Integrated monitoring and assessment to support adaptive management and planning | Final report

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australian wildlife conservancy

kakadu NATIONAL PARK

BAWINANGA DJELK CARING FOR COUNTRY

WARDDEKEN LAND MANAGEMENT

National Environmental Research Program

NORTHERN AUSTRALIA HUB

Northern Territory Government

Acknowledgements

We would like to acknowledge the Traditional Owners past and present who allowed us on their country.

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Cover photos

Front cover - Photo of Warddeken Rangers during the Warrdeken culture survey in November 2013, by Michael Lawrence-Taylor.

Back cover - Photo by Michael Lawrence-Taylor

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Contents

Summary

This project sought to develop and evaluate different approaches to biodiversity monitoring, with different governance structures and different levels of Indigenous participation and engagement, across northern Australia. In particular it sought to develop and evaluate biodiversity monitoring methods to augment delivery of improved biodiversity conservation outcomes on Indigenous managed lands, through developing collaborative approaches with Indigenous landowners with varying levels of land management capacity and experience.

The project established a framework and platform from which to build and refine monitoring programs for Indigenous managers that inform their management. Specific objectives, methods, level of support and participation from scientists and ecologists are contingent on a wide range of factors related to existing capacity and momentum with targeted land management. Overall design and most aspects of data management will continue to require strong partner support from ecologists and natural resource managers for the foreseeable future.

Broader engagement with a wider network of Indigenous land managers about the value of monitoring and evaluation is desirable. There is further potential for development of tools to aid Indigenous groups with uptake and implementation of monitoring. Further work is required to develop a higher level of coordination and integration of biodiversity monitoring and reporting across different land tenures and traditional custodial arrangements.

1 Background

Monitoring and evaluation are integral to environmental and natural resource management, enabling decision makers to respond to changing circumstances, or to revise ineffective or detrimental management practices for achieving desired outcomes. Biodiversity monitoring is essential for forewarning impending species declines, establishing triggers for management intervention, evaluating the effectiveness of conservation management actions, and to measure and evaluate ongoing status of biodiversity (Lindenmayer *et al*. 2012). Much of the supporting evidence for mammal declines in northern Australia comes from monitoring programs established in selected protected areas (Woinarski *et al*. 2010).

Until now biodiversity monitoring has occurred in relatively small areas of Northern Australia, including selected protected areas managed by federal, state and territory governments, and non-government conservation organisations, such as the Australian Wildlife Conservancy (AWC http://www.australianwildlife.org). Information on the biodiversity condition of large parts of northern Australia is lacking. In addition to limiting more general inference from the existing monitoring about biodiversity patterns and ecological processes across northern Australia, we are unable to evaluate ongoing status of biodiversity and other potential biodiversity loss, evaluate the effectiveness of existing management activities, or identify new management interventions.

Large proportions of northern Australia are managed by Aboriginal people. Within the Northern Territory at least 40% of the conservation estate is managed or co-managed by Aboriginal people through various arrangements, such as joint management arrangements and Indigenous Protected Areas (Australian Department of the Environment 2014; NTG Parks and Wildlife Commission 2013). Indigenous land managers, including those not in formally recognised conservation areas, are increasingly involved in undertaking biodiversity conservation activities. There is a growing recognition amongst groups wishing to undertake conservation-based management of the need to evaluate the benefits and consequences of their management activities. Collectively the increasing Indigenous land management estate provides significant potential to grow the current, limited, network of biodiversity monitoring programs, and increase opportunities for biodiversity conservation, through increased capacity to manage ecological threats, and opportunities for research and development of management solutions.

Figure 1: Within the Northern Territory at least 40% of the conservation estate is managed or co-managed by Aboriginal people. Indigenous land managers, like the Warddeken Rangers above, are increasingly involved in undertaking biodiversity conservation activities.

Established terrestrial ecological monitoring programs in northern Australia, such as the Three Parks Fireplot network in Kakadu, Nitmiluk and Litchfield National Parks, and monitoring undertaken by the AWC on its properties, are based on conventional scientific principles; site selection is derived from stratification and randomisation, incorporating environmental gradients and management units from management plans. Data collection methods are developed from scientific experience of optimised methods for systematically sampling various biota with consideration of statistical power. Data are stored digitally in institutional databases. Participation of Indigenous owners or managers is typically limited to assisting with field work with some limited input into site selection.

In addition to being informative about management, the successful establishment and long-term sustainability of monitoring programs across Indigenous-managed land is dependent on their support and much greater levels of involvement. Programs need to be relevant to their social and environmental values. To achieve this, conventional biodiversity monitoring methodologies must be modified to ensure that:

- They are understandable and accessible
- They are culturally acceptable
- They reflect the biodiversity and cultural values that are important to Indigenous managers
- It is technically feasible for them to undertake and highly participatory.

The nature of modifications is likely to vary amongst groups, depending upon circumstances, such as past history of land management and engagement with research and biodiversity conservation, and inherent cultural differences. Capacity in terms of resources and support also strongly affects their ability to participate. Furthermore, programs need to foster community engagement and understanding to ensure relevance, which is essential for their sustainability, and for uptake of monitoring and evaluation outputs in management decision-making.

Through developing, trialling and the evaluation of different approaches to biodiversity monitoring, with different governance structures and different levels of Indigenous participation and engagement, it may be possible to refine and optimise monitoring to best integrate with varying land management arrangements and cultural settings across northern Australia.

2 Objectives

Develop and evaluate different approaches to biodiversity monitoring, with different governance structures and different levels of Indigenous participation and engagement.

