Rehabilitation of vertebrate assemblages at Ranger Uranium Mine: Assessment standards and monitoring methodology

Report

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Cover photographs

Front cover: Black-footed Tree-rat (mainland sub-species: *Mesembriomys gouldii gouldii*) (photo Kym Brennan).

Back cover: Agile Wallaby (photo R.M.T./Shutterstock.com).

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Contents

List of tables

List of figures

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Executive summary

A major rehabilitation program is underway at Ranger Uranium Mine in the Northern Territory, where mining ceased in 2012. To meet national and international standards of ecosystem restoration the rehabilitation area must support a diversity of characteristic flora and fauna species, with high similarity to adjacent areas of lowland woodland in Kakadu National Park. Specific standards are required to gauge progress and to signal whether faunal restoration has been successful. The vertebrate fauna occurring in surrounding natural habitat can serve as a benchmark for assessing the success of rehabilitation at Ranger Mine. Fortunately, Kakadu has been the focus of long-term fauna monitoring implemented by NT Department of Environment and Natural Resources (DENR), in conjunction with Parks Australia and Traditional Owners. Monitoring over 20 years has amassed a large and robust dataset providing a good understanding of existing bird, reptile and mammal communities.

This report includes:

(i) an overview of key attributes of the current vertebrate fauna community across a range of commonly used metrics;
(ii) a description of the methods required to derive the relevant metrics from fauna survey data;
(iii) recommendations on how to operationalise these metrics for assessment standards; and
(iv) the most appropriate sampling design to measure rehabilitation success at Ranger Mine.

We applied several analytical approaches to assess the current state of the bird, reptile and mammal community across 29 survey sites located in lowland woodland of northern Kakadu. The range of metrics derived included: species richness; community evenness; trophic guild; community composition; and species-level occupancy (which accounts for imperfect detection). These metrics range from easily derived attributes of diversity, through to more complex and informative measures of species and community states requiring robust analysis. When applied to fauna survey data collected across a set of reference sites these metrics provide a benchmark of conditions against which to measure rehabilitation success at the mine site.

Our results show there is extensive variation in vertebrate diversity and species composition between the survey sites we assessed, revealing the degree of inherent variability in lowland woodland faunal assemblages. Richness of mammals and reptiles was low, compared to relatively rich bird communities. Modelling results reveal that only a small proportion of the bird, reptile and mammal species (34, 11 and 5 species respectively) can be monitored with a high degree of confidence using contemporary survey methods and sampling protocols. This subset of species that are generally more common and detectable are the best candidates for single-species assessments (i.e. species-level occupancy analysis). The threatened Partridge Pigeon and Black-footed Tree-rat are included in this group of species that can be monitored effectively.

Based on the analysis and results presented herein we propose four complementary assessment standards that need to be applied collectively to assess different attributes of vertebrate communities, thereby providing a comprehensive indication of faunal restoration.

This approach will provide certainty that ecosystem diversity and functionality is restored. To help operationalise these standards we provide recommendations on potential thresholds for each metric to define what constitutes a suitable degree of 'similarity' between rehabilitation and references sites.

To inform decisions on the most appropriate sampling design for monitoring faunal rehabilitation at Ranger Mine we assessed the effect of alternative sampling scenarios (i.e. different combinations of survey sites and survey nights) on precision and confidence in our faunal metrics. Both precision and confidence increased with survey effort, resulting in improved monitoring confidence for a larger proportion of the vertebrate community. We recommend each round of monitoring involve five days of survey at 30 reference sites and 20 rehabilitation sites implementing the Northern Territory Top End National Parks Ecological Monitoring Program methodology. This monitoring framework is suitably robust and sensitive to reliably measure and report on faunal response to rehabilitation. The Northern Territory Top End National Parks Ecological Monitoring Program methodology is a good fit for Ranger Mine as it incorporates multiple methods that sample vertebrate communities (mammals, reptiles and birds) of relevance at Ranger Mine, and provides sufficient confidence to detect particular species based on contemporary data for the region.

1. Introduction

A major rehabilitation program is underway at Ranger Uranium Mine in the Northern Territory (NT), where mining ceased in 2012. The overall goal of rehabilitation of the Ranger Project Area is “to establish an environment similar to the adjacent areas of Kakadu National Park such that the rehabilitated area could be incorporated into the Kakadu National Park” (DEE 1999). Revegetation is required to use “local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long-term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park” (DEE 1999). However, there are no rehabilitation specifications for fauna, other than that no exotic species should be introduced (DEE 1999).

International standards in relation to ecological restoration are described in a recent report by the Society for Ecological Restoration (McDonald et al. 2016a) and have been reproduced as Australian standards (McDonald et al. 2016b). These standards highlight the need to identify specific and measurable indicators of key ecosystem attributes that underpin successful restoration and note the need to include measures of faunal composition (McDonald et al. 2016a). For a 5-star rating, there must be a “High diversity of characteristic species …., with high similarity to the reference ecosystem.” This is consistent with rehabilitation objective 2: *Established habitats will support faunal communities similar to that in KNP* adopted by rehabilitation manager Energy Resources of Australia Ltd (Ecological Australia 2017). The challenge is to operationalise such objectives in the form of specific standards that signal that faunal restoration has been successful.

The Supervising Scientist Branch of Environmental Research Institute of the Supervising Scientist (ERISS) seeks faunal rehabilitation standards for Ranger Mine to meet international standards in mine rehabilitation and fulfil their obligations. Pursuant to this, the project ‘Rehabilitation of faunal assemblages at Ranger Uranium Mine’ was funded by the Northern Australia Environmental Resources Hub of the Australian Government’s National Environmental Science Program (NESP) in 2018–2019, with the objective of developing specifications for faunal rehabilitation standards that represent successful ecosystem rehabilitation of the mine site.

Specific aims of the project are to:

(i) identify appropriate vertebrate and invertebrate species for incorporation into faunal standards;
(ii) design a robust sampling methodology at rehabilitation and reference sites for ongoing faunal survey and assessment of rehabilitation success in relation to vertebrate fauna; and
(iii) incorporate the above information into specifications for faunal standards to measure successful ecosystem restoration at Ranger.

The findings of the project will be broadly applicable to mine site rehabilitation throughout northern Australia. This report addresses the vertebrate component (Milestone 5) of NESP project 2.8 and has been prepared by the NT Department of Environment and Natural Resources (DENR), based on the analysis of existing vertebrate survey data.

The success of ecosystem restoration can be determined by assessing how close the attributes of the rehabilitated site are to the reference ecosystem. This assessment is mostly based on key indicator values that are derived from the compositional, structural and functional ecosystem attributes of the reference ecosystem, including the range of spatial and temporal variability (EPA 2006). The Supervising Scientist Branch of ERISS identifies a range of indicator values for fauna restoration in their document 'Ecosystem Restoration – Rehabilitation Standard for the Ranger Uranium Mine', including species richness, species composition, trophic guilds and faunal occupation. Other commonly used metrics of fauna restoration at mine sites include species evenness and density (Cristescu et al. 2012). Ideally, an integrated approach will be applied where several metrics are used concurrently, as each metric explains a different attribute of faunal communities (Ruiz-Jaen and Aide 2005). For example, a rehabilitated site may succeed in attaining similar richness to a reference ecosystem but with an entirely different species composition, meaning rehabilitation goals are not met. Few studies have the financial resources or capacity to monitor and apply a large range of ecosystem attributes, so it is important to select the most informative but parsimonius set.

Faunal assemblage analysis is commonly applied to quantitatively measure the success of community restoration at mine sites (Cristescu et al. 2012). Incorporation of faunal assemblage targets into rehabilitation standards is important to ensure that a broad range of characteristic species occur at rehabilitation sites (e.g., McCoy and Mushinsky 2002). The occurrence of representative species from a range of trophic guilds provides an additional lens through which to assess community composition, complexity and integrity. The guild approach is widely used as an index of biotic integrity and ecological condition, and to assess the ecological status of terrestrial (O'Connell et al. 2000, Gray et al. 2007) and aquatic systems (Noble et al. 2007). There are a growing number of examples incorporating trophic guilds in standardised ecological assessment methods (e.g., bird communities O'Connell et al. 2000, fish communities Noble et al. 2007), and their utility in the assessment of forest restoration and rehabilitation (O'Connell et al. 2000, Edwards et al. 2009).

The number (or proportion) of survey sites occupied by a species (occupancy) is a useful metric for assessing the re-establishment of characteristic species in an area. Species-level occupancy provides a precise numeric target against which to measure rehabilitation success, and hence provides a basis for auditable and defensible rehabilitation standards. To accurately estimate occupancy, it is vital to account for instances of imperfect detection, where a species is present at a site but goes undetected (Kellner and Swihart 2014). Failure to do so can result in biased estimation and erroneous conclusions. Species that are challenging to detect with standard methods are poor candidates for use as indicators of rehabilitation. Furthermore, species with low occupancy may naturally have a patchy distribution and therefore would be expected to have less chance of occurring in a rehabilitated area, even if conditions were ideal, as they may not occur in the immediate vicinity. Moreover, detectability is an important consideration that can guide decisions on the most appropriate survey methods and sampling effort required for effective monitoring (Guillera-Arroita and Lahoz-Monfort 2012). This is because the effect of imperfect detection can be countered by conducting multiple surveys of the sampling sites within a relatively short timeframe to minimise the possibility of a false absence.

In this report we apply a range of analyses to identify vertebrate species and assemblages that can serve as a benchmark for assessing the success of faunal rehabilitation of Ranger mine, and develop measurable standards that signal faunal restoration. Furthermore, we identify the survey design and sampling methods required to measure these metrics with high precision and confidence, and we discuss what constitutes an acceptable standard in rehabilitation. This information will be valuable for guiding rehabilitation and monitoring specifications for vertebrate fauna at Ranger Mine specifically, but the general approach is likely to be broadly applicable in similar ecosystems across northern Australia.

2. Methodology

2.1 Data sources and sampling methods

To identify the current vertebrate community that occurs in lowland woodlands of northern Kakadu we examined survey data from the “Three Parks Fireplot Monitoring Program” fauna dataset held by DENR. Sites established during this program were surveyed for mammals, birds and reptiles every five years following a standardised plot-based protocol used throughout the Northern Territory (see Appendix 1 for more details). Fauna data includes total counts of mammals, birds and reptiles detected with each sampling method. We acknowledge that the Three Parks Fireplot Monitoring Program has not exhaustively sampled vertebrate communities, as some species are known to occur within the park but are not sampled adequately with the methods used (e.g., bats, amphibians, some snakes). Despite this, species readily detected during these fauna surveys represent a large proportion of the vertebrate community, and they provide a good cross-section of vertebrates of interest as candidates for incorporation into faunal standards for Ranger Mine, especially if a similar set of sampling methods are applied.

We examined survey data collected from 29 sites located within lowland woodland habitat of the northern half of Kakadu (Figure 2.1). Proximity of the 29 study sites to the Ranger mine ranges from three to 91 km. To account for temporal patterns of change, particularly the declines of small mammals in recent decades (Woinarski et al. 2010), only records from the most recent sampling session of the Three Parks Fireplot Monitoring Programs (2012–2014), as well as more recent sampling for some sites (Kakadu National Park Biodiversity Hotspots Survey 2015, Einoder and Gillespie 2016) were included in the analysis. Lowland woodland sites located on ecotones (i.e. edges of other habitat types such as floodplain, wet rainforest, or sandstone woodland) were excluded from the analysis as they are less likely to be representative of typical lowland woodland.

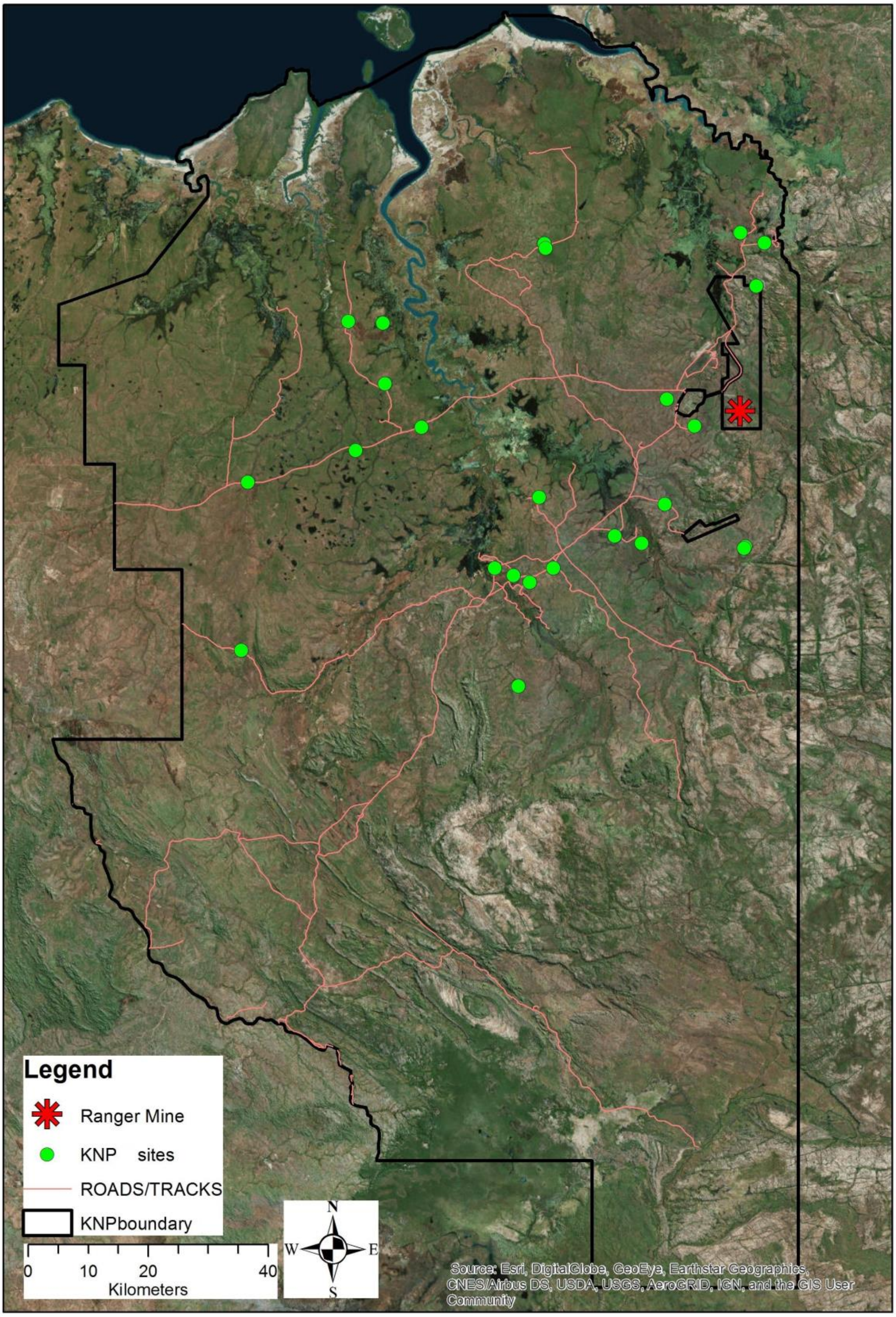

Figure 2.1. Map of Kakadu National Park showing the location of 29 lowland woodland sites surveyed for fauna between 2012 and 2015.

