Pardalote | *Pardalotus striatus* | Change/Decline |
| Sulphur-crested Cockatoo | *Cacatua galerita* | Change/Decline |
| Tawny Frogmouth | *Podargus strigoides* | Change/Decline |
| Torresian Crow | *Corvus orru* | Change/Decline |
| Varied Lorikeet | *Psitteuteles versicolor* | Change/Decline |
| Varied Triller | *Lalage leucomela* | Change/Decline |

| | | |
|---|---|---|
| Weebill | *Smicrornis brevirostris* | Change/Decline |
| Whistling Kite | *Haliastur sphenurus* | Change/Decline |
| White-bellied Cuckoo-shrike | *Coracina papuensis* | Change/Decline |
| White-gaped Honeyeater | *Lichenostomus unicolor* | Change/Decline |
| White-throated Honeyeater | *Melithreptus albogularis* | Change/Decline |
| White-winged Triller | *Lalage sueurii* | Change/Decline |
| Willie Wagtail | *Rhipidura leucophrys* | Change/Decline |
| Yellow Oriole | *Oriolus flavocinctus* | Change/Decline |
| **Reptiles** | | |
| Northern Shovel-nosed Snake | *Brachyurophis roperi* | Change/Decline |
| Two-Spined Rainbow Skink | *Carlia amax* | Change/Decline |
| Slender Rainbow Skink | *Carlia gracilis* | Change/Decline |
| Shaded-litter Rainbow-skink | *Carlia munda* | Change/Decline |
| Wall skinks | *Cryptoblepharus spp.* | Change/Decline |
| Northern Ctenotus | *Ctenotus borealis* | Change/Decline |

| | | |
|---|---|---|
| Port Essington Ctenotus | *Ctenotus essingtonii* | Change/Decline |
| Plain Ctenotus | *Ctenotus inornatus* | Change/Decline |
| Sharp-browed Ctenotus | *Ctenotus superciliaris* | Change/Decline |
| Scant-Striped Ctenotus | *Ctenotus vertebralis* | Change/Decline |
| Rusty-topped Delma | *Delma borea* | Change/Decline |
| Two-Lined Dragon | *Diporiphora bilineata* | Change/Decline |
| Northern bar-lipped skink | *Eremiascincus isolepis* | Change/Decline |
| Northern Dtella | *Gehyra australis* | Change/Decline |
| Northern Spotted Rock Dtella | *Gehyra nana* | Change/Decline |
| Arnhem Land Spotted Dtella | *Gehyra pamela* | Change/Decline |
| Darwin Skink | *Glaphyromorphus darwiniensis* | Change/Decline |
| Bynoe's Gecko | *Heteronotia binoei* | Change/Decline |
| Lined Firetail Skink | *Morethia ruficauda* | Change/Decline |
| Top End Firetail Skink | *Morethia storri* | Change/Decline |
| Jewelled Velvet Gecko | *Oedura gemmata* | Change/Decline |

| | | |
|---|---|---|
| Slender Snake-Eyed Skink | *Proablepharus tenuis* | Change/Decline |
| Long-Tailed Rock Monitor | *Varanus glebopalma* | Change/Decline |
| Spotted Tree Monitor | *Varanus scalaris* | Change/Decline |

# Appendix VI. Kakadu vertebrate species that can be monitored effectively with more sites

Vertebrate species found in Kakadu National Park with high detection probability using the revised Top End Ecological Monitoring Program methods, but an increased number of monitoring sites is required to detect trends with confidence.

| Common Name | Species Name |
|---|---|
| **Threatened species** | |
| Yellow-snouted ground gecko | *Lucasium occultum* |
| Floodplain monitor | *Varanus panoptes* |
| Northern blue-tongue lizard | *Tiliqua scincoides intermedia* |
| **Mammals** | |
| Donkey | * *Equus assinus* |
| Sugar Glider | *Petaurus breviceps* |
| Swamp Buffalo | * *Bubalus bubalis* |
| Water-rat | *Hydromys chrysogaster* |
| **Birds** | |
| Australasian Figbird | *Sphecotheres vieilloti* |