In collaboration with Traditional Owners (TO's) and land managers in different Indigenous management and cultural contexts, develop and evaluate monitoring methods to augment delivery of improved biodiversity conservation outcomes on Indigenous managed lands. Specifically:

- Refine and adapt conventional biodiversity monitoring methods that are compatible with Indigenous cultural and social objectives
- Utilise Indigenous knowledge and approaches, devise new tools to improve understanding of biodiversity condition and threatening processes operating on Aboriginal managed lands
- Contribute to improved understanding of the nature of mammal declines in northern Australia
- Build capacity of Indigenous managers to undertake environmental monitoring and evaluation as part of their land management
- Provide recommendations for establishing research and monitoring programs in partnership with Aboriginal groups.

3 Methods

3.1 Geographic context

Kakadu National Park is located within the Alligator Rivers Region of the Northern Territory, covering 19,804 km^2. The Park is managed through a joint management arrangement between the Aboriginal traditional owners and the Director of National Parks. A fauna monitoring program commenced in the Park 20 years ago, with the purpose of providing surveillance of spatial and temporal patterns of change in informing on Park management – particularly fire management (Russell-Smith *et al*. 2014).

Australian Wildlife Conservancy, a not-for-profit non-government organisation, manages Mornington and Marion Downs, covering 6000 km^2 in the Kimberley, WA. AWC undertakes biodiversity monitoring that allows it to report on changes over time, particularly as a consequence of its management actions, and then respond to them as needed.

Fish River Station (FRS) is a 1780 km^2 former cattle lease in the Daly River catchment of the NT (Fig. 4). With extensive intact savanna, sandstone ranges, monsoon forest and wetlands, FRS has high biodiversity conservation values, as well as cultural values to the local TO's. However, Indigenous occupation and management was disrupted by pastoralism, and TO's currently live in nearby settlements. FRS was purchased in 2010 by the Indigenous Land Corporation (ILC), with the intention of ecological rehabilitation and carbon credit generation, through rectifying inappropriate fire regimes, destocking of feral herbivores, weed management, and maintaining/enhancing cultural values (ILC 2012). An Indigenous ranger group is being built from the local TO's to undertake this work and to build capacity in Indigenous conservation land management. Eventually, when capacity and infrastructure are established, FRS and its management will be handed over to the TO's. Presently FRS has a small, developing, ranger team, with limited experience with research or biodiversity-related activities.

Declared in 2009, the Djelk and Warddeken IPA's together cover more than 31,000 km^2 of land and sea country in Arnhem Land (6,700 and 24,000 km^2 respectively; Fig. 4). Djelk IPA extends from the central Arnhem coast, through extensive freshwater floodplains and tropical savanna ecosystems to the fringing uplands of the Arnhem Sandstone Plateau, where Warddeken IPA adjoins, extending over the stone country to Kakadu National Park. An unbroken history of Indigenous use and management exists within these IPA's; a continuous stewardship that today includes the Djelk and Warddeken Rangers. Due to remoteness and inaccessibility, there was less direct conflict and no forced removal of Aboriginal people in the IPA's; however, various political and social influences have seen many people leave their ancestral estates in the past, particularly in the stone country of Warddeken IPA (Cooke 2001).

Djelk IPA comprises over 100 clan groups with a population of approximately 3000, centred on Maningrida, from where the rangers operate (Djelk Rangers 2009). Warddeken IPA covers 32 clan estates, with a permanent population of approximately 300 across 5 outstations (WLML 2009). The rangers operate from Kabulwarnamyu outstation, specifically established as a work base.

Djelk and Warddeken IPA's are very well resourced with strong support staff and management, established management plans and structures, experienced rangers, and strong momentum in land management. They have some prior experience with scientists and biodiversity projects.

3.2 Planning and design

Monitoring program design and sampling methods for Kakadu National Park and AWC are documented elsewhere (see Woinarski *et al*. 2010; Russell-Smith *et al*. 2014; Legge and Flemming 2012).

Planning and consultation with Indigenous landowner partners was essential and a key project element. However differences in past history of traditional land use and custodianship, stages of land management development and planning, and ranger capacity, led to the development of different planning approaches and levels of consultation at FRS and the IPA's.

FRS management and TO's used the Healthy Country Planning (HCP) process to develop their plan of management (ILC 2012). Conservation targets were identified, along with the need to develop monitoring to evaluate performance in meeting those targets through mitigation of inappropriate fire regimes and reduction of feral herbivore populations. Further consultation was undertaken with TO's to identify specific biodiversity indicators that were important to them. This list was then vetted to select species that scientist thought were relevant indicators for the management questions and feasible to measure, resulting in a defined list of wildlife species to monitor:

- Northern Quoll (see Fig. 2)
- Black-footed Tree Rat
- Northern Brown Bandicoot
- Brush-tailed Possum
- Dingo (see Fig. 3)
- Macropod species
- Emu.

Figure 2: Seven species, including the Northern Quoll above, were selected as biodiversity indicators. The indicator species were selected due to importance to Traditional Owners, relevance to management questions and feasibility to monitor.

Figure 3: Dingos were selected as another biodiversity indicator species in the monitoring program.