2.2 Analytical methods

2.2.1 Identifying species that can be monitored with confidence

We applied three analytical approaches to identify which of the species that currently occur in lowland woodland of northern Kakadu can be monitored and evaluated effectively – thus, are of value for inclusion in faunal rehabilitation standards for Ranger Mine.

Firstly, we calculated naïve occupancy for every species recorded, being the ratio of number of sites where a species is detected to total number of sites surveyed (29 sites), without correcting for imperfect detection. We compared the proportion of species of birds, reptiles and mammals with low, medium and high naïve occupancy for an initial assessment of the makeup of communities with rare or common species.

Secondly, for those species with naïve occupancy >0.1 (deemed relatively common) we applied occupancy and detectability models to data collected from the 29 sites to account for imperfect detection (see Appendix 2 for detailed method). This approach provides major advantages over naïve occupancy by accounting for detectability (the probability that a species will be detected at occupied sites; see below). Modelled occupancy accounting for detection probability (across the suite of survey methods applied) provides a more accurate indication of species occurrence at sampling sites. Included in this list of species were the threatened Partridge Pigeon and Black-footed Tree-rat.

Thirdly, we reviewed existing detection probability estimates for all species from a range of data sources (see Appendix 2 for detailed method) to gauge how easy or hard they are to detect with the sampling methods used. A broader set of survey data were examined to provide more accurate estimates of detectability than achievable with the sample size of 29 lowland woodland sites within Kakadu. Species that are highly visible or trappable have high detectability. However, species that are cryptic or avoid traps may go undetected when the species is actually present, resulting in a false absence. Ignoring these false absences will lead to underestimates of site species richness and species occupancy across the landscape (Guillera-Arroita et al. 2010). A detection probability of >0.1 was applied as a threshold, above which species can be detected readily enough with the multi-day survey approach to be applied with a relatively high degree of confidence. Detection probabilities were calculated per day of live trapping and diurnal/nocturnal active searching, and per week of camera deployment.

Importantly, a new list of species that can be monitored with confidence should be generated from each future round of sampling of reference sites, as patterns of occupancy are highly dynamic, and detectability will change, especially with the addition of improved technologies. The number of species that can be monitored with high confidence may therefore vary over time.

Modelling species-level occupancy generates a precise numeric value that provides a true representation of species occurrence at rehabilitation sites. Achieving occupancy levels equivalent to the reference sites across a suite of species will provide a high level of confidence that the rehabilitation area is adequately restored, at least for the more common component of the vertebrate fauna. It must be noted that this approach cannot be applied to rare or very cryptic species, as species with low occupancy and/or low detectability cannot be modelled. In the context of Ranger Mine rehabilitation, this standard can currently be applied to Partridge Pigeon and Black-footed Tree-rat, but a number of other threatened species potentially present in lowland woodlands are not included as they are too rare or too hard to detect (e.g. Fawn Antechinus, Northern Quoll).

2.2.2 Identifying species diversity, trophic guild and community representativeness

We examined faunal assemblages at 29 lowland woodland fauna survey sites in Kakadu to assess the 'benchmark' diversity and composition of communities. The proposed measure of species diversity is the Shannon-Wiener (Shannon) Index, along with its two component metrics species richness and species evenness. However, the Shannon Index has been criticised as being ecologically insensitive and even misleading, because it confounds two very different measures that need to be considered separately (MacDonald et al. 2017, Santini et al. 2017). It is therefore recommended that species richness and species evenness alone be used as the metric for species diversity at each site. We calculated observed species richness, as a tally of all species detected (i.e. presence data) at each site over the entire duration of the survey. Observed species richness is the most straightforward measure of diversity. However, it should not be mistaken as true richness, as a proportion of assemblages go undetected during site surveys (Gotelli and Colwel 2001). Community evenness (Pielou's evenness) was calculated at a site and refers to how similar the abundance of each species is. High evenness occurs when many species have similar abundance, with no single species dominating. These two diversity measures were calculated from a site-by-species abundance matrix by applying the '*vegan'* package (Oksanen et al. 2018) in R (R Core Team 2018). Application of these diversity metrics will reveal if the rehabilitation area is supporting a similar number of species at a similar density as the reference ecosystem, but not necessarily the same species present at reference sites. These simple calculations of diversity provide a useful measure of several attributes of community structure, accounting for both common and rare species and subtle changes in community structure.

To provide an additional lens through which to assess community composition and completeness we assigned each species to one of 14 trophic guilds using the classification approach of Gonzáles-Salazar et al. (2014): aerial insectivore; arboreal and ground-dwelling insectivore; arboreal and ground-dwelling generalist; arboreal frugivore; arboreal herbivore; arboreal insectivore; foliage gleaner; arboreal nectivore; nectivore/insectivore; ground-dwelling granivore; ground-dwelling herbivore; ground-dwelling insectivore; ground-dwelling omnivore; predator. This approach groups together species that use resources in a similar way, regardless of taxonomic relationships. We also assessed whether or not they are likely to use tree hollows. To demonstrate this approach guilds were assigned only to the 50 species that could be monitored with confidence (see above) for this report, but in practice this approach should be applied to all sampled species irrespective of how common or rare they are. Trophic guild representation was assessed for all 29 fauna survey sites to gauge the number of guilds represented (out of a maximum of 14). Representation of species from the full spectrum of trophic guilds present in surrounding lowland woodland can be interpreted as an indicator of a diverse and complex faunal community (O'Connell et al. 2000, Gray et al. 2007, Edwards et al. 2009). Some guilds require the establishment of a diverse community of mature flowering or fruiting trees and shrubs, which may only be achieved in the later stages of rehabilitation. The successful establishment of some guilds is dependent on a diverse community of mature flowering or fruiting trees and shrubs, which may only be achieved in the later stages of rehabilitation. During mine rehabilitation we would expect a relatively rapid recovery of some insectivores, and a delayed recovery of frugivores. Key habitat features, such as tree hollows require a longer time frame to develop, but are a critical resource for some species. Thus, the establishment of both a variety of dietary-based trophic guilds and hollow-dependent species signifies successful rehabilitation of sites as faunal structural requirements have been restored. Species on reference sites should be assigned as hollow users following Taylor, Woinarski and Chatto (2003).

Species composition analysis was applied to determine how similar sites are in their species assemblages, and to identify the extent of inherent natural variability in vertebrate community composition across reference sites. This approach can identify which species are contributing most to similarity between sites (i.e. occur across more sites), and which species are contributing little to inter-site similarity (i.e., relatively rare). Specifically, we applied two-dimensional Non-metric Multi-Dimensional Scaling (NMDS) analysis based on the Bray-Curtis dissimilarity matrix (as in Van Etten et al. 2014) to a site-by-species matrix of taxa abundance. Species were plotted on top of sites across the same two axes to identify the species contributing to inter-site similarities and differences.

Once data become available the application of several additional analytical steps (see Appendix 4 for detailed methods) is recommended to assess the similarity of rehabilitation sites to reference sites based on their faunal assemblage. Plotting reference sites and rehabilitation sites together will identify those rehabilitation sites with an assemblage similar to reference sites (some overlap in ordination space), versus those that do not resemble reference sites (Figure 2.2). The spatial distribution in ordination space of sites within a group (rehabilitation or reference sites) reveals the degree of inter-site variation in species composition (Figure 2.2). Significance testing can be applied to aid in interpretation.

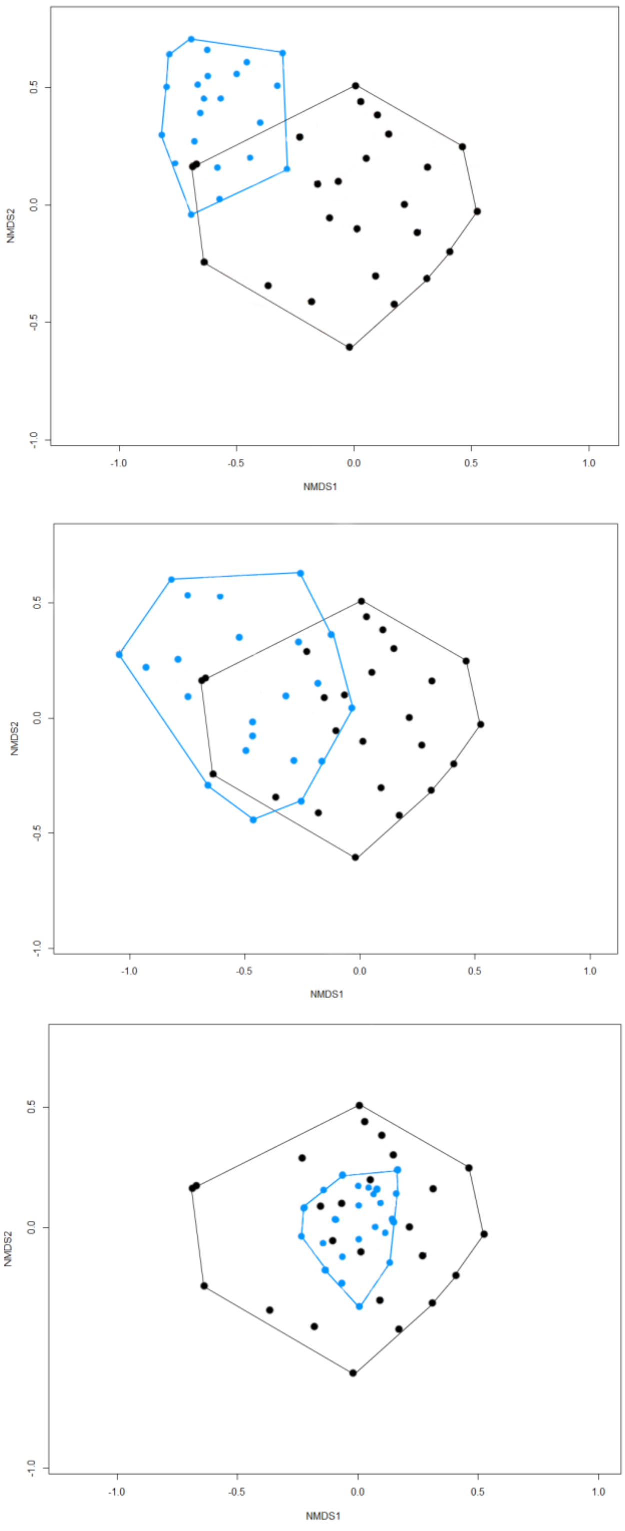

Figure 2.2. Illustrative NMDS plots overlaying the faunal assemblage of hypothetical rehabilitation sites (blue lines and dots) with the reference sites (black lines and dots – reference fauna survey sites) for several potential rehabilitation scenarios: Upper panel - very few rehabilitation sites are similar to reference sites due to the occurrence and dominance of different species, with reduced inter-site variance at rehabilitation sites compared to reference sites; Middle panel – half the rehabilitation sites have a faunal assemblage similar to reference sites, with similar variance between groups; and Lower panel – rehabilitation sites overlap entirely with reference sites, but with lower variety of composition compared to reference sites – indicating rehabilitation sites share the same common species but lack the diversity of reference sites.

2.2.3 Optimising sampling design

To measure and report on faunal rehabilitation and derive meaningful comparisons with reference systems requires a known and agreed degree of confidence in the accuracy of the monitoring data collected. We ran a sensitivity analysis to explore the role of varied survey effort on the resultant precision in estimates of diversity, occupancy and detectability.

For a range of sampling designs we calculated:

- 95% confidence intervals around mean estimates of richness and evenness;
- precision/variance in estimates of species-level occupancy; and,
- the probability of false absences (see Appendix 3 for detailed methods).

Lower variance around the occupancy estimate provides greater precision and confidence in the estimates obtained. Mackenzie and Royle (2005) identify an occupancy variance of 0.1 as a suitably high degree of precision in their provision of general advice on designing occupancy studies, based on the assumption "that the ultimate goal of an occupancy-type study is to obtain as precise an estimate of occupancy as possible". We consider 0.1 a threshold level of variance at or below which precision in the occupancy estimate of a species is deemed deemed to be acceptable. Relaxing the precision to 0.125 or 1.5 reduces confidence in the accuracy of the estimate gained. Our sensitivity analysis for occupancy estimates involved re-calculating precision with alternative sampling designs, each time assessing the proportion of species in the community that fall below the 0.1 variance threshold.

The alternative sampling designs considered in the sensitivity analysis included: 4 nights of survey; 5 nights of survey; and, 6 nights of survey, applying the daily trapping and survey schedule of the Northern Territory Top End National Parks Ecological Monitoring Program (see Appendix 1 for more details). The range of survey designs considered included: 10, 20, 30 rehabilitation sites and 10, 20, 30 reference sites with a combination of 4, 5 and 6 nights of survey effort. The DENR-led program is a revision of the standardised NT 50m plot sampling methodology with design modifications to increase the detectability of a suite mammal, reptile and bird species, including improved technologies such as a five camera-trap array (full details on the method including SOPs are available in Einoder et al. 2018a). The existing methodology is considered to be a good fit for measuring rehabilitation progress and success at Ranger Mine as it incorporates a number of methods that sample vertebrate communities (mammals, reptiles and birds) of relevance at Ranger Mine, and provides sufficient confidence to detect particular species based on contemporary data for the region. Sensitivity analysis results will guide decisions on the number of rehabilitation and reference sites, and days of site-level survey that are appropriate to meet a desired level of confidence.

