

Looking back to move forward: Collaborative ecological monitoring in remote Arnhem Land

By Emilie J. Ens, Gillian M. Towler, Cherry Daniels, the Yugul Mangi Rangers and the Manwurrk Rangers

Indigenous land and sea managers are working across Australia for natural and cultural resource conservation. Justifying the outcomes of effort to funding bodies, the broader public and local communities is thwarted, however, by language differences, lack of technical capacity and complex local socio-economic and political histories. This paper details ways that two remote Indigenous ranger groups are collaborating with non-Indigenous ecologists to address this situation using Indigenous and non-Indigenous (two-way) techniques.

Key words: biodiversity monitoring, Caring for Country, Indigenous land and sea management, northern Australia, participatory research.

Emilie Ens is an Ecologist with the Centre for Aboriginal Economic Policy Research (The Australian National University, Canberra, ACT 0200, Australia. Tel: 02 6125 0672; Email: emilie.ens@anu.edu.au). **Gillian Towler** is a Technical Officer with the National Herbarium of New South Wales, Sydney (on temporary appointment with the Centre for Aboriginal Economic Policy Research, The Australian National University, Canberra, ACT 0200, Australia). **Cherry Daniels** is a retired senior ranger and founder of the Yugul Mangi Rangers (Yugul Mangi Land and Sea Management Corporation, PMB 92, via Katherine, NT 0852, Australia). **The Manwurrk Rangers** are staff of Warddeken Land Management Limited (PO Box 244, Jabiru, NT 0866, Australia).



Figure 1. Collaborative recording of Indigenous ecological knowledge with the Manwurrk Rangers and local community members. From left to right: Laura Runggurwanga, Sylvia Ragurk, Jamie Billese, Emmanuel Namarnyilk, Salone Djandjomerr, Gillian Towler, Alesha Daylight and George Watson. (Photograph: Emilie Ens).

Introduction

An estimated twenty per cent of Australia, almost all of which lies in remote regions, is legally owned by Indigenous people (Altman *et al.* 2007). Over the last few decades, many Indigenous communities have established land and sea management organisations (known as ranger groups) to fulfil cultural responsibilities for 'looking after country'; to create jobs and manage environmental threats (Blanch 2008). In support of these community-based initiatives, governments (Australian Government 2011; Hoffmann *et al.* 2012), non-

government agencies (Fitzsimons *et al.* 2012; Moorcroft *et al.* 2012) and the private sector (Russell-Smith *et al.* 2009) have increasingly developed programmes to assist Indigenous Australians living and working on country to maintain conservation and cultural values. However, financial support is often coupled with expectations and demands for increased accountability (a 'Western' notion, see Muller 2008) and incorporation of monitoring programmes that demonstrate outcomes of cultural and natural resource management (NCRM) activities, for example, through the federal government's Monitoring, Evaluation, Reporting and

Improvement framework. The limited implementation of environmental outcome monitoring is not specific to the Indigenous land management sector, but is a broader concern of the conservation sector in Australia (Australian National Audit Office 2008) and internationally (OECD 2002). However, to enable monitoring of work outcomes, baseline data, information about environmental threats and technical capacity to monitor and report are needed.

For remote parts of Australia, non-Indigenous biodiversity and ecological data are scant, and technical capacity is limited (Russell-Smith *et al.* 2009). However, Indigenous people have inherited rich ecological knowledge of their ancestral country, which contains valuable pre-history 'baseline data' (e.g. Russell-Smith *et al.* 1997; Horstman & Wightman 2001). Unfortunately, in many areas, external influences associated with colonisation have dramatically affected customary lifestyles and the processes and activities required for effective ongoing inter-generational transmission of this knowledge, although there is also renewed effort to regain and preserve this knowledge for present and future generations (McConvell & Thieberger 2001).

In the contemporary land management context, there are very few documented examples where Indigenous knowledge has been used to explain ecological change and inform management (but see, for example, Russell-Smith *et al.* 1997; Ens *et al.* 2010). There are several reasons for this including lack of cross-cultural awareness, language barriers and differing forms of knowledge storage and use, as Indigenous ecological knowledge is largely oral, not written, and therefore tends to be de-valued by non-Indigenous people. As a result of such issues, use of Indigenous ecological knowledge as baseline data is contested – and mainstream funding bodies tend to request that Indigenous organisations use non-Indigenous forms of monitoring including measured outcomes communicated through written reports.