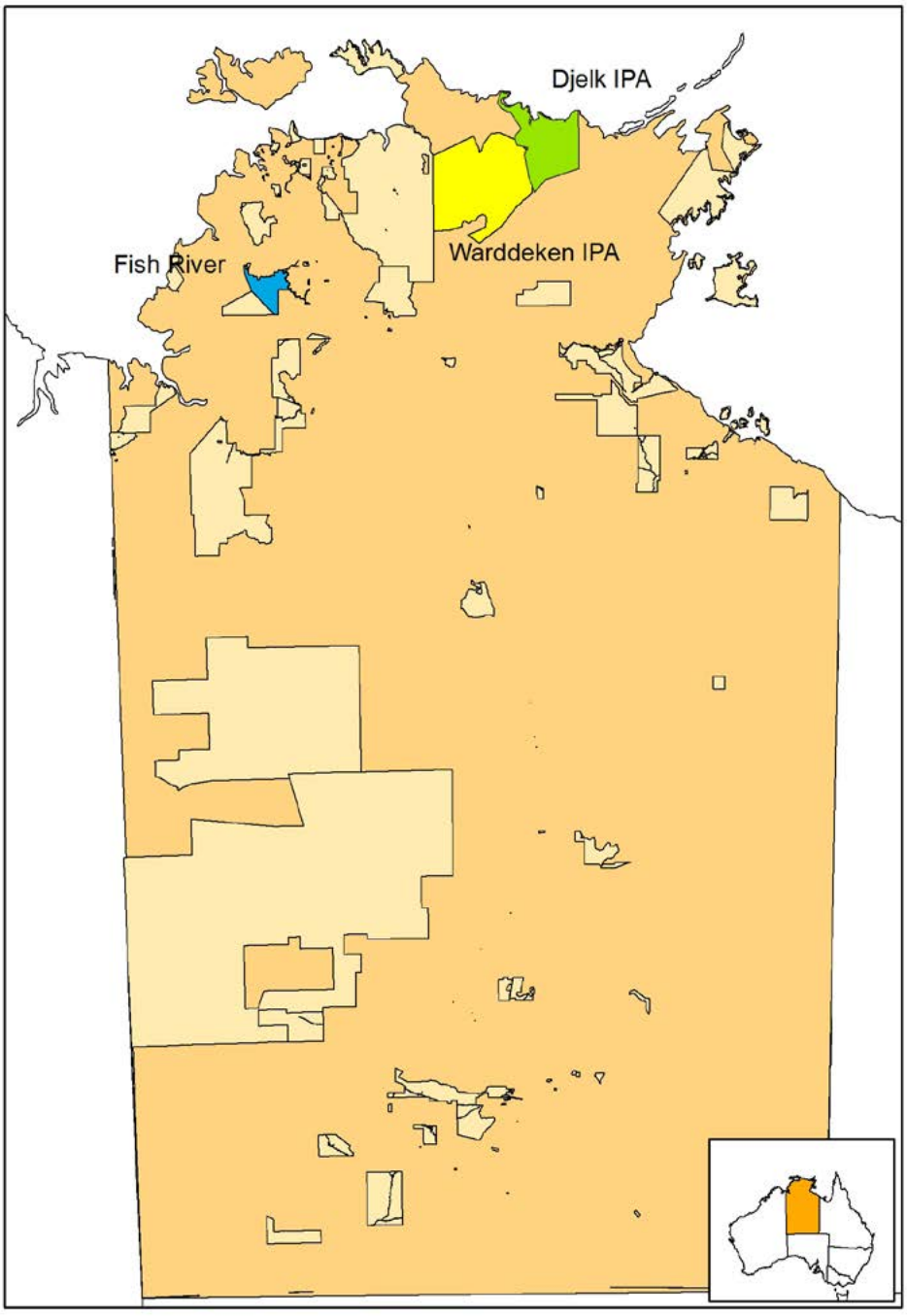
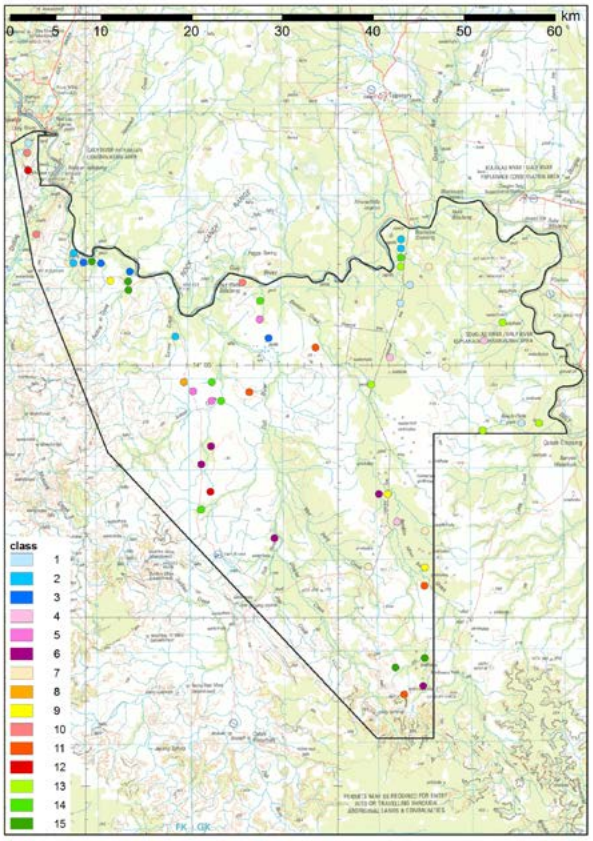


Figure 4: Conservation areas of the Northern Territory. Fish River (blue), Djelk (green) and Warddeken (yellow), other conservation areas (cream) (Dept. Environment 2014).

Sample design was undertaken using conventional scientific approaches. Sites were randomly selected from a candidate set stratified by habitat (lowland savanna, stony uplands, and riparian/monsoon thickets), historic fire frequency and feral herbivore density derived from aerial assessment. Selected sites that were close to locations of sacred sites, previously recorded by the TO's and registered with the Aboriginal Areas Protection Authority in NT, were excluded, resulting in 67 sample sites across 15 stratified environmental units spread across the property (Fig. 5). Transects 5 km long were uniformly placed along the road network throughout the property (Fig. 6), ensuring representative coverage by transects of the main habitats and management treatments.



Class	Habitat	Fire	Feral
1	Savanna	Low	Low
2	Savanna	Low	Medium
3	Savanna	Low	High
4	Savanna	Medium	Low
5	Savanna	Medium	Medium
6	Savanna	Medium	High
7	Savanna	High	Low
8	Savanna	High	Medium
9	Savanna	High	High
10	Rocky	Low	any
11	Rocky	Low	any
12	Rocky	Low	any
13	Riparian	any	Low
14	Riparian	any	Medium
15	Riparian	any	High

Figure 5: Locations of remote camera monitoring sites at FRS across 15 stratification classes. Colour-coded environmental stratification corresponds to the table.