3. Results

3.1 Species that currently occur in lowland woodland of northern Kakadu

A total of 146 species of bird (94), reptile (36) and mammal (16) were recorded during surveys of 29 sites in lowland woodlands of northern Kakadu (Table 3.1, Table 3.2, Table 3.3). A large proportion of species from each community (bird, reptile, mammal) were rarely recorded, with 59% of birds, 64% of reptiles, and 56% of mammals recorded at less than 10% of sites (i.e., naïve occupancy <0.1, Table 3.1, Table 3.2, Table 3.3, Figure 3.1). Low naïve occupancy suggests these species are either naturally rare (e.g., Short-beaked Echidna, Peregrine Falcon, the snake *Furina ornata*); rare due to previous declines (e.g. Northern Quoll, frilled lizard *Chlamydosaurus kingii*); naturally hard to detect (due to cryptic habits e.g., Brown Quail, *Varanus spp*.); hard to detect due to the application of inadequate sampling methods (e.g., Black Flying-fox); or lowland woodlands are not a preferred habitat (e.g., Straw-necked Ibis, Table 3.1, Table 3.2, Table 3.3). Relatively few species have very high occupancy across lowland woodlands. No mammals were recorded at more than 50% of sites, but a small proportion of birds and reptiles were (Figure 3.1).

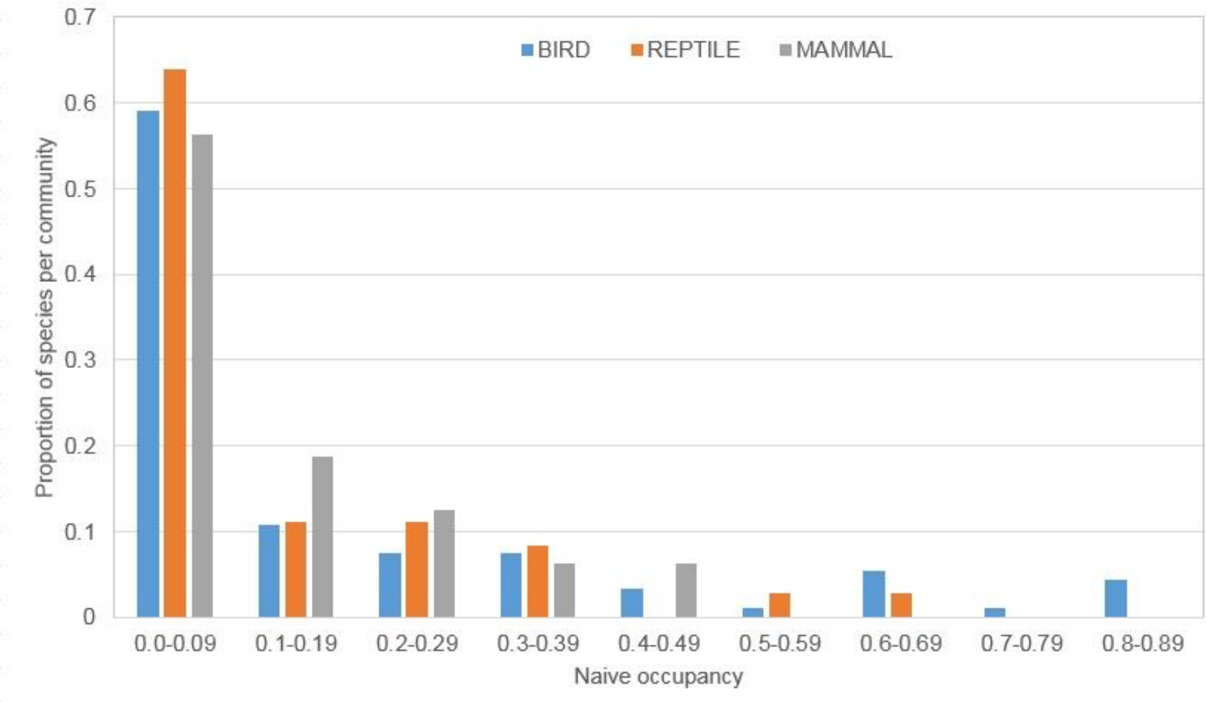

Figure 3.1. Proportion of each fauna community (94 birds, 36 reptiles and 16 mammals) within naive occupancy classes (proportion of sampled sites occupied), showing the predominance of rare species. Twenty-nine lowland woodland sites in northern Kakadu National Park were surveyed using a range of survey methods in 2012–15).

*Table 3.1. Ninety-four bird species detected at 29 lowland woodland fire plots in northern Kakadu National Park in recent sampling (2012–2015), showing those species (in bold; n = 34) deemed suitable for monitoring based on detectability and occupancy estimates. Naïve occupancy is provided for all species, but modelled estimates of occupancy and standard errors (SE) are presented only for those more common and readily detected species. Detection probability estimates (per day/night of search/spotlight) and standard errors (SE) are derived from a broader pool of Top End sites using the same standardised fauna sampling approach. An assessment of species status in lowland woodlands of Kakadu is provided to direct decisions on each species potential use in species-specific rehabilitation standards for Ranger Mine. Threatened species marked with *.*

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
Apostlebird	1	0.03					Search	Low occupancy
Australian Hobby	1	0.03					Search	Low occupancy
Australian Owlet-nightjar	1	0.04			0.07	0.03	Spot	Low occupancy and low detectability
Banded honeyeater	2	0.08	0.10	0.05	0.39	0.10	Search	Low occupancy and moderate detectability
Bar-breasted Honeyeater	1	0.03					Search	Low occupancy
Barking Owl	1	0.04			0.03	0.02	Spot	Low occupancy and low detectability
Bar-shouldered Dove	**15**	**0.60**	**0.63**	**0.12**	**0.61**	**0.05**	**Search**	**High occupancy and high detectability**
Black Kite	2	0.07					Search	Low occupancy. Usually flying overhead
Black-breasted Buzzard	1	0.04					Search	Low occupancy
Black-faced Cuckoo-shrike	**2**	**0.08**	**0.21**	**0.13**	**0.32**	**0.06**	**Search**	**Moderate occupancy and high detectability**
Black-faced Woodswallow	1	0.04					Search	Low occupancy
Black-necked Stork	1	0.03					Search	Low occupancy. Not usually in LW
Black-tailed Treecreeper	**6**	**0.24**	**0.23**	**0.09**	**0.51**	**0.11**	**Search**	**Moderate occupancy, high detectability**
Blue-faced Honeyeater	**6**	**0.24**	**0.36**	**0.19**	**0.39**	**0.08**	**Search**	**Moderate occupancy, high detectability**
Blue-winged Kookaburra	**9**	**0.36**	**0.42**	**0.13**	**0.24**	**0.05**	**Search**	**High occupancy and moderate detectability**
Brown Falcon	2	0.07			0.11	0.07	Search	Low occupancy and low detectability
Brown Goshawk	1	0.04			0.06	0.05	Search	Low occupancy and low detectability
Brown Honeyeater	**7**	**0.28**	**0.26**	**0.09**	**0.68**	**0.05**	**Search**	**High occupancy and high detectability**
Brown Quail	2	0.08			0.17	0.09	Search	Low occupancy and low detectability
Brush Cuckoo	**6**	**0.24**	**0.36**	**0.19**	**0.28**	**0.15**	**Search**	**Moderate occupancy and moderate detectability**

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
Bush Stone-curlew	1	0.04					Search	Low occupancy
Cicadabird	1	0.04			0.10	0.09	Search	Low occupancy and low detectability
Collared Sparrowhawk	1	0.03			0.01	0.03	Search	Low occupancy and low detectability
Crimson Finch	2	0.08			0.35	0.10	Search	Low occupancy and moderate detectability
Diamond Dove	2	0.07			0.31	0.07	Search	Low occupancy and moderate detectability
Dollarbird	1	0.04			0.28	0.15	Search	Low occupancy and moderate detectability
Double-barred Finch	2	0.08			0.16	0.14	Search	Low occupancy and low detection probability
Dusky Honeyeater	**7**	**0.28**	**0.46**	**0.24**	**0.24**	**0.05**	**Search**	**High occupancy, moderate detectability**
Eastern Koel	5	0.17					Search	Low occupancy
Forest Kingfisher	2	0.08	0.12	0.05	0.63	0.10	Search	Low occupancy and high detectability
Galah	2	0.08	0.10	0.08	0.20	0.09	Search	Low occupancy and low detectability
Golden-headed Cisticola	1	0.04			0.45	0.11	Search	Low occupancy and high detectability. Not usually in LW
Great Bowerbird	1	0.04					Search	Low occupancy
Grey Butcherbird	1	0.03			0.53	0.11	Search	Low occupancy, high detectability
Grey Shrike-thrush	**3**	**0.12**	**0.13**	**0.08**	**0.30**	**0.09**	**Search**	**Low occupancy, moderate detectability**
Grey-crowned Babbler	**4**	**0.16**	**0.29**	**0.22**	**0.38**	**0.13**	**Search**	**Low occupancy, moderate detectability**
Helmeted Friarbird	3	0.10			0.66	0.07	Search	Low occupancy, high detectability
Hooded Robin (Mainland)	1	0.03					Search	Low occupancy
Large-tailed Nightjar	1	0.03					Spot	Low occupancy
Leaden Flycatcher	**9**	**0.36**	**0.49**	**0.22**	**0.56**	**0.07**	**Search**	**Moderate occupancy and high detectability**
Lemon-bellied Flycatcher	2	0.08	0.10	0.05	0.63	0.08	Search	Low occupancy, high detectability. In LW adjacent to riparian areas.
Little Corella	2	0.08			0.32	0.17	Search	Low occupancy, moderate detectability
Little Friarbird	**5**	**0.20**	**0.27**	**0.14**	**0.59**	**0.08**	**Search**	**Moderate occupancy, high detectability**
Little Woodswallow	2	0.08			0.20	0.07	Search	Low occupancy, moderate detectability

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
Long-tailed Finch	4	0.16			0.09	0.07	Search	Low occupancy, low detectability
Magpie-lark	1	0.04	0.04	0.04	0.46	0.08	Search	Low occupancy, high detectability
Masked Finch	2	0.08			0.09	0.09	Search	Low occupancy, low detectability
Masked Owl	2	0.08					Spot	Low occupancy
Mistletoebird	**18**	**0.72**	**0.78**	**0.12**	**0.69**	**0.05**	**Search**	**High occupancy, high detectability**
Nankeen Kestrel	1	0.03					Search	Low occupancy
Nankeen Night Heron	1	0.03					Search	Lot occupancy. Not usually in LW
Northern Fantail	**6**	**0.24**	**0.29**	**0.12**	**0.42**	**0.05**	**Search**	**Moderate occupancy, high detectability**
Northern Rosella	2	0.08	0.08	0.05	0.30	0.07	Search	Low occupancy, moderate detectability. Usually flying overhead
Olive-backed Oriole	1	0.04			0.13	0.08	Search	Low occupancy, low detectability. Not usually in LW
Partridge Pigeon*	**2**	**0.08**	**0.10**	**0.08**	**0.29**	**0.15**	**Search**	**Low occupancy, but may be locally abundant near Ranger Mine. Moderate detectability.**
Peaceful Dove	**22**	**0.88**	**0.83**	**0.05**	**0.78**	**0.03**	**Search**	**High occupancy, high detectability**
Peregrine Falcon	1	0.03					Search	Low occupancy
Pheasant Coucal	9	0.31			0.08	0.07	Search	Moderate occurrence, highly detectability
Pied Butcherbird	**9**	**0.36**	**0.36**	**0.10**	**0.44**	**0.04**	**Search**	**Moderate occupancy, high detectability**
Pied Imperial-Pigeon	2	0.07			0.55	0.15	Search	Low occupancy, high detectability. Not usually in LW.
Rainbow Bee-eater	**17**	**0.68**	**0.72**	**0.12**	**0.51**	**0.05**	**Search**	**High occupancy, high detectability**
Rainbow Lorikeet	**15**	**0.60**	**0.67**	**0.14**	**0.45**	**0.05**	**Search**	**High occupancy, high detectability**
Red-backed Button-quail	1	0.03					Camera	Low occupancy
Red-backed Fairy-wren	**3**	**0.12**	**0.13**	**0.08**	**0.38**	**0.07**	**Search**	**low occurrence and highly detectable**
Red-backed Kingfisher	1	0.03			0.11	0.10	Search	Low occupancy, low detectability
Red-tailed Black-cockatoo	12	0.41					Search	Moderate occupancy. Usually flying overhead.
Red-winged Parrot	**13**	**0.52**	**0.69**	**0.10**	**0.45**	**0.06**	**Search**	**High occupancy, high detectability**

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
Restless Flycatcher	1	0.04			0.33	0.09	Search	Low occupancy, moderate detectability
Rufous Whistler	**16**	**0.64**	**0.63**	**0.10**	**0.66**	**0.05**	**Search**	**High occupancy, high detectability**
Rufous-throated honeyeater	2	0.08			0.24	0.14	Search	Low occupancy, moderate detectability. Not usually in LW.
Sacred Kingfisher	2	0.07			0.24	0.11	Search	Low occupancy, moderate detectability
Silver-crowned Friarbird	**8**	**0.32**	**0.33**	**0.10**	**0.67**	**0.04**	**Search**	**Moderate occupancy, high detectability**
Southern Boobook	4	0.16			0.14	0.03	Spot	Low occupancy, low detectability
Spangled Drongo	3	0.10			0.31	0.06	Search	Low occupancy, high detectability. In LW adjacent to riparian areas.
Spotted nightjar	2	0.08			0.44	0.21	Spot	Low occupancy, high detectability
Straw-necked ibis	1	0.04			0.28	0.15	Search	Low occupancy, moderate detectability. Not usually in LW
Striated Pardalote	**17**	**0.68**	**0.68**	**0.11**	**0.62**	**0.06**	**Search**	**High occupancy, high detectability**
Sulphur-crested Cockatoo	**12**	**0.48**	**0.55**	**0.14**	**0.23**	**0.05**	**Search**	**High occupancy, moderate detectability**
Tawny Frogmouth	2	0.08			0.09	0.04	Spot	Low occupancy, low detectability
Torresian Crow	**8**	**0.32**	**0.57**	**0.31**	**0.62**	**0.05**	**Search**	**High occupancy, high detectability**
Varied Lorikeet	1	0.04			0.28	0.09	Search	Low occupancy, moderate detectability. Usually flying overhead.
Varied Triller	**1**	**0.04**	**0.08**	**0.04**	**0.53**	**0.12**	**Search**	**Low occupancy, high detectability, but may be locally abundant near Ranger Mine.**
Weebill	**21**	**0.84**	**0.81**	**0.09**	**0.55**	**0.03**	**Search**	**High occupancy, high detectability**
Whistling Kite	10	0.40	0.45	0.13	0.34	0.06	Search	Moderate occupancy, moderate detectability. Usually flying overhead.
White-bellied Cuckoo-shrike	**21**	**0.84**	**0.87**	**0.10**	**0.55**	**0.06**	**Search**	**High occupancy, high detectability**
White-bellied Sea-eagle	1	0.04			0.20	0.17	Search	Low occupancy, high detectability. Usually flying overhead.
White-gaped Honeyeater	**2**	**0.08**	**0.10**	**0.08**	**0.72**	**0.05**	**Search**	**Low occupancy, high detectability**
White-throated Gerygone	2	0.07					Search	Low occupancy. Not usually in LW.