| | |
|---|---|
| Australian Owlet-nightjar | *Aegotheles cristatus* |
| Barking Owl | *Ninox connivens* |
| Black Kite | *Milvus migrans* |
| Blue-faced Honeyeater | *Entomyzon cyanotis* |
| Blue-winged Kookaburra | *Dacelo leachii* |
| Brown Quail | *Coturnix ypsilophora* |
| Brush Cuckoo | *Cacomantis variolosus* |
| Bush Stone-curlew | *Burhinus grallarius* |
| Chestnut-backed Button-quail | *Turnix castanotus* |
| Common Bronzewing | *Phaps chalcoptera* |
| Crimson Finch | *Neochmia phaeton* |
| Double-barred Finch | *Taeniopygia bichenovii* |
| Emerald Dove | *Chalcophaps indica* |
| Fork-tailed Swift | *Apus pacificus* |
| Green-backed Gerygone | *Gerygone chloronota* |

| | |
|---|---|
| Grey Butcherbird | *Cracticus torquatus* |
| Grey-crowned Babbler | *Pomatostomus temporalis* |
| Lemon-bellied Flycatcher | *Microeca flavigaster* |
| Little Corella | *Cacatua sanguinea* |
| Little Woodswallow | *Artamus minor* |
| Olive-backed Oriole | *Oriolus sagittatus* |
| Rainbow Pitta | *Pitta iris* |
| Rufous-banded Honeyeater | *Conopophila albogularis* |
| Sandstone Shrike-thrush | *Colluricincla woodwardi* |
| Shining Flycatcher | *Myiagra alecto* |
| Spotted Nightjar | *Eurostopodus argus* |
| Variegated Fairy-wren | *Malurus lamberti* |
| White-lined Honeyeater | *Meliphaga albilineata* |
| **Reptiles** | |
| Red-sided Rainbow-skink | *Carlia rufilatus* |

| | |
|---|---|
| Three-spined Rainbow Skink | *Carlia triacantha* |
| Frilled Lizard | *Chlamydosaurus kingii* |
| Slater's Ring-tail Dragon | *Ctenophorus slateri* |
| Arnhemland Ctenotus | *Ctenotus arnhemensis* |
| Ten-Lined Ctenotus | *Ctenotus decaneurus* |
| Orange-sided bar-lipped skink | *Eremiascincus douglasi* |
| Banded Prickly Gecko | *Heteronotia planiceps* |
| Ornate Snake-Eyed Skink | *Notoscincus ornatus* |
| Marbled Velvet Gecko | *Oedura marmorata* |
| Giant Cave Gecko | *Pseudothecadactylus lindneri* |
| Kimberley Rock Monitor | *Varanus glauerti* |
| Black-tailed Monitor | *Varanus tristis* |

# Appendix VII. Kakadu fauna that require a targeted program to monitor effectively

Vertebrate species found in Kakadu National Park with low detectability and occupancy using Top End Ecological Monitoring Program methods. Targeted survey/monitoring programs are required incorporating new methods and/or including new sites in key habitat. Prior data likely to be adequate to design sampling methods.

| Common Name | Species Name |
|---|---|
| **Threatened species** | |
| Nabarlek | *Petrogale concinna canescens* |
| Northern Brush-tailed Phascogale | *Phascogale pirata* |
| Water mouse | *Xeromys myoides* |
| Ghost bat | *Macroderma gigas* |
| Arnhem leaf-nosed bat | *Hipposideros inornatus* |
| Northern leaf-nose bat | *Hipposideros stenotis* |
| Bare-rumped sheath-tailed bat | *Saccolaimus saccolaimus nudiclunitus* |
| Crested shrike-tit | *Falcunculus frontatus whitei* |
| Gouldian Finch | *Erythrura gouldiae* |
| Masked Owl (mainland Top End) | *Tyto novaehollandiae kimberli* |

| | |
|---|---|
| White-throated Grasswren | *Amytornis woodwardi* |
| Yellow Chat | *Epthianura crocea tunneyi* |
| Arnhemland gorges skink | *Bellatorias obiri* |
| Oenpelli python | *Nyctophilopython oenpelliensis* |
| Plains deathadder | *Acanthopsis hawkei* |
| Mertens' Water Monitor | *Varanus mertensi* |
| Mitchell's Water Monitor | *Varanus mitchelli* |
| **Mammals** | |
| Dusky Rat | *Rattus colletti* |
| Kakadu Pebble-mouse | *Pseudomys calabyi* |
| Northern Short-tailed Mouse | *Leggadina lakedownensis* |
| Rock Ringtail | *Petropseudes dahli* |
| Planigale spp. | *Planigale spp.* |
| Arafura Fantail | *Rhipidura dryas* |
| Australian Pratincole | *Stiltia isabella* |