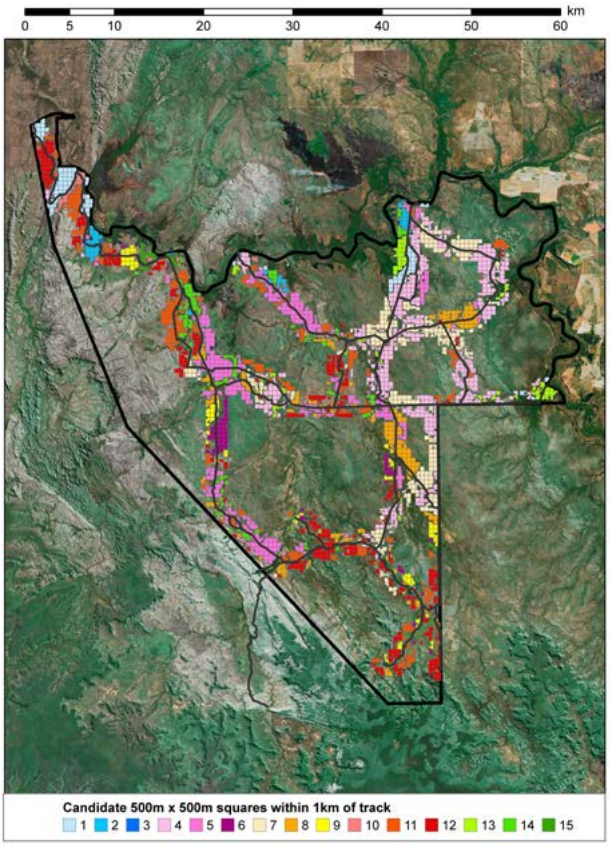


Figure 6: Road transect network across Fish River Station with overlay of stratified units (see Fig. 5).

Both Djelk and Warddeken IPA's had identified broad ecological objectives in their management plans. Preliminary fauna surveys undertaken prior to NERP in collaboration between the rangers and DLRM scientists indicated declines in small mammals. This experience, along with the HCP process, which highlighted concerns about impacts of cats, buffalos, pigs and fire, led to the identification of the following objectives in each IPA:

- Warddeken IPA
  - Locate and monitor populations of small-medium mammals, to evaluate the impacts of fire regimes
  - Examine feral cat distribution and ecology (see NERP project 4.2 for detailed examination)
- Djelk IPA
  - Locate and monitor populations of small-medium mammals, to evaluate the impacts of fire regimes, along with buffalo and pigs

The differences in objectives between the IPA's reflect the different priorities, experiences and values of the respective TO's and Indigenous managers. Djelk TO's also agreed to contribute to research and surveys on feral cats (see NERP 4.2), but cats were less of a concern to them than buffalos and pigs.

The unbroken Indigenous occupation and connection with the land demanded a much higher level of TO and community engagement than at FRS. A "two-tool box" approach to developing the research and monitoring was adopted, recognising that both western and Aboriginal groups have particular skills and knowledge to contribute toward the project. Indigenous Rangers/TO's have intimate knowledge of the country, plants and animals, and exceptional observation and tracking skills. Scientists have technical knowledge of project design and research methodology, and responsibility for reporting on outcomes of the project.

All aspects of the project were planned and agreed to through frequent, regular, consultation with TO's and Indigenous rangers, including:

- Locations of all field work, ensuring sites of cultural significance were avoided
- Timing of activities, taking consideration of cultural priorities
- Who would/could be involved ensuring consideration of cultural relationship and that all non-Indigenous workers had appropriate approvals
- Design and methodology of research
- Development and production of project products including video, reports, posters, media and conference presentations and ensuring that culturally appropriate people were speaking on particular issues.

The timing and attendees/composition of planning and consultation meetings always aimed to strike a balance between the project needs and timelines and Indigenous cultural/social priorities. Planning and consultations involved IPA management staff, ensuring their awareness and that adequate capacity existed to support all proposed activities.

Scientists also needed to be respectful and take account of other cultural issues:

- Responsibilities and rules regarding land ownership are complex and dictate who can make decisions and who can perform work. Particular clan/family groups have responsibility for certain parts of country; there are both "owner" and "manager" responsibilities. Owners make decisions, in consultation with their managers, about what can/cannot be done in an area. Managers ensure decisions are carried out and must be present when working in that area.
- Complex avoidance relationships also govern with whom one can associate, talk, or work. Consequently, scientists needed to be sensitive to the makeup of work teams and defer to TO's and rangers for those decisions.
- The land is imbued with spiritual meanings and sensitivity; different places have varying levels of cultural significance which dictate who has access. Sacred and cultural sites are areas of restricted access on a permanent basis, and though they may have varying levels of security and permissions within landowner groups themselves, they are generally off-limits to non-local people.
- Temporary country closures occur when people pass away or when there are ceremonies active in the area. These closures are determined within the appropriate Aboriginal power structures and may vary from a few weeks to over a year, this influencing where and when field activities may be undertaken.

Throughout the project we endeavoured to be guided by TO's and Rangers in relation to all cultural matters to ensure we maintained healthy and respectful working relationships. Ultimately at Djelk and Warddeken the Traditional Owners maintained control over what was done, when and where.

Consequently site selection for research and monitoring in the IPA's was undertaken by stratification that considered both cultural and ecological attributes. A random set of sites was then selected from within this set and subsequently vetted by appropriate TO's and knowledgeable senior people to ensure access is permitted (Fig. 7). This included 145 sites on the mid-Cadell River in Djelk previously sampled in 1997 (Yibarbuk, Whitehead *et al*. 2001).