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
White-throated Honeyeater	**21**	**0.84**	**0.82**	**0.09**	**0.84**	**0.03**	**Search**	**High occupancy, high detectability**
White-winged Triller	**4**	**0.16**	**0.29**	**0.22**	**0.54**	**0.09**	**Search**	**Moderate occupancy and high detectability**
Willie Wagtail	**9**	**0.36**	**0.46**	**0.16**	**0.50**	**0.07**	**Search**	**Moderate occupancy and high detectability**
Yellow Oriole	**4**	**0.16**	**0.19**	**0.10**	**0.43**	**0.07**	**Search**	Low occupancy, high detectability. In LW adjacent to riparian/rainforest areas.
Yellow-throated Miner	1	0.04			0.45	0.09	Search	Low occupancy, high detectability

Table 3.2. Thirty-six reptile species detected at 29 lowland woodland fire plots in northern Kakadu National Park in recent sampling (2012–2015), showing those deemed suitable for monitoring based on detectability and occupancy estimates (n = 11; in bold). Naïve occupancy for all species and modelled estimates of occupancy for those more common and readily detected species are shown. Detection probability estimates (per day/night of Pit/Funnel/Search/Spotlight, and per week of camera trapping) derived from a broader pool of Top End sites using the same standardised fauna sampling approach. An assessment of species status in lowland woodlands of Kakadu is provided.

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection prob	Detection prob SE	Best method	Status at Lowland Woodland (LW) sites
Antaresia childreni	2	0.07					Funnel	Low occupancy
Carlia amax	**17**	**0.65**	**0.80**	**0.13**	**0.47**	**0.05**	**Search**	**High occupancy, high detectability**
Carlia gracilis	**3**	**0.10**	**0.16**	**0.11**	**0.48**	**0.08**	**Search**	**Low occupancy, high detectability**
Carlia munda	**6**	**0.23**	**0.33**	**0.14**	**0.59**	**0.05**	**Search**	**Moderate occupancy, high detectability**
Carlia rufilatus	1	0.03			0.38	0.18	Search	Low occupancy, moderate detectability
Chlamydosaurus kingii	2	0.07					Camera	Low occupancy
Cryptoblepharus cygnatus	3	0.10					Search	Low occupancy
Cryptoblepharus metallicus	**6**	**0.21**	**0.33**	**0.12**	**0.26**	**0.12**	**Search**	**Moderate occupancy and detectability.**
Crypto. plagiocephalus	**9**	**0.31**	**0.36**	**0.09**	**0.26**	**0.12**	**Search**	**Moderate occupancy and detectability. Uncertain taxonomy.**
Ctenotus arnhemensis	**0**	**0**					**Pit**	**May be locally abundant near Ranger Mine**
Ctenotus borealis	1	0.03					Pit	Low occupancy
Ctenotus decaneurus	1	0.03			0.22	0.10	Pit	Low occupancy, moderate detectability
Ctenotus essingtonii	**8**	**0.31**	**0.39**	**0.13**	**0.37**	**0.05**	**Pit**	**Moderate occupancy, high detectability**
Ctenotus robustus	2	0.07			0.33	0.12	Pit	Low occupancy, moderate detectability
Ctenotus vertebralis	1	0.03			0.57	0.07	Pit	Low occupancy, high detectability
Delma borea	2	0.07					Pit	Low occupancy. Inadequate methods.
Dendrelaphis punctulatus	1	0.03					Spot	Low occupancy
Diporiphora bilineata	**9**	**0.35**	**0.47**	**0.19**	**0.34**	**0.08**	**Pit**	**Moderate occupancy, high detectability**
Furina ornata	2	0.07					Pit	Low occupancy
Gehyra australis	**7**	**0.27**	**0.42**	**0.11**	**0.13**	**0.05**	**Spot**	**High occupancy, high detectability**
Glaphyromorphus darwiniensis	1	0.03			0.02	0.02	Search	Low occupancy, low detectability
Glaphyromorphus isolepis	1	0.03					Pit	Low occupancy

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection prob	Detection prob SE	Best method	Status at Lowland Woodland (LW) sites
Heteronotia binoei	**15**	**0.58**	**0.88**	**0.13**	**0.34**	**0.09**	**Spot**	**High occupancy, high detectability**
Lerista karlschmidti	1	0.03					Pit	Low occupancy
Lerista orientalis	1	0.03			0.23	0.18	Pit	Low occupancy
Lucasium stenodactylum	1	0.03					Pit	Low occupancy
Menetia greyii	4	0.14			0.22	0.13	Search	Low occupancy, moderate detectability
Menetia maini	4	0.14			0.46	0.15	Search	Low occupancy, high detectability
Morethia storri	**6**	**0.23**	**0.48**	**0.09**	**0.34**	**0.17**	**Pit**	**Moderate occupancy, high detectability**
Notoscincus ornatus	1	0.03			0.30	0.08	Search	Low occupancy, moderate detectability
Oedura rhombifer	2	0.08					Spot	Low occupancy
Proablepharus tenuis	1	0.03					Pit	Low occupancy
Ramphotyphlops guentheri	1	0.03					Pit	Low occupancy
Varanus mertensi	1	0.03					Camera	Low occupancy. Not usually in LW.
Varanus scalaris	1	0.04			0.13	0.09	Camera	Low occupancy, low detectability
Varanus tristis	2	0.07			0.13	0.09	Camera	Low occupancy, low detectability

*Table 3.3. Sixteen native mammal species detected at 29 lowland woodland fire plots in northern Kakadu National Park in recent sampling (2012–2015), showing those species deemed suitable for monitoring based on detectability and occupancy estimates (n = 5; in bold). Naïve occupancy for all species and modelled estimates of occupancy for those more common and readily detected species are shown. Detection probability estimates (per day/night of survey – Spot and Pit method, and per week of 5 camera array deployment) are derived from a broader pool of Top End sites using the same standardised fauna sampling approach. An assessment of species status in lowland woodlands of Kakadu is provided to direct decisions on each species potential use in species-specific rehabilitation standards for Ranger Mine. Threatened species marked with *.*

SPECIES	Sites with records	Naïve occupancy	Occupancy estimate	Occupancy SE	Detection probability estimate	Detection probability SE	Best method	Status at Lowland Woodland (LW) sites
Agile Wallaby	**14**	**0.48**	**0.51**	**0.18**	**0.49**	**0.06**	**Camera**	**Moderate occupancy, high detectability**
Antilopine Wallaroo	**2**	**0.07**	**0.14**	**0.14**	**0.27**	**0.05**	**Camera**	**Low occupancy, moderate detectability**
Black Flying-fox	6	0.21					Spot	Low occupancy. Inadequate methods
Black-footed Tree-rat*	**3**	**0.10**	**0.27**	**0.14**	**0.68**	**0.03**	**Camera**	**Low occupancy due to past decline, but may be locally abundant near Ranger Mine. High detectability**
Common Brushtail Possum	2	0.07	0.25	0.15	0.47	0.04	Camera	Low occupancy, high detectability
Common Planigale	1	0.03			0.08	0.06	Pit	Low occupancy, low detectability
Common Wallaroo	2	0.07	0.25	0.15	0.41	0.05	Camera	Low occupancy, high detectability. Not usually in lowland woodland as mainly rock areas
Delicate Mouse	1	0.03			0.02	0.02	Camera	Low occupancy due to past declines, low detectability
Dingo	**8**	**0.28**	**0.39**	**0.05**	**0.44**	**0.05**	**Camera**	**Moderate occupancy, high detectability**
Fawn Antechinus*	3	0.12					Camera	Low occupancy due to past declines, but may be locally abundant near Ranger Mine.
Little Red Flying-fox	3	0.10					Spot	Low occupancy. Inadequate methods
Northern Brown Bandicoot	**9**	**0.31**	**0.56**	**0.18**	**0.85**	**0.02**	**Camera**	**Moderate occupancy, high detectability**
Northern Quoll*	1	0.03	0.05	0.02	0.25	0.08	Camera	Low occupancy due to past decline, moderate detectability
Red-cheeked Dunnart	1	0.03	0.06	0.07	0.09	0.06	Pit	Low occupancy and low detectability
Short-beaked Echidna	1	0.03	0.12	0.09	0.19	0.06	Camera	Low occupancy and low detectability
Sugar Glider	2	0.07			0.67	0.16	Spot	Low occupancy, high detectability

3.2 Species that can be monitored with confidence

A subset of 50 species (34 birds, 11 reptiles and 5 mammals) were detected easily with the standard survey methods used and were recorded regularly enough to be monitored with high confidence (Table 3.4). These species:

- Had moderate to high occurrence, resulting in adequate naïve occupancy to run occupancy models (generally recorded at >10% of sites, see Table 3.1, Table 3.2, Table 3.3). Species with low occupancy (e.g., Magpie-lark, Northern Quoll) may not occur in the immediate vicinity of the Ranger Mine area and therefore would not necessarily be expected to re-colonise the site during rehabilitation.
- Had moderate to high detectability based on the sampling scenarios considered. Species with low detectability (e.g., Red-Cheeked Dunnart) were omitted due to the challenges of detecting them during surveys. Low detection probability contributes to low confidence that fauna surveys will accurately report on the status of those species.
- Were deemed to provide an indication of on-ground site conditions, which is not the case for those bird species primarily recorded flying over a survey site (e.g., Northern Rosella, Red-tailed Black Cockatoo).

*Table 3.4. Trophic guild and habitat requirements of 50 vertebrates of northern Kakadu's lowland woodland that can monitored with a high degree of confidence using the standard survey protocol of the Northern Territory Top End National Parks Ecological Monitoring Program. An assessment of the habitat requirements of each species is shown. Ctenotus arnhemensis has been included in this list as it is expected to be locally common around the Ranger Mine area. Threatened species marked with *.*

Trophic guild	Group	Species	Habitat requirements
Aerial insectivore	BIRD	Rainbow Bee-eater	insects in trees and over grassland
	BIRD	Leaden Flycatcher	grasslands and trees of dry habitat
Arboreal and ground-dwelling insectivore	BIRD	Willie Wagtail	insects over grasslands and in trees
	BIRD	Brush Cuckoo	varied dry woodland types
	BIRD	White-bellied Cuckoo-shrike	insects in trees
	BIRD	White-winged Triller	insects over grasslands and in trees
	BIRD	Northern Fantail	insects over grasslands and in trees
	BIRD	Black-faced Cuckoo-shrike	varied woodland types
	BIRD	Grey Shrike-thrush	varied woodland types
	BIRD	Grey-crowned Babbler	varied woodland types
Arboreal and ground generalist	BIRD	Torresian Crow	varied dry woodland types
Arboreal frugivore	MAMMAL	Black-footed Tree-rat*	established woodland with fruiting trees, including regrowth areas
	BIRD	Mistletoebird	mistletoe thus established eucalypts
Arboreal herbivore	BIRD	Sulphur-crested Cockatoo	varied dry woodland types
	BIRD	Yellow Oriole	decent riparian vegetation
Arboreal insectivore	BIRD	Rufous Whistler	varied dry woodland types
	BIRD	Varied Triller	insects over grasslands and in trees
	BIRD	Weebill	insects over grasslands and in trees
	BIRD	Black-tailed Treecreeper	feeds on insects under bark of established trees
	REPTILE	*Cryptoblepharus metallicus*	open forests and woodland
	REPTILE	*Cryptoblepharus plagiocephalus*	open forests and woodland, uncertain sp ID, taxonomic issues
	REPTILE	*Gehyra australis*	open forests and woodland
Arboreal insectivore/foliage gleaner	BIRD	Striated Pardalote	varied dry woodland types
	BIRD	Weebill	
Arboreal nectivore	BIRD	Little Friarbird	flowering Eucalypts, thus regenerated stands of trees
	BIRD	Rainbow Lorikeet	flowering Eucalypts, thus regenerated stands of trees
	BIRD	Red-winged Parrot	flowering Eucalypts, thus regenerated stands of trees
	BIRD	Silver-crowned Friarbird	flowering Eucalypts, thus regenerated stands of trees