| | |
|---|---|
| Australian White Ibis | *Threskiornis molucca* |
| Azure Kingfisher | *Ceyx azureus* |
| Banded Fruit-dove | *Ptilinopus cinctus* |
| Bar-breasted Honeyeater | *Ramsayornis fasciatus* |
| Black Bittern | *Ixobrychus flavicollis* |
| Black-necked Stork | *Ephippiorhynchus asiaticus* |
| Brahminy Kite | *Haliastur indus* |
| Brolga | *Grus rubicunda* |
| Buff-sided Robin | *Poecilodryas cerviniventris* |
| Collared Sparrowhawk | *Accipiter cirrocephalus* |
| Comb-crested Jacana | *Irediparra gallinacea* |
| Eastern Great Egret | *Ardea modesta* |
| Eastern Koel | *Eudynamys orientalis* |
| Eastern Osprey | *Pandion cristatus* |
| Eurasian Coot | *Fulica atra* |

| | |
|---|---|
| Golden-headed Cisticola | *Cisticola exilis* |
| Great-billed Heron | *Ardea sumatrana* |
| Green Pygmy-Goose | *Nettapus pulchellus* |
| Hardhead | *Aythya australis* |
| Hooded Parrot | *Psephotus dissimilis* |
| Intermediate Egret | *Ardea intermedia* |
| Large-tailed Nightjar | *Caprimulgus macrurus* |
| Little Black Cormorant | *Phalacrocorax sulcirostris* |
| Little Egret | *Egretta garzetta* |
| Little Pied Cormorant | *Microcarbo melanoleucos* |
| Magpie Goose | *Anseranas semipalmata* |
| Magpie-lark | *Grallina cyanoleuca* |
| Masked Lapwing | *Vanellus miles* |
| Nankeen Night Heron | *Nycticorax caledonicus* |
| Pied Cormorant | *Phalacrocorax varius* |

| | |
|---|---|
| Pied Heron | *Egretta picata* |
| Pied Imperial-Pigeon | *Ducula bicolor* |
| Radjah Shelduck | *Tadorna radjah* |
| Red-backed Fairy-wren | *Malurus melanocephalus* |
| Red-headed Honeyeater | *Myzomela erythrocephala* |
| Restless Flycatcher | *Myiagra inquieta* |
| Rose-crowned Fruit-dove | *Ptilinopus regina* |
| Royal Spoonbill | *Platalea regia* |
| Rufous Owl | *Ninox rufa* |
| Straw-necked Ibis | *Threskiornis spinicollis* |
| Swamp Harrier | *Circus approximans* |
| Tawny Grassbird | *Megalurus timoriensis* |
| Wedge-tailed Eagle | *Aquila audax* |
| White-bellied Sea-eagle | *Haliaeetus leucogaster* |
| White-faced Heron | *Egretta novaehollandiae* |

| | |
|---|---|
| White-necked Heron | *Ardea pacifica* |
| White-throated Gerygone | *Gerygone albogularis* |
| Yellow-billed Spoonbill | *Platalea flavipes* |
| Yellow-tinted Honeyeater | *Lichenostomus flavescens* |
| Zitting Cisticola | *Cisticola juncidis* |
| **Reptiles** | |
| Northern Small-eyed Snake | *Cryptophis pallidiceps* |
| Rusty-topped Delma | *Delma borea* |
| Green Tree Snake | *Dendrelaphis punctulata* |
| Water Python | *Liasis mackloti* |
| Gilbert's Dragon | *Lophognathus gilberti* |
| Yellow-snouted Gecko | *Lucasium occultum* |
| Jabiluka Dwarf Skink | *Menetia concinna* |
| Northern Knob-tailed Gecko | *Nephrurus sheai* |
| Zig-zag Gecko | *Oedura rhombifer* |

| | |
|---|---|
| Black-spotted Ridge-tailed Monitor | *Varanus baritji* |
| Sand Goanna | *Varanus gouldii* |