3.3 Sampling methods (FRS)

Camera traps were deployed and retrieved by scientists at each site with the assistance of Indigenous rangers (see details in NERP 4.2). Scientists trained the rangers in the use and deployment methods for cameras, including use of GPS and recording data on datasheets. Typically one or two rangers accompanied a scientist during these activities. By the end of the project, some rangers were able to reliably deploy cameras with limited supervision, and most could recover cameras without supervision. Cameras were deployed at each site for 1 month in 2013, repeated in 2014. Some photo data were downloaded and processed in the field to show rangers some of the trapping results; however most data processing was undertaken back in Darwin.

Road transects were used to sample occurrence of macropods, dingos and emu. Two rangers made observations from the back of a slow-moving vehicle following the methods of Ritchie et al. (2008). A CyberTracker sequence was developed for the rangers to record their observations, including locations and times. However implementation of this method posed several challenges. The surveys needed to be undertaken either first at sun rise or just before dusk; after a long day of other work, rangers were often tired and unmotivated to undertake the transects. Furthermore, swift macropod identification and CyberTracker data entry were problematic, resulting in missing and erroneous data. Consequently this project component was discontinued.

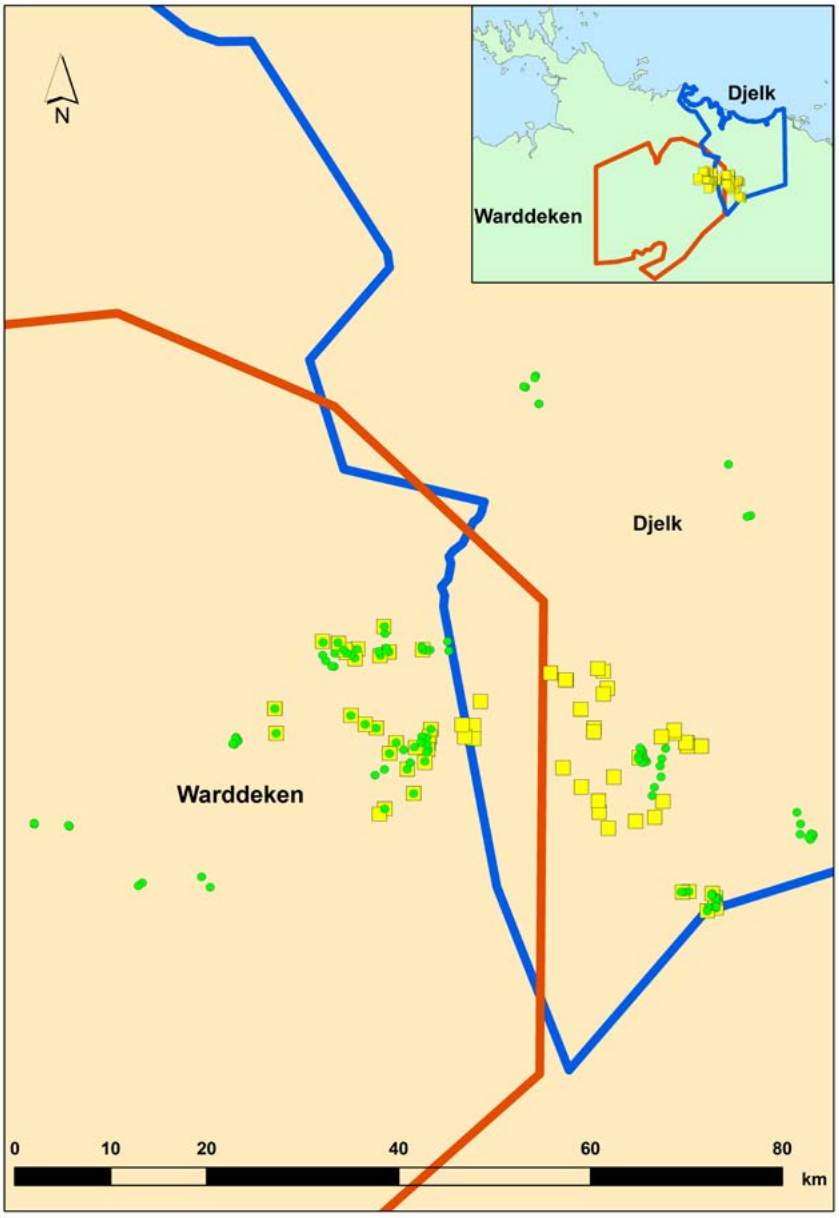


Figure 7: Fauna trapping sites (green circles) and 5-camera-array sites (yellow squares) across Djelk IPA (east of blue line) and Warddeken IPA (west of orange line). The IPA boundaries overlap, indicating a shared management and kinship connection across the intervening country.

3.4 Sampling methods (IPA's)

Initially general fauna survey sampling (mammals, birds and herpetofauna) was undertaken, using standard methods employed by DLRM (http://www.lrm.nt.gov.au/plants-and-animals/survey-and-monitoring); trap sites were established by ranger teams with training and supervision by a scientist. However, primary interest and concern of the Indigenous rangers revolved around mammals and large reptiles, so bird and small herpetofauna censuses were discontinued early in the project. In the later years of the project rangers could independently set up trap sites with a scientist providing 'quality control'. By 2014 rangers in both IPA's were able to check and run sites independently, with scientists providing species identification and data processing support back at camp.

Camera traps were used in both IPA's to increase detection of native mammals and to survey cats – a primary objective in Warddeken. However, conventional trapping and single camera trap deployments yielded very low detections of native mammals and cats, despite regular observations of cats and their tracks by TO's and rangers. In order to increase detection rates of species, deployments of five cameras per site were trialled in 2013.