Trophic guild	Group	Species	Habitat requirements
	BIRD	White-gaped Honeyeater	flowering Eucalypts, thus regenerated stands of trees
	BIRD	White-throated Honeyeater	flowering Eucalypts, thus regenerated stands of trees
Arboreal nectivore/insectivore	BIRD	Blue-faced Honeyeater	flowering Eucalypts, thus regenerated stands of trees
	BIRD	Brown Honeyeater	flowering Eucalypts, thus regenerated stands of trees
	BIRD	Dusky Honeyeater	flowering Eucalypts, thus regenerated stands of trees
Ground dwelling granivore	BIRD	Bar-shouldered Dove	mixed sp grassland
	BIRD	Partridge Pigeon*	seeds in mixed sp grassland
	BIRD	Peaceful Dove	seeds in mixed sp grassland
Ground-dwelling herbivore	MAMMAL	Agile Wallaby	open grassy areas - established woodland
	MAMMAL	Antilopine wallaroo	open grassy areas - established woodland
Ground-dwelling insectivore	BIRD	Red-backed Fairy-wren	insects over grasslands and in woodland
	REPTILE	*Carlia amax*	open woodland with leaf litter and ground cover
	REPTILE	*Carlia gracilis*	open woodland with leaf litter and ground cover
	REPTILE	*Carlia munda*	open woodland with leaf litter and ground cover
	REPTILE	*Ctenotus arnhemensis*	open forests and woodland
	REPTILE	*Ctenotus essingtonii*	grassland and low woodland
	REPTILE	*Diporiphora bilineata*	grassland and low woodland
	REPTILE	*Heteronotia binoei*	generalist, using most areas
	REPTILE	*Morethia storri*	varied dry woodland types
Ground-dwelling omnivore	MAMMAL	Northern Brown Bandicoot	requires well established woodland
	MAMMAL	Dingo	generalist, using most areas
Predators	BIRD	Blue-winged Kookaburra	woodland adjacent to riparian corridors
	BIRD	Pied Butcherbird	varied dry woodland types

3.3 Species diversity, trophic guild and community representativeness

Vertebrate species diversity varied among lowland woodland sites in northern Kakadu (Figure 3.2). Species richness of birds, reptiles and mammals combined varied from 15 to 37 detected during a 4 day/night surveywrnr (mean 25.6 ± 4.5 (SD), Figure 3.2). Birds were most diverse with a mean richness of 17.9 ± 5.4 (SD), compared to low richness for reptiles (4.1 ± 1.3 (SD)) and mammals (3.6 ± 1.6 (SD)). Evenness also varied (Figure 3.2) with mean evenness of 0.87 ± 0.02 (SD) indicating that most of the lowland woodland sites commonly contain a group of more abundant species and a group of less abundant (rarer, or less detectable) species.

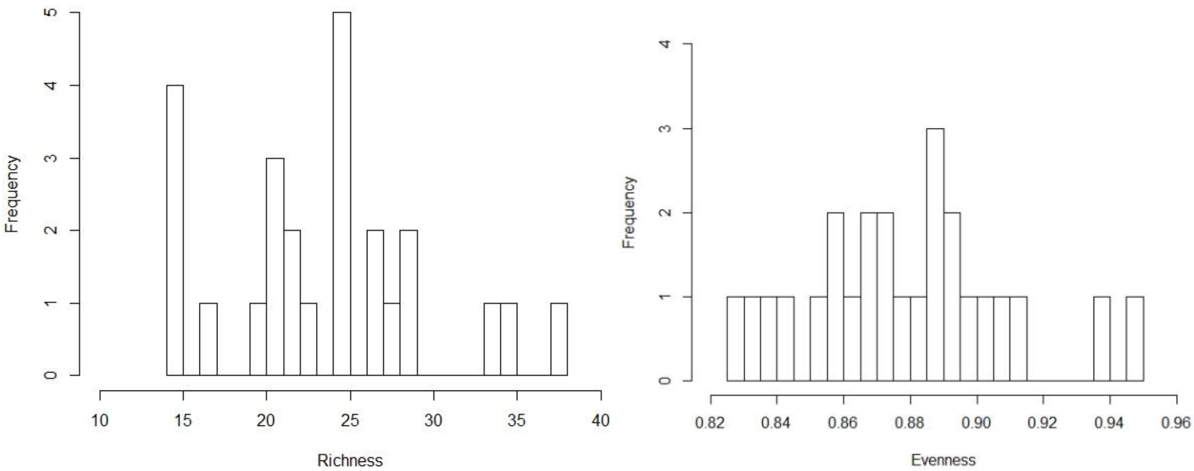

Figure 3.2. Frequency histograms of species richness and species evenness, across 29 lowland woodland fauna survey sites in northern Kakadu showing variation in diversity due to variation in the total number of species (birds, reptiles and mammals) recorded, and variation in their comparative abundance at a site-level.

Of the 14 trophic guilds considered, representation at the site level ranged from 5 to 12 (mean 8.7 ± 1.9 (SD)) across lowland woodland survey sites (Figure 3.3). At four sites, guild representation was low, with less than half (<7) of the recognised guilds recorded during survey. In contrast, guild representation was relatively high at 10 sites with 10-12 guilds represented.

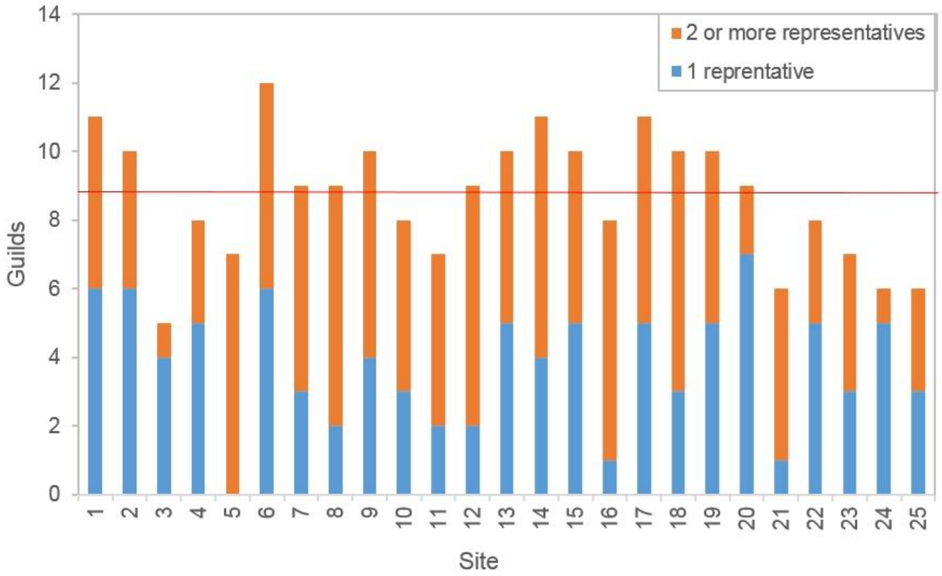

Figure 3.3. Site-level representation of 14 guilds assessed from a pool of 50 species that can be monitored with confidence (Table 3.4), and number of guilds with a single species and guilds with 2 or more representatives. Overall mean is also represented as the red line.

Ordination of the 29 sites by species composition and their retative abundance is shown in Figure 3.4. Those sites toward the centre of the ordination space (1, 7, 8, 16 and 17) could be considered to have 'characteristic' faunal assemblages, and species plotted in the same area are relatively ubiquitous common species (eg. Agile Wallaby, Grey Shrike-thrush, Rufous Whistler, Weebill, *Ctenotus essingtonii*, and *Cryptoblepharus metallicus*). Sites falling near the margin of the ordination space have more anomalous composition, and the position of species on the plot indicate how they contribute to the spatial separation of sites within the plot.

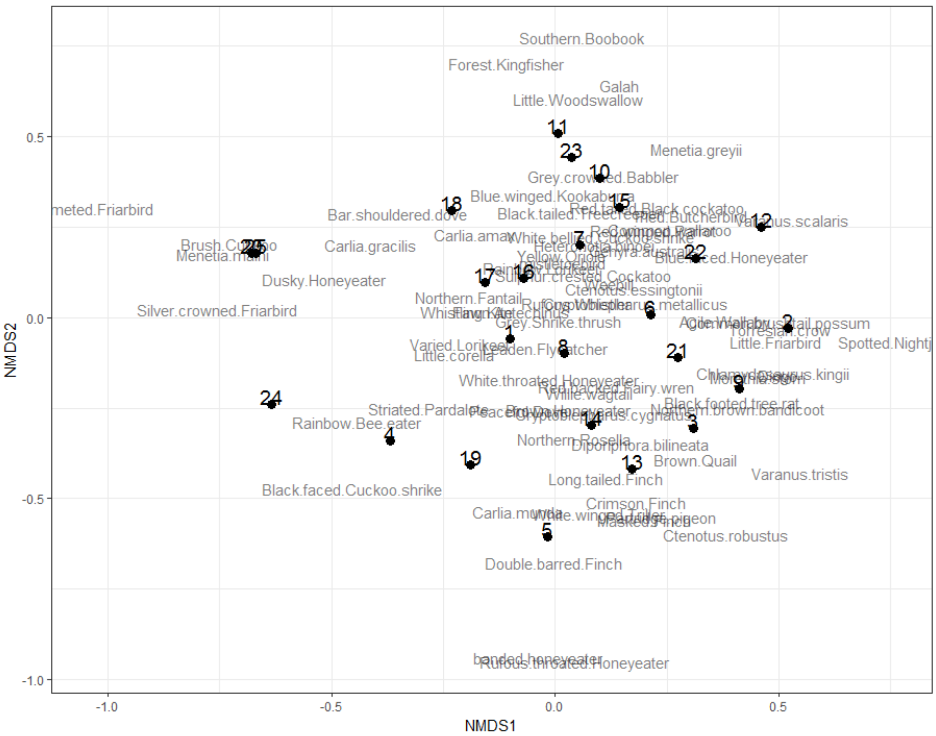

Figure 3.4. NMDS ordination of 29 lowland woodland sites in Kakadu based on Bray-Curtis similarity measure, overlaid with weighted species distribution within the ordination space. The lowest stress level of the ordination was 0.13.

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3.4 Optimising sampling design

Confidence intervals around estimates of mean richness and evenness were narrower with the addition of more sampling sites, highlighting the importance of adequate sampling effort when attempting to gain precise estimates of faunal diversity (Figure 3.5). Based on our calculations, when richness was calculated across 5 sites the mean number of species could fall anywhere between 14.8 to 28.0 species (applying 95% confidence). In contrast, when calculated across 30 sites, mean richness could fall between 22.4 to 25.4 species - a considerably narrower range. Sampling designs that generate more precise diversity estimates will be more useful for discerning similarity between groups of sites (reference and rehabilitation).

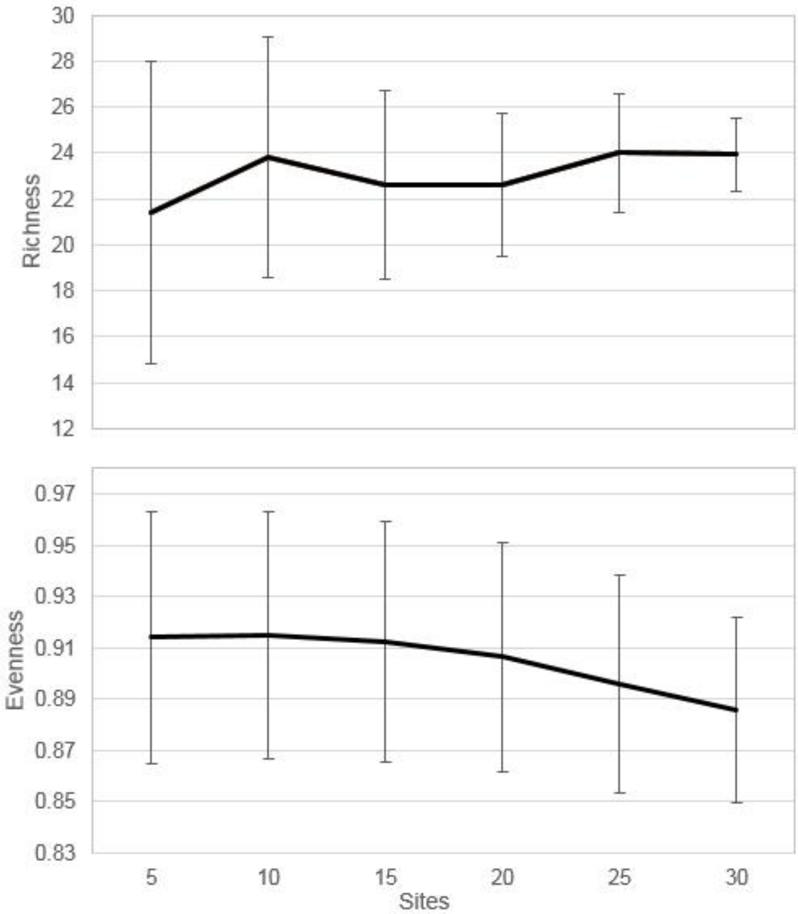

Figure 3.5. Precision in a range of diversity estimates (Richness – upper pane, Evenness – lower pane) gained from alternative sampling designs, showing tighter 95% confidence intervals with the addition of more survey sites. Estimates based on analysis of existing survey data where sites were randomly selected from a pool of 29 lowland woodland sites located in northern Kakadu.

Increasing the number of survey nights at each site boosted detectability of a broad range of species (Figure 3.6). Based on our calculations of detection probability for the 50 focal species (Table 3.4) from 4 days/nights survey and 5-weeks camera deployment, 26 species were detected with a suitably high probability (≥ 0.85 detection probability, or ≤ 0.15 probability of false absence, Figure 3.6). Increasing sampling by one day/night and two weeks of camera deployment added a further 13 species (39/50). However, a further increase in survey effort added only three more species (42/50, Figure 3.6).