The Warddeken Rangers also participated in an experimental trial of alternate lure types to increase detection rates of cats on their lands, which was undertaken concurrently with mammal surveys and monitoring. Details of this, and other cat research work, are described in *NERP Project 4.2 Feral cat management on Indigenous lands*.

Rangers developed their own methods, aids and tools of organising equipment and ensuring methodological consistency, such as colour-coding rather than numerical recording. CyberTracker sequences were developed for recording geo-referenced field data on PDAs by the rangers. A camera sequence was developed with both Djelk and Warddeken IPA rangers, and was then made freely available through the NAILSMA I-Tracker project's Land Patrol Application (http://www.nailsma.org.au/i-tracker/download-i-tracker-land-patrol-application).

Often fieldwork dovetailed with other cultural activities, and involved large numbers (up to 100) of community members, including families with children, who participation various components of the work. This provided powerful engagement and learning opportunities.

Figure 8: Djelk Rangers used PDAs in the field loaded with Cybertracker sequences to record geo-referenced field data.

3.5 Data management, analysis and sharing

FRS and the IPA's did not have the capacity to manage, analyse and store data, due to limited IT infrastructure and internet access; low literacy and numeracy levels; variable computing skills. Consequently all data management and analyses were undertaken by the scientists, stored on NTG databases, and copies provided to the ranger groups. However, it was recognised from the outset that development of some data management and interpretative capability within the ranger groups was essential. Furthermore, Indigenous groups may have different data requirements and priorities than scientists and require data in more appropriate forms than technical reports, scientific literature or numeric databases. Considerable effort was made with the ranger groups to develop improved and appropriate ways to process, share and store data and information generated from project work in formats that were accessible and useful to Indigenous rangers.

4 Results – Outputs and Outcomes

4.1 Kakadu and AWC

Key findings from resampling of 134 fire plot fauna sites between 2012 and 2014 were that (i) mammal declines have not continued on the trajectory previously identified (Fig. 9); and (ii) local fire regimes were likely responsible for some of the community changes through changes in habitat structure; however, 50-60% of the variability remains unexplained, indicating other unmeasured factors are also at play (DLRM unpublished data). Monitoring by AWC in the Kimberley has demonstrated significant recovery of small mammal communities in response to systematic fire management and reduction of introduced herbivores (AWC unpublished data).

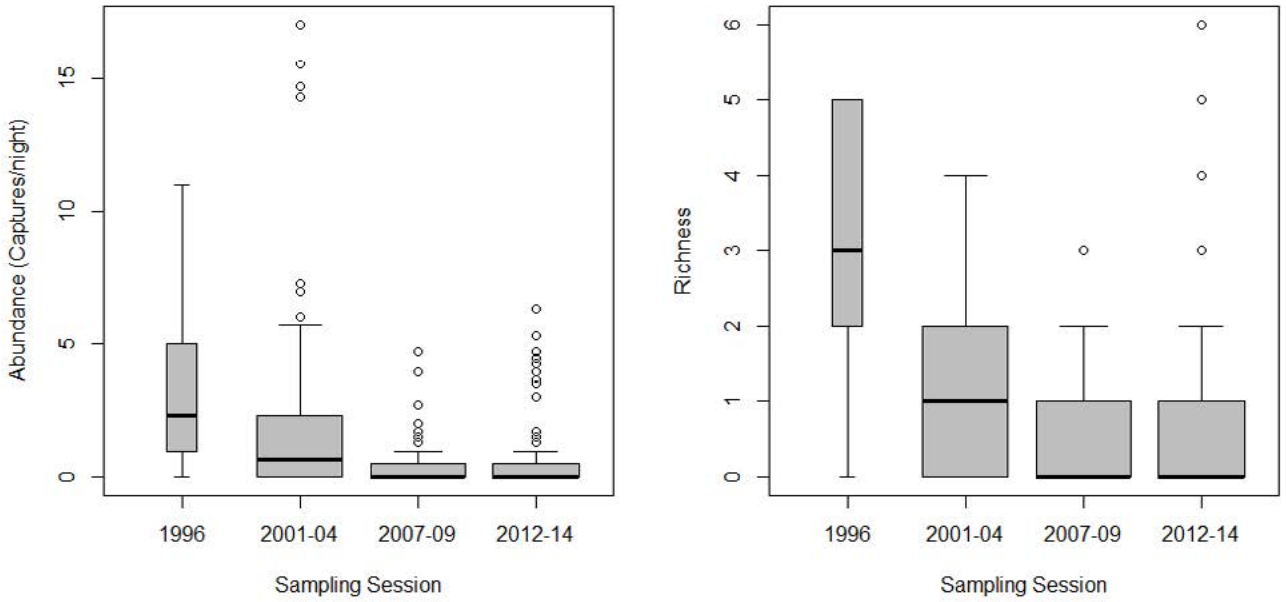


Figure 9: Pattern of decline in small mammal total abundance (all species) and richness across Kakadu National Park from 188 sites. Box plots show median (black line), 25 – 75 percentiles (grey box) and outliers (dots). Width of box-plots represents number of plots sampled per session.

Table 1. Remote camera detections of native mammal at FRS monitoring sites over two sampling years. *Priority species for FRS TO's.

Native Mammal Species	Aggregate no. of sites detected	Mean detection rate per deployment
Black-Footed Tree-rat*	23	94
Northern Brown Bandicoot*	31	167
Dingo*	47	134
Northern Quoll*	1	0.5
Northern Brushtail Possum*	7	3.5
Euro/Antilopine Wallaroo*	15	17
Agile Wallaby*	12	22
Nailtail Wallaby*	1	1
Short-eared Rock-Wallaby	1	1
Common Rock Rat	1	1

4.2 Fish River Station

The high prevalence of Black-footed Tree Rats and Bandicoots, and the single record of a Northern Quoll are significant. These species have declined throughout most of their ranges and are now either absent or very rare in many places. These findings provide evidence that, for reasons unknown at this stage, FRS is unusual with respect to the current general status of small and medium sized mammals in the NT.

FRS rangers quickly learnt how to deploy and recover cameras; however, due to high ranger turnover during the project, only a few rangers became proficient with the use of remote cameras. By the end of the project some rangers were able to reliably recover cameras, but scientist supervision of all deployments was still required.

The amount of time spent by scientists with Indigenous rangers was limited to a series of short spells of fieldwork of several days throughout the dry season. Most of this time was spent training rangers in field methods. The rangers lived on FRS while they were working, but their families and other TO's lived elsewhere and did not participate in field activities. These factors, along with ranger turnover, severely limited opportunities for establishing relationships between individual scientists and rangers or the wider community, or for fostering broader community awareness and engagement in the project and its outcomes.

4.3 Indigenous Protected Areas (IPA's)

Fauna sampling using conventional trapping methods undertaken at 105 sites across the IPA's detected significantly lower trap rates and species richness to monitoring sites in Kakadu National Park sampled during the same period (Fig. 8). Resampling of sites in Djelk IPA previously sampled in 1997 revealed declines in mammal trap rates and species richness of similar orders of magnitude to those reported in Kakadu National Park during the same time frame (Fig. 10). These findings indicate that small and medium-sized mammals declined in Arnhem Land concurrently with declines in Kakadu NP, but that declines in the Arnhem Land Plateau outside Kakadu NP may have been more severe.

Introduced Black Rats, not detected in remote areas of Arnhem Land previously, made up 23% of all mammal captures – the second most frequently encountered species. This finding coincided with Black Rats appearing at relatively remote monitoring sites in Kakadu during the same time period. It is presently unknown whether Black Rats are just filling vacated native niches or facilitating small mammal declines.

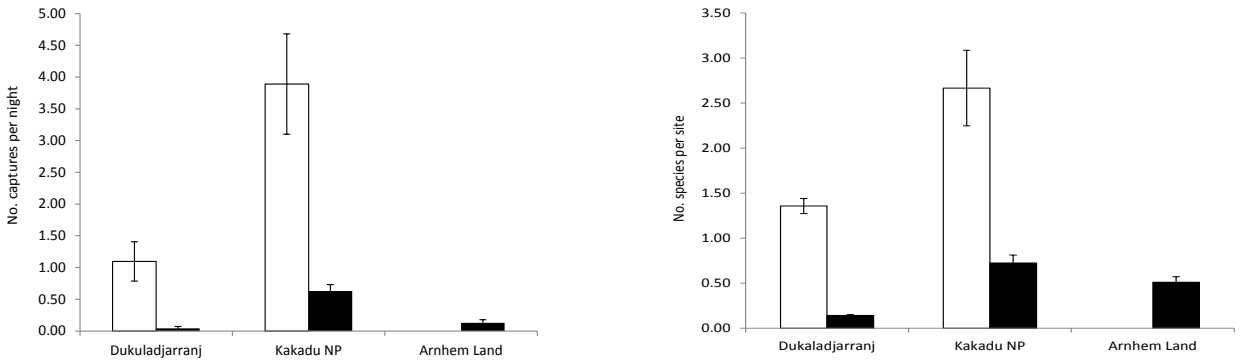


Figure 10: Means and standard errors of (A) mammal capture rates and (B) species richness in Dukaladjarranj (within Djelk), Kakadu National Park fireplot monitoring sites, and all Arnhem Land sites sampled in this project. Open bars - 1996-97; Solid bars – 2010-2014.

Initial results from deployments of arrays of five remote cameras at 20 sites in the IPAs greatly increased detection rates of native mammals and cats. Cat detection probabilities improved from <0.1 with single camera to >0.75 with five cameras. This finding led to the development and roll-out of a larger experimental trial, involving Warddeken and Djelk IPA's FRS and Kakadu National Park, to evaluate the efficacy of multi-camera deployments to detect cats (reported in NERP Project 4.2).

Although camera traps improved detection rates of native mammals, this was restricted mostly to large macropods (Black Wallaroo), Dingoes, and small rodent and dasyurid species, some of which could not be confidently identified. In contrast to FRS Bandicoots, Black-footed Tree Rats and Northern Quolls were absent. Introduced species (buffalo and pig) also had high camera detection rates, along with the first record of Donkey, previously not known from Djelk IPA.

General fauna sampling methods were difficult to apply at appropriate spatial scales with ranger groups, due to the highly regimented and time constrained process requiring specialist training for species identification and involving abstract scientific concepts, and the need for a high level of hands-on scientific support. In contrast, development and application of track transect sampling (Bokno Manborlh – reported in NERP 4.2) required minimal support from scientists, probably because this approach genuinely incorporated Indigenous traditional know-how.

Camera trapping also had a high rate of uptake; people with no prior experience could learn to deploy and recover cameras in line with regimented methods, and reliably record metadata using CyberTracker, with limited oversight from a scientist. Using CyberTracker, provided Indigenous Rangers with an accessible, paperless means of accurately recording camera deployment and recovery metadata, greatly assisted with uptake and accessibility of these methods

Uptake of fauna sampling was much higher in the IPA's compared with FRS (Table 2), most likely due to the following:

- Larger numbers of established and more experienced rangers who were interested in biodiversity issues prior to the project and had ownership of its objectives and delivery
- Consistency and continuity of ranger involvement throughout the project
- Frequent and in depth pre-field planning with strong ranger input, and post-trip review with strong two-way feedback
- Refinement and adoption of field sampling methods that reflected their interests and cultural values, and that were within their capability to implement comfortably and competently
- Development of aids and tools such as Cybertracker sequences on portable PDA's.