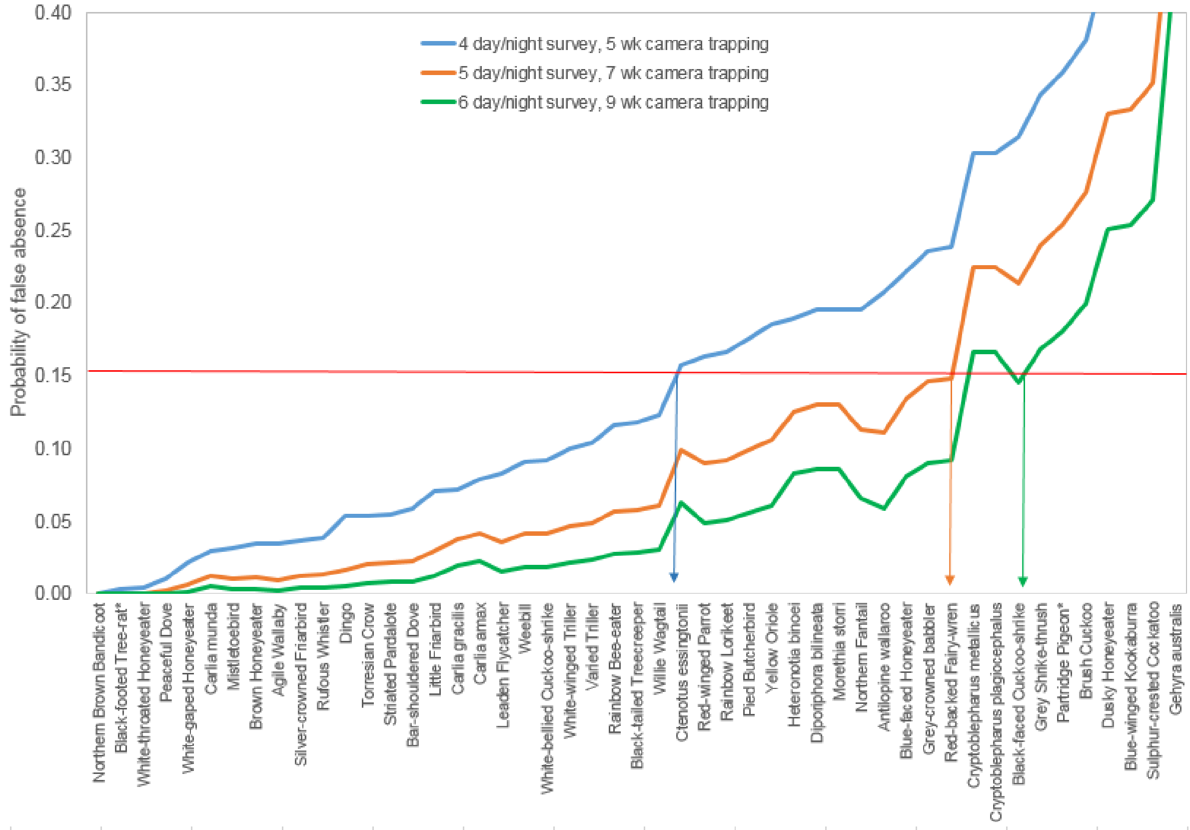

Figure 3.6. Probability of measuring a false absence (i.e. incorrectly assigning an occupied site as unoccupied) with the application of varied sampling effort at a site, for vertebrate fauna that can be monitored with confidence. The red line, denotes a probability of false absence <0.15, which is recommended as an appropriate threshold.

Increasing the number of sites resulted in improved precision in the occupancy estimate across all 50 focal species (Figure 3.7a and b). When applying a variance threshold of 0.1 (high precision/certainty), 4 days/nights of survey with 5-weeks camera deployment across 10 sites resulted in precise occupancy estimates for only 2 species (Figure 3.7a). Re-calculating variance across 20 sites resulted in precise occupancy estimates for 6 birds, 2 mammals and 1 reptile (Figure 3.7a). The addition of 10 more sites (to 30) boosted the number of species for which precise occupancy estimates were attained to over half of those considered (27/50, adding 13 birds, 3 mammals and 2 reptiles, Figure 3.7a). Re-running calculations with increased survey effort (5 days/nights of survey with 7-weeks camera deployment) boosted the performance of the 20 and 30 site sampling scenarios in terms of the number of species that attained an acceptable level of precision (20 sites 15/50, 30 sites 36/50, Figure 3.7a and b). Increased performance was attributable to higher detection probabilities across all species. These results provide an indication of the preferred sampling design, and the potential value of each species for inclusion in rehabilitation standards. When precision is relaxed to 0.15 the number of species that can be monitored effectively with a range of survey designs increases dramatically. Therefore, a decision is required as to the appropriate balance between the total number of species that can be modelled and monitored, and the level of confidence associated with that monitoring.

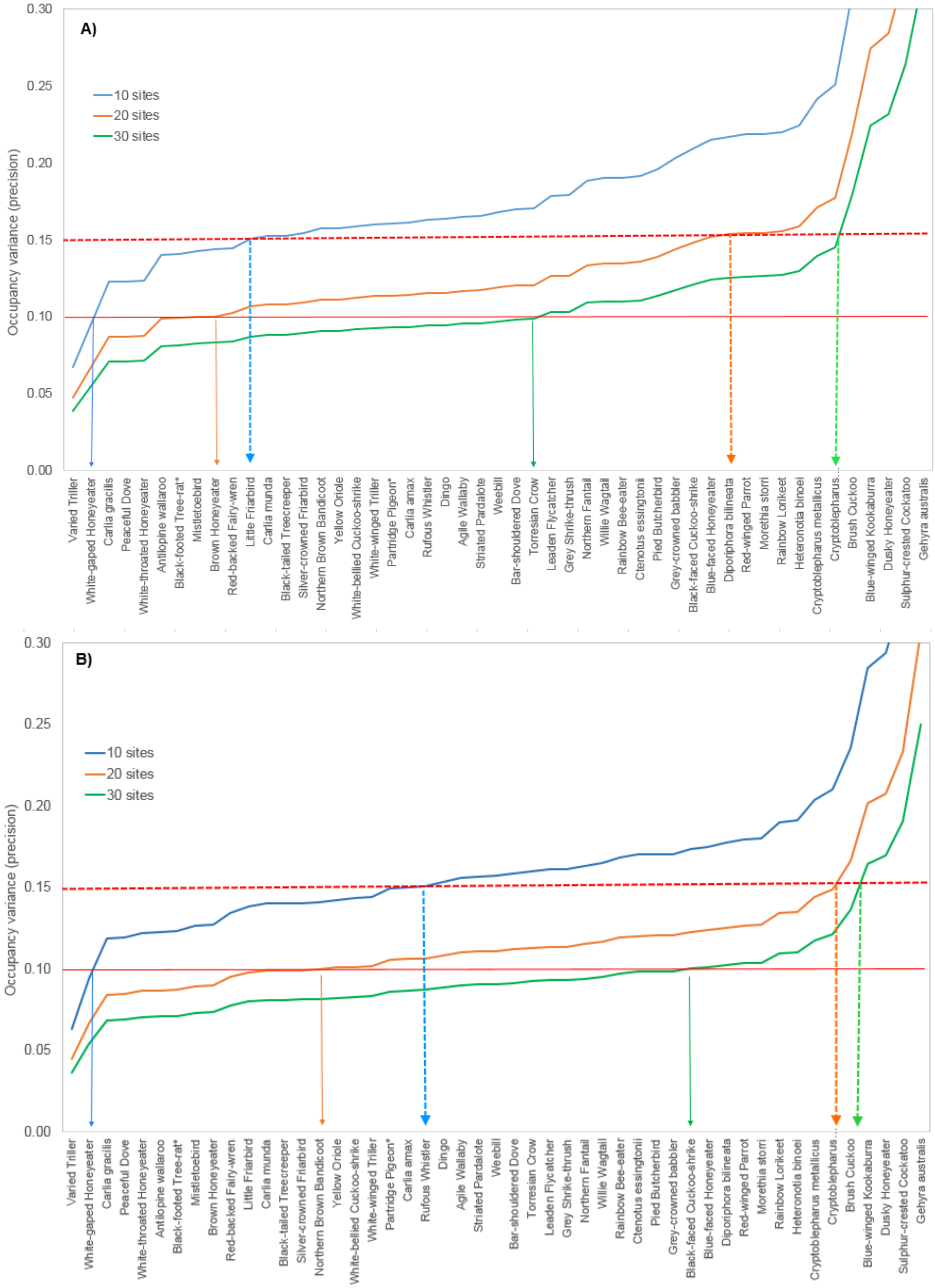

Figure 3.7. Variation in precision in the occupancy estimate for 50 lowland woodland vertebrate species with varied sampling effort in terms of number of sites and number of nights of survey (A: 4 day/night survey and 5 week camera trapping, B: 5 day/night survey and 7 weeks camera trapping). The red line indicates a high level of precision (0.10) and the red-dashed line a more relaxed level (0.15).

4. Discussion

4.1 Sampling design recommendations

Objectively measuring progress towards the overall goal of successful rehabilitation of Ranger Mine will require a well designed and implemented vertebrate monitoring program. We recommend the adoption of the site-level survey protocol currently used by the Northern Territory Top End National Parks Ecological Monitoring Program (Einoder et al. 2018a). This monitoring protocol is a robust and achievable sampling design that represents current best-practice in terrestrial vertebrate fauna monitoring in northern Australia. It combines a range of sampling methods for detecting a diversity of birds, reptiles and mammals that occur in lowland woodlands of Kakadu National Park. We acknowledge that this method does not sample animal communities in their entirety, as some species known to occur within the park are not adequately sampled (e.g., bats, amphibians, some snakes). Despite this, species readily detected during these fauna surveys represent a large proportion of the community and provide a good cross-section of vertebrates likely to be useful for inclusion in faunal rehabilitation standards for Ranger Mine.

We recommend site-level survey effort be increased above the 4 days/nights of the Top End National Parks Ecological Monitoring Program survey protocol to boost detection probability of a range of vertebrate indicator species. An increase to a 5 day/night survey (5 nights of live trapping, 5 nocturnal spotlighting surveys, 8 diurnal reptile surveys, and 12 diurnal bird surveys), allows commensurate increases in the detection probability of species, especially those rare and more cryptic members of faunal communities. The value of increasing sampling effort on detection has been demonstrated previously for mammals, reptiles and birds at a broader range of sites and in varied habitats across the Top End (Einoder et al. 2018a). The benefits of increased detection probabilities include a more accurate representation of the fauna community present at each site and improved accuracy in estimates of occupancy (Mackenzie 2005), as well as increased power to detect change in species over time (Einoder et al. 2018b).

We demonstrated improved precision across a range of metrics with the addition of sampling sites and site-level sampling effort. Based on the results presented here, we recommend fauna sampling at a minimum of 20 rehabilitation sites and 30 reference sites to provide a high degree of confidence in the accuracy and precision of the metrics calculated. A larger number of reference than rehabilitation sites is recommended to attain a more precise benchmark of species-level occupancy, diversity, and composition, given the inherent natural variability in lowland woodland communities (see Section 3.3). There is a need for adequate site replication and well-spaced reference sites to gain an accurate representation of the community in the reference ecosystem and to avoid any localised disturbances (Hobbs and Norton 1996). Spatial scale is an important consideration in the selection of reference sites. Sampling reference sites across a broader area will introduce inherently higher variability than would be expected across a clustered set sites in a relatively small area (Peterson et al.1998), but clustering sites in a small area may bias the total sample toward non-representative environmental conditions present in that area. Therefore, sampling sites should neither be clustered in a small area in an attempt to replicate the clustering of sites at Ranger Mine, or widley spread across northern Kakadu. For this reason, it is not recommended to use all existing sites from the Three Parks Fireplot Monitoring Program (this study) as the set of reference sites.

Reference sites should be positioned within the landscape so that the faunal community sampled are typical and thus representative, of lowland woodland. Disturbance, ecotones, and landscape position should be considered in the selection of reference sites to avoid unwanted variation in the benchmarks collected. For example, ranger's stations and campgrounds are not appropriate locations for survey sites as they are not representative of the broader areas of less disturbed, more natural lowland woodland. Furthermore, ecotones (i.e., edges of other habitat types) should be avoided as these areas are more likely to include a greater faunal diversity as species move in and out from the adjacent habitat. Ranger Mine is bisected by several minor drainage lines and bordered by Magela Creek to the north and west, all containing narrow linear corridors of riparian vegetation. The broader landscape position of the mine site is approximately two kilometres from the nearest sandstone woodland/shrubland (escarpment), and 10 km from nearest floodplain (Fig 1). Proximity to these and other broad habitat types (e.g., wet/dry rainforest, wetlands) will influence the mix of species that occur in the immediate surrounds of the mine, hence those available to re-colonise the rehabilitation area.

Identical methods and survey effort should be implemented at rehabilitation and reference sites. Also, to effectively measure fauna rehabilitation, surveys of rehabilitation and reference sites need to occur at the same time, or at least within the same season of the same year to capture any broader seasonal community change that may be occurring. Timing is imperative as the composition, abundance, activity and detectability of faunal communities in the Top End are well known to change throughout the year (Einoder et al. 2018a). We recommend the early dry season as a time for fauna surveys to avoid the influx of wet season migrants, and the risk of fires in the mid-late dry season. We expect recolonisation of the rehabilitation area by species that occur in adjacent areas will vary between species due to their habitat requirements. Recolonisation by ground-dwelling herbivores and granivores (e.g., Agile Wallaby, Peaceful Dove) will likely be rapid, whereas those species requiring mature and diverse vegetation communities (e.g., Black-footed Tree-rat, Yellow Oriole) may take decades to colonise the rehabilitation area. In general, the recovery of bird communities requires the re-establishment of vegetation structure (e.g., height, foliage layers, and basal area, George and Zack 2001). Therefore, fauna monitoring is likely to need to continue for an extended period (decades). However, a moderate return interval between samples (eg. 3 years) is likely to be sufficient to track temporal change attributable to rehabilitation progress.

4.2 Rehabilitation standards for vertebrate fauna

We advocate the use of a set of metrics (diversity, community composition and species occupancy) to assess the state of vertebrate communities in rehabilitated areas at Ranger Mine. Based on the analysis and results presented here, we identify four faunal complementary standards, each relating to a different aspect of community structure and complexity. We recommend their collective use in order to provide a high degree of certainty that faunal diversity and functionality has been restored to an acceptable state. These recommended standards were selected as they are measurable, practical and informative. The standards form a hierarchy of complexity and ease of implementation, from simple metrics (Standard 1), through to more complex and informative measures of community composition (Standard 2), complexity (Standard 3), and species-level occupancy (Standard

4) that are more challenging to implement. As assessment tool is provided in Section 4.2.1 for use in the evaluation of rehabilitation progress towards a standard set for each criterion.