Direct involvement in field-based activities by Aboriginal people was much higher in the IPA's compared to FRS, including rangers, senior consultants, landowners, and families with children (Table 2). Reasons for this were:

- High level of consultation with landowners and land managers ensuring high level of understanding and support for all activities
- Extensive direct contact and engagement between scientists, rangers and landowners in the field and in communities, fostering strong personal/professional relationships
- Synergies between on country project work and delivery of cultural/social goals whenever possible (e.g. regular survey-cultural camps with up to 100 community members attending)
- Living on country with families
- Relationships established between scientists and local schools; classes attended many on-country events
- Numerous engagement and educational tools, booklets, posters, photos, movies, were produced targeting Indigenous throughout the project.

Participation with, and uptake of, aspects of projects pertaining to data management and interpretation were low across all groups (Table 2). This outcome resulted from varying numeracy and literacy skills, and lack of IT infrastructure and appropriate databases for entering and storing data.

5 Discussion – Key findings and messages, problems and lessons learnt, future needs

The ability to develop biodiversity monitoring programs on indigenous-managed lands, and the level of collaboration, participation, and therefore engagement and support, are contingent on numerous interconnected factors. Firstly, all groups are different and the inherent ability of Indigenous land managers to incorporate monitoring and evaluation is dependent upon:

- Capacity of the group – in terms of resources, leadership, functional management structures,
- Connection to country, and ability to live on country
- Level of ability to integrate on-country activities with cultural and social imperatives
- Level of engagement with biodiversity issues
- Stability of the ranger group (staff turnover).

Table 2. Summary of Indigenous participation and engagement in research activities and outputs across three approaches. Brown – none; orange – low; yellow – medium; Blue – high (equal or greater contribution to scientists).

Component	Three Parks Monitoring	AWC Kimberley	Fish River Station	Warddeken and Djelk IPA's
Determining land management objectives				
Designing monitoring program				
Site assessment and approval				
Choice of sampling methods				
Field sampling (data collection)				
Methods refinement/ modification				
Species identification				
Data recording				
Data management				
Data analysis				
Reporting				
Broader Indigenous community participation				
Input into review of management actions				
Indigenous capacity to undertake monitoring programs				

Secondly, conservation and natural resource managers wishing to engage with and establish biodiversity monitoring programs with Indigenous managers should:

- Ensure that monitoring goals address relevant Indigenous land management objectives
- Be receptive and respectful of cultural and social issues that may influence implementation, such as ensuring that avoidance relationships are respected
- Plan and consult every step of the way, with all community and management stakeholders
- Be adaptive and responsive to refinement of objectives and priorities during the course of implementation;
- Be prepared to provide technical support, such as data management and interpretation
- Be committed to consistency of staff, to foster enduring relationships with TO's and communities.

Thirdly, level of participation by Indigenous managers, and engagement with Indigenous communities, is contingent on methods used:

- Aligning with inherent indigenous knowledge
- Aligning spatially and temporally with cultural and other social activities
- Able to be broken into a manageable number of clearly defines tasks, and assigning responsibility to them easily
- Compatible with support tools, such as Cybertracker.

Figure 10: Participation by Indigenous managers and engagement with Indigenous communities is increased by aligning with cultural and social activities.

This project has provided baseline information from which to build and refine monitoring programs that will be informative to Indigenous managers about biodiversity changes and responses to their management. All three Indigenous management groups are using the HCP process to revise their management plans with consideration of the findings of this project, and wish to incorporate refined monitoring into their work programs. However the objectives of each program, methods, level of support and participation from scientists and ecologists will vary markedly. Most Indigenous groups are closer to the capacity level of FRS rather than Warddeken or Djelk, and will therefore require a much higher level of input and on-going support from ecologists to design and implement monitoring programs. Despite relatively highs level of capacity and engagement of Warddeken and Djelk IPA's, data collection and management aspects of research and monitoring projects will continue to require strong partner support from ecologists and natural resource managers for the foreseeable future.

This project has provided new insights into Northern Australian mammal declines and management responses.

- The decline occurred in remote regions of Arnhem Land over the same time period as Kakadu National Park; however it appears to have been more severe in Arnhem Land Plateau, outside of Kakadu National Park.
- An influx of introduced Black Rats has occurred in this part of Arnhem Land coincident with the native mammal decline; however it remains unknown whether Black Rats are part of the cause or simply a symptom.
- The relatively high prevalence of several medium-sized mammals at FRS, despite ecologically inappropriate fire regimes up until recently, and persistence of high densities of feral herbivores, is at odds with patterns elsewhere, and may help in the further investigation of causes of northern Australian mammal declines.
- On-going monitoring in Kakadu and the Kimberley has provided further evidence that the current frequent fire regime on most parts of northern Australia has contributed to mammal declines.

5.1 Constraints

Due to other priorities, carrying out biodiversity monitoring in a cross-cultural environment presented significant constraints. Balancing scientific rigour with thorough consultation, group decision making, working at a suitable pace for Indigenous rangers, and using methodologies that were appropriate for rangers, was challenging. Flexibility was needed to accommodate cultural priorities including ceremonies and funerals. A key learning from this was that implementing programs of this nature in highly cross-cultural settings requires considerably more time and energy, which needs to be properly accounted for in future planning.

5.2 Future needs

Broader engagement is necessary with a wider network of Indigenous land managers about the value of monitoring and evaluation. Building from this project, more tools could be developed to aid Indigenous groups with uptake and implementation of monitoring.

Further work is required to develop a higher level of coordination and integration of biodiversity monitoring and reporting across different land tenures and traditional custodial arrangements.

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Motion detection cameras were a popular technique with the Indigenous Rangers in this project. Object in the foreground is a bait station, the camera is mounted on the tree in the background.

Arnhem Land Rock Rat observed during a monitoring camp in 2014.

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