4.2.1 Similarity assessment tool

Effectively integrating the Ranger Mine site with the surrounding landscape involves re-establishing flora and fauna communities to a state deemed suitably similar to adjacent areas. To help operationalise these standards we provide recommendations for each metric to define targets of how ‘similar’ rehabilitation sites should be to references sites (Figure 4.1). We also suggest an assessment tool to assist scoring the standards and measure progress towards faunal rehabilitation success. Scoring across a matrix will result in an assessment of either POOR, FAIR, ACCEPTABLE, or IDEAL (Figure 4.1).

One axis represents how similar a site-level community metric should be to the reference sites mean value. Outcomes range from not similar (0 – 29% of the reference site value) through to very similar (within 80% of the reference site value). A second axis represents the proportion of sites that fall within each ‘similarity’ class. The matrix is weighted to ensure that the assessment result does not provide perverse outcomes, where metrics including a high number of sites with low similarity are not scored above those with a small number of sites with moderate similarity and all other sites being equal. The value in the matrix is recorded for the proportion of sites within each similarity class. These values are added and the assessment outcome relates to the state under the summed number. This assessment can be applied at various stages of rehabilitation can gives a scale of progress for each of the standards.

We provide two scenarios to demonstrate the application of the assessment tool (Figure 4.2). In scenario one, species richness at most sites was of low to moderate similarity (<60%) of the mean diversity benchmark across reference sites, with three sites attaining a richness 60-79% of the benchmark, and only one site ≥ 80% (very similar, Table 4.1). The resultant score from this scenario would result in an assessment of POOR. In scenario two, 65% of the sites were ≥ 80% of the benchmark richness providing a score that results in an assessment of ACCEPTABLE (Table 4.1, see Appendix 5 for an additional range of scenarios).

An ACCEPTABLE state can be attained by either ≥ 60% of rehabilitation sites attaining ≥ 80% of the benchmark, or ≥ 80% of rehabilitation sites attaining ≥ 60% of the benchmark (Figure 4.1). These thresholds reflect two important concessions: 1) not all rehabilitation sites may attain comparable animal communities to the surrounding reference area; and, 2) rehabilitation sites may never support exactly the same animal communities as the surrounding reference area. This standard accounts for the fact that not all indicator vertebrate species will occur in the immediate vicinity of Ranger Mine to provide a source population, especially those with moderate to low occupancy.

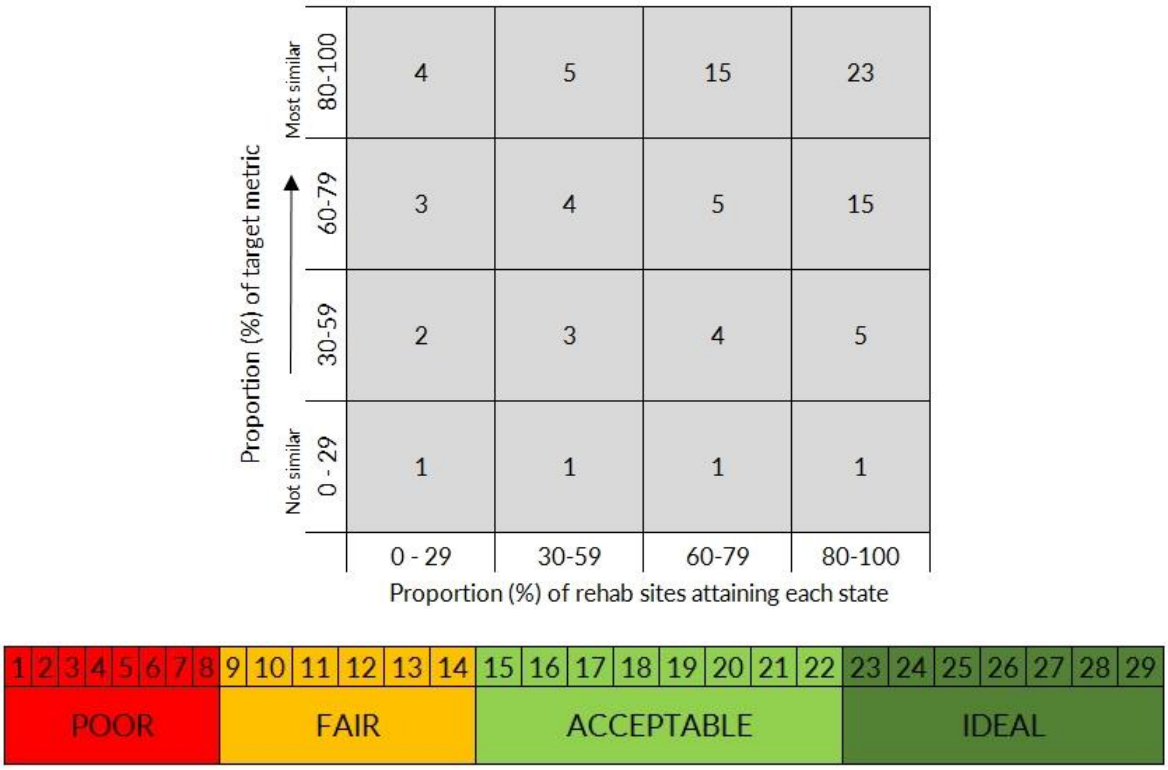

Figure 4.1. Assessment tool to assist scoring faunal standards and measure progress towards faunal rehabilitation success, from a state of POOR through FAIR, ACCEPTABLE and IDEAL. The vertical axis represents how similar a site-level community metric (richness, evenness, and species composition) is to the reference sites mean; horizontal axis represents the proportion of sites that fall within each 'similarity' class.

Table 4.1. Two scenarios showing the application of the assessment tool.

Scenario 1

Simialarity	Sites per category	% of sites
80-100	1	5
60-79	3	15
30-59	11	55
0-29	5	25
Total sites	20	100

	0 - 29	30-59	60-79	80-100
80-100	4	5	15	23
60-79	3	4	5	15
30-59	2	3	4	5
0 - 29	1	1	1	1

Proportion (%) of rehab sites attaining each state

Score = 11 (FAIR)

Scenario 2

Simialarity	sites per category	% of sites
80-100	13	65
60-79	3	15
30-59	0	0
0-29	4	20
Total sites	20	100

	0 - 29	30-59	60-79	80-100
80-100	4	5	15	23
60-79	3	4	5	15
30-59	2	3	4	5
0 - 29	1	1	1	1

Proportion (%) of rehab sites attaining each state

Score = 18 (ACCEPTABLE)

4.2.2 Standard 1: Similar diversity in bird, reptile and mammal communities across Ranger Mine rehabilitation sites as surrounds

Site-level richness and evenness should be ≥ 60% (moderately similar) of the mean of reference sites at ≥80% of rehabilitation sites, or ≥ 80% (very similar) at ≥60% of rehabilitation sites, for each of the bird, reptile and mammal components, as well as for the entire vertebrate community (i.e. all species combined). Note, evenness can only be calculated for sites where more than one species is present for any community component.

4.2.3 Standard 2: Species composition at Ranger Mine rehabilitation sites is similar to surrounds

a) Site-level species composition should be ≥ 60% (moderately similar) of that at reference sites at ≥ 80% of rehabilitation sites, or ≥ 80% (very similar) at ≥ 60% of rehabilitation sites.
b) In addition to achieve a state of Acceptable or Ideal at least 50% of the EPBC listed threatened species occurring across the reference sites must be represented across the rehabilitation sites.

Application –Once survey data become available apply an ordination approach (e.g., NMDS, as demonstrated here), to assess which rehabilitation sites overlap with reference sites in ordination space (hence share a similar species composition of moderate to common birds, reptiles and mammals (Figure 4.2). Similarity in composition can be gauged from the application of significance tests using ANOSIM or ADONIS (see Appendix 4).

4.2.4 Standard 3: Adequate site-level representation of trophic guilds at Ranger Mine rehabilitation sites as surrounds

c) Site-level representation of trophic guilds should be either ≥ 60% (moderately similar) of the benchmark (mean trophic guilds per site at reference sites) at ≥ 80% of rehabilitation sites, or ≥ 80% (very similar) at ≥ 60% of rehabilitation sites.
d) In addition to achieve a state of Acceptable or Ideal at least 50% of the hollow using and frugivorous species occurring across the reference sites must be represented across the rehabilitation sites.

Application – The demonstration of trophic guild representation that was applied in this report only considered a subset of the entire community, resulting in a tally of 14 trophic guilds. In practice once survey data becomes available guilds should be assessed for all bird, reptile and mammal species detected during surveys of reference sites for a more comprehensive list (i.e., beyond the list provided in Table 3.4, Figure 4.2). Species on reference sites should be assigned as hollow users following Taylor, Woinarski and Chatto (2003).

4.2.5 Standard 4: Similar species-level occupancy of a cross-section of birds, reptiles and mammals at Ranger Mine rehabilitation sites as surrounds

At least 60% of the 50 target species should attain ≥ 80% of their occupancy at reference sites; alternatively, ≥ 80% of the 50 species attain ≥ 60% of the occupancy of reference sites. Furthermore, representative species reaching this occupancy target should include at least two representatives of bird, reptile and mammal, and at least one of the two EPBC-listed threatened species monitored with confidence (Partridge Pigeon and Black-footed Tree-rat).

Application – Recommended analysis: species-specific occupancy modelling, accounting for imperfect detection, should be applied to detection/non-detection data collected from all reference and rehabilitation sites. The derived occupancy estimates at rehabilitation sites can then be compared directly with the occupancy estimates derived from reference sites (Figure 4.2).

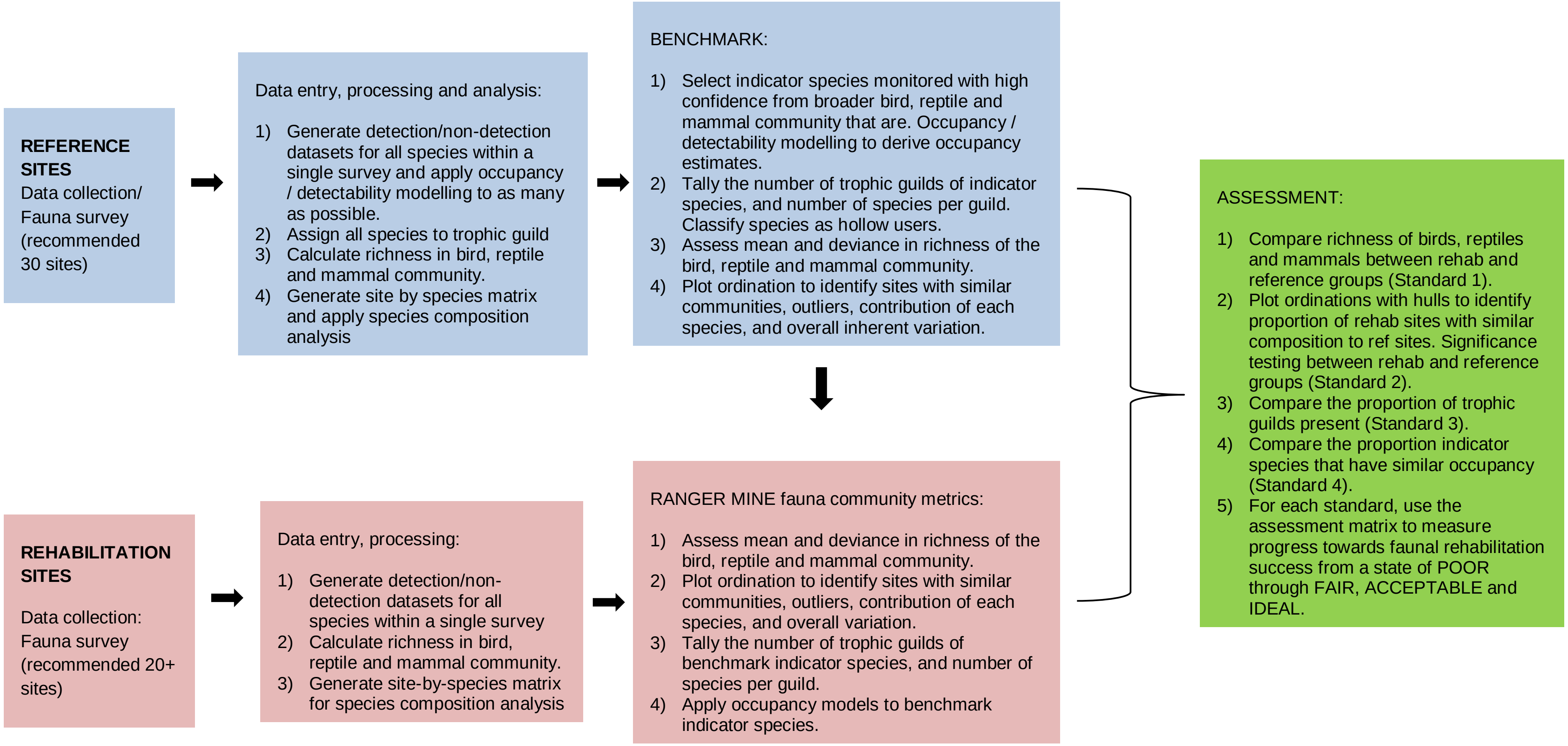

Figure 4.2. Data collection and analysis phases with each future round of monitoring showing the sequential order of steps required for data from reference sites (blue) and rehabilitation sites (pink) to generate the relevant metrics, then assess points 1–4 (green). Note, concurrent reference and rehabilitation site sampling is required.

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Appendix 1: Sampling methodology of the Three Parks Fireplot Monitoring Program and Northern Territory Top End National Parks Ecological Monitoring Program

In the Three Parks Fireplot Monitoring Program (1996-2014) surveys consisted of live trapping using cage, Elliot and pitfall traps, active searches, and spotlighting within a 50 x 50 m, in addition to bird surveys within a 100 x 100m quadrat for three or four days/nights at each site (*for detailed methods see* Woinarski et al. 2010). A re-survey occurred at some of these sites in 2015 (Kakadu National Park Biodiversity Hotspots Survey 2015, Einoder and Gillespie 2016), where live trapping was complimented with camera trapping, following the method of Gillespie et al (2015). Camera trapping provides improved detectability of a wide range of mammals over traditional live trapping methods (Einoder et al. 2018c).

In the Northern Territory Top End National Parks Ecological Monitoring Program (2015 – ongoing) each site contains 2 adjacent 100m x 100m plots within which timed area searches are performed during the day for birds and reptiles (separate surveys for each), and during the night for nocturnal animals. The primary plot contains a 50 m x 50 m trapping grid with 8 cage traps and 16 Elliott traps arranged around the perimeter, along with 3 pit traps and 6 funnel traps arranged inside the grid. Each pit trap comprises a 20 L plastic bucket dug into the ground with 10 m of drift-fence, along which 2 funnel traps are positioned. Overlaid over the trapping grid is a 5-camera trap array containing 4 outer cameras offset from trap grid corners, and a central high sensitivity short focal length camera set over a drift fence and cork board to reduce false triggers. The adjacent plot contains a central 50 m x 50 m area within which 3 pit traps and 6 funnel traps are positioned. See Einoder et al. (2018) for full details. Three repeat diurnal searches for birds are performed per day, two repeat diurnal searches for reptiles are performed per day, and one nocturnal search for nocturnal mammals and reptiles are preformed per night of survey.

Appendix 2: Occupancy and detectability modelling procedure

We generated detection histories for species observed at least once during the study: a 1 represented the detection of a species, a 0 represented a non-detection. We collapsed detection histories so that the sampling occasion was one day/night for live trapping, bird surveys and nocturnal searches. This resulted in four repeat sampling occasions per site for these methods. For camera trapping, we collapsed detection histories so that the sampling occasion was one week, resulting in five repeat visits to sites with this method. Separate detection histories were generated for each sampling method. For example, a detection history of [0,1,0,0,1] with camera trapping and [1,0,0,0] with cage trapping meant a species was detected (one or more individuals) in the second and fifth week with cameras, and only in the first day/night with cages. For species with multiple sampling methods, we appended the detection histories for each species and modelled the sampling method in *unmarked* as an observational-level factor. Occupancy models were applied using the *unmarked* package (Fiske and Chandler 2011) in R (R Core Team 2018).

We derived species-level detection probability estimates for the vertebrate species detected at the 29 lowland woodland survey sites in northern Kakadu from an existing dataset collected across a broader set of sites located in eight protected areas (Gregory National Park, Nitmiluk National Park, Kakadu National Park, Litchfield National Park, Garig Gunak Barlu National Park, Warddeken IPA, Djelk IPA, Fish River Station) in the Top End of the NT, sampled between 2014 - 2016. Data was collected following the Top End National Parks Ecological Monitoring Program survey protocol (Einoder et al. 2018), hence detection probability estimates are of relevance to this study. Detection histories were generated (as for occupancy modelling - see above) for those sites located in lowland woodland, and occupancy/detectability models were applied using the *unmarked* package (Fiske and Chandler 2011) in R (R Core Team 2018). Detection probability estimates were calculated per day/night of live trapping and active searching, where three repeat diurnal searches for birds per were performed per day, two repeat diurnal searches for reptiles were performed per day, and one nocturnal search for nocturnal mammals and reptiles were preformed per night (for details see Einoder et al. 2018). Detection probability estimates for species on cameras were calculated per week of deployment of a 5-camera trap array (for details see Einoder et al. 2018).

Appendix 3. Sensitivity analysis to assess the effect of survey effort on precision/confidence in estimates

Confidence intervals around richness and diversity estimates were calculated on a range of datasets generated from random selection 10, 20 and 29 sites from the 29 survey sites for which we have fauna survey data. This approach illustrates the influence of increased number of sites on precision in the richness and diversity estimates.

For focal vertebrate species that can be monitored with confidence (Table 4) we ran a series of sensitivity analysis to assess: 1) the influence of an increasing number of sampling sites on precision/variance in the occupancy estimate, and confidence intervals around richness and diversity estimates; and 2) the influence of increasing sampling effort on the probability of false absences. Precision in the occupancy estimate was calculated by applying Equation 1 from Mackenzie and Royle (2005). In our calculations we applied a 0.1 error rate (i.e., will only accept 10% error rate) in the occupancy estimate as a high level of precision was deemed of importance in this study. Generally, an increased number of sites will provide a more precise estimate of the actual occupancy of a species across the landscape (Mackenzie 2005). Probability of a false absence was calculated as 1 – det*, where det* is the probability of detecting a species at a site at least once (Mackenzie and Royle 2005). Monitoring programs should be designed to minimise the probability of a false absence, thereby providing a high level of certainty about the occupancy status of sites. Mackenzie and Royle (2005) recommendation of a value <0.15 as being suitable for wildlife monitoring programs.

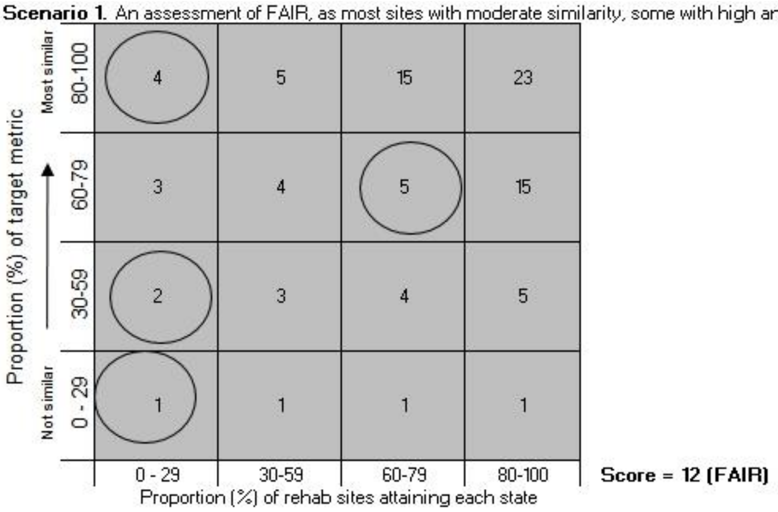
Appendix 4. NMDS plotting to compare faunal assemblages

For both reference and rehabilitation datasets collected in the same round of sampling apply two-dimensional non-metric multi-dimensional scaling (NMDS) analysis to community-by-species matrix of taxa frequency using 100 iterations and based on the Bray-Curtis dissimilarity matrix (as in Van Etten et al. 2014). Plot sites across two axis such that sites with similar faunal assemblages are closer together and sites with dissimilar assemblages are further apart in ordination space. Plot species on top of sites across the same two axis to identify the species contributing to inter-site similarities and differences. Groups can be visualised with the application of hull around each of the groups. This can be achieved by re-plotting NMDS scores in the package ggplot2 (Wickham 2009) and applying the *chull* function.

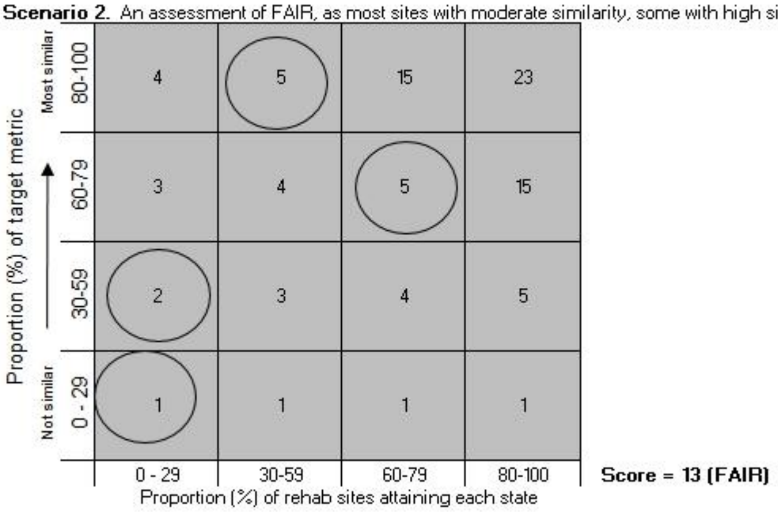
Then ANOSIM or ADONIS can be applied to test if the groups are significantly different. Differences between rehabilitation and reference groups can be tested using the ANOSIM permutation routine with 9999 iterations. Taxa most contributing to differences between sites can be identified using the SIMilarity-PERcentages (SIMPER) routine (cut-off at 95% cumulative similarity).

Appendix 5. Scoring several scenarios - application of the similarity assessment tool

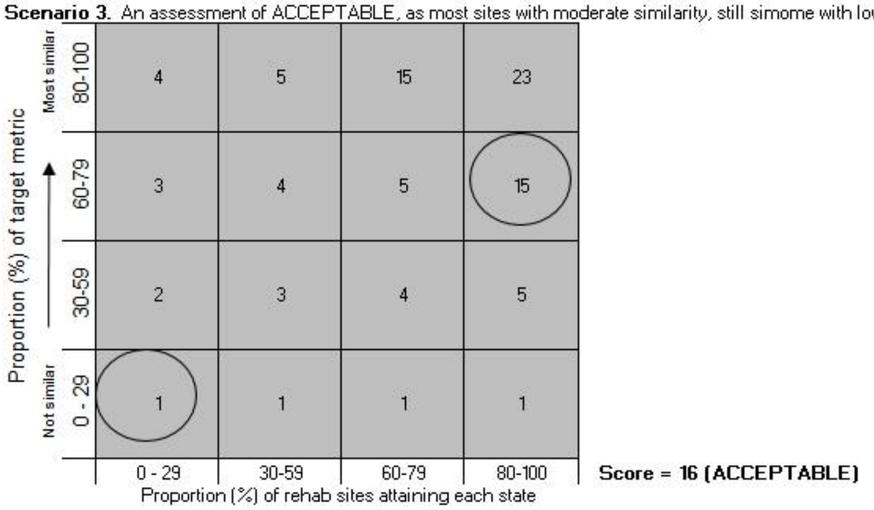
Scenario 1. An assessment of FAIR, as most sites with moderate similarity, some with high and low similarity



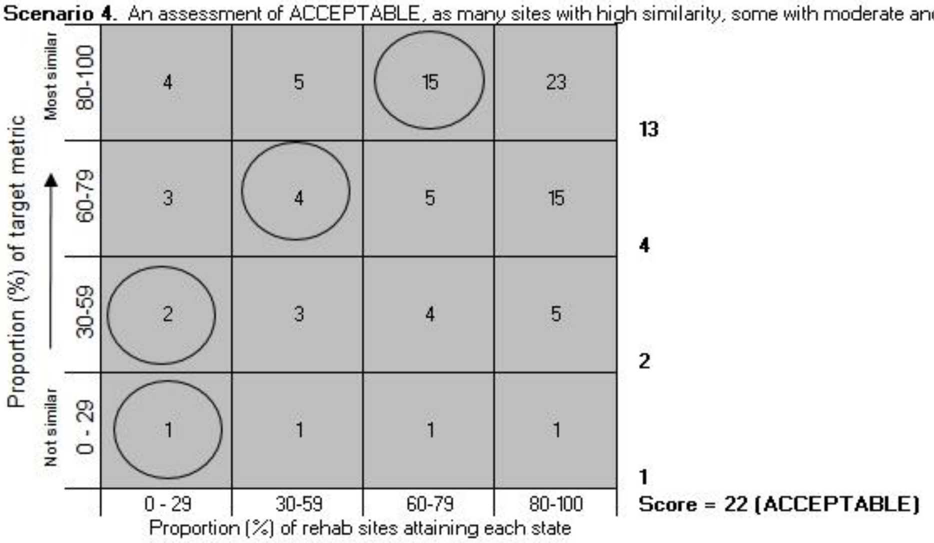
Scenario 2. An assessment of FAIR, as most sites with moderate similarity, some with high similarity, and some with low similarity



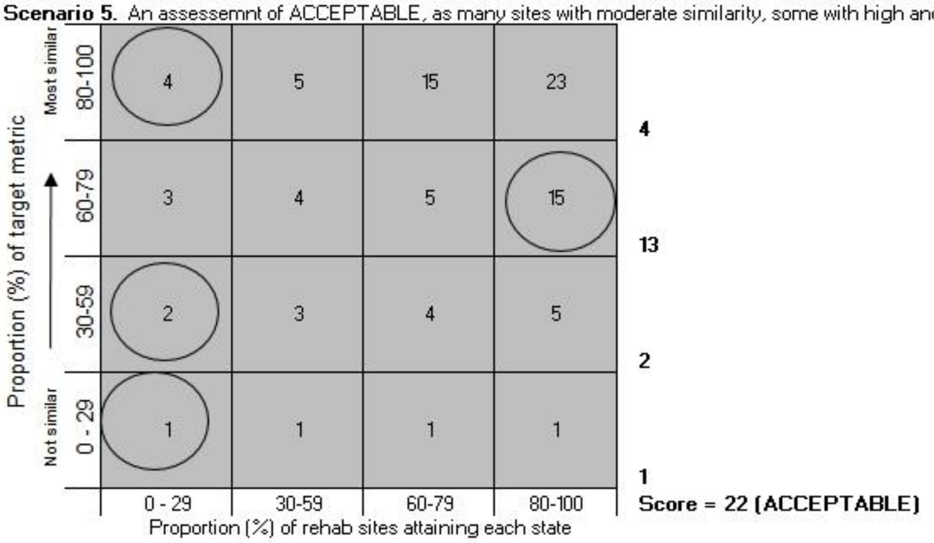
Scenario 3. An assessment of ACCEPTABLE, as most sites with moderate similarity, still simome with low similarity



Scenario 4. An assessment of ACCEPTABLE, as many sites with high similarity, some with moderate and low similarity



Scenario 5. An assessemnt of ACCEPTABLE, as many sites with moderate similarity, some with high and low similarity



Scenario 6. An assessment of IDEAL, as most sites with high similarity, some with moderate and low similarity