This situation presents a significant challenge for Indigenous ranger groups, particularly those in remote regions, who often have low numeracy and literacy skills, contested governance structures (Hunt *et al.* 2008) and do not speak English as their first, everyday language. Consequently, in these situations, non-Indigenous people are typically employed or offer expertise in the coordination of work. As Indigenous people generally aspire to regain control over their businesses and livelihoods, Indigenous commentators argue for the need for increased incorporation of Indigenous knowledge and preferred methods of work, monitoring and reporting (Sithole & Hunter-Xenie 2007; Barbour & Schlesinger 2012), while retaining meaningful and useful elements of non-Indigenous methods and knowledge that can also be used to address the requirements of funding bodies.

There are many examples where Indigenous people have worked with non-Indigenous collaborators to successfully facilitate cross-cultural awareness of different knowledge systems and land management methods in Australia (e.g. Kennett *et al.* 2004; Russell-Smith *et al.* 2009) and internationally (e.g. Luzar *et al.* 2011). However, many efforts have been fragmented in space and time, lack long-term partnerships and funding, and have often failed to deliver enough baseline data or foresight to encourage sustained research or work, particularly in remote Australia. In this study, we have looked back to these efforts and evaluations of Indigenous engagement in NCRM projects (Roughley & Williams 2007; Sithole & Hunter-Xenie 2007; Carter 2008) and Indigenous knowledge systems in remote Arnhem Land to collaboratively explore approaches that could be used to enhance baseline data, ecological monitoring and local capacity on remote Indigenous land (Fig. 1). Such 'bottom-up' or community-based ecological research methods are preferred by Indigenous land managers,

but are rarely pursued by non-Indigenous scientists (Sithole & Hunter-Xenie 2007), and successes and failures are infrequently documented. Such methods, however, are needed to guide continued development of the sector (Roughley & Williams 2007; Carter 2008). We hope that the following case studies from south-eastern and western Arnhem Land, northern Australia, will contribute to a more grounded understanding of how two-way knowledge and methods can be used to improve baseline data and ecological monitoring capacity.

Case Studies

Case study 1: Feral animal exclusion monitoring with the Yugul Mangi Rangers

Background and aims

Anecdotal evidence suggests that the abundance of feral ungulates (horse (*Equus caballus*), pig (*Sus scrofa*), buffalo (*Bubalis bubalis*) and donkey (*Equus asinus*)) has increased in south-eastern Arnhem Land since the surveys carried out by Bayliss and Yeomans (1989). Similar to many other parts of northern Australia, management is thwarted by local differences in cultural, ethical and economic perceptions of these species (Robinson *et al.* 2005; Ens *et al.* 2010). Keen to protect their freshwater resources and raise community awareness of the environmental and cultural impacts of feral ungulates, the Yugul Mangi Rangers expressed interest in fencing off culturally significant billabongs close to the main township of Ngukurr (Fig. 2).

Founder and senior cultural advisor of the Ranger group, Cherry Daniels, remembers times when these billabongs were not heavily used by feral ungulates and were like 'supermarkets' full of bush foods including water chestnut (*Eleocharis dulcis*) and water lily (*Nymphaea* spp.). This was at a time, however, when according to Cherry, most of the community had not yet been born; so they had not seen what these places looked like



Figure 2. Map of Arnhem Land (shaded area) showing main townships (larger dots), outstations/homelands (smaller dots), Warddeken Indigenous Protected Area (dashed line) and adjacent National Parks (heavy black line). Settlement data from Northern Territory Government, July 2011.

prior to the proliferation of feral animals. Furthermore, with the exception of the rangers, many local people are without transport and tend to stay in Ngukurr; so they lack broader awareness of the threats and changes to the natural and cultural integrity of their ancestral lands.

The objective of this project was to help community members 'look back' to better understand the natural and cultural impacts of feral animals and 'move forward' to develop an informed strategic feral animal management plan that included ecological, cultural as well as economic considerations. Our first aim was to build the ecological and cultural evidence of impacts by collaboratively developing a monitoring programme that included Indigenous values and methods; contained enough scientific rigour to facilitate broader applicability of the findings and built local technical capacity for further monitoring.

Our methods

In 2009, the Yugul Mangi Rangers received a small grant from Greening Australia (NT) to fence off three culturally significant billabongs (or parts thereof) near Ngukurr – Costello, Namiliwirri and Nalawan. These

billabongs were selected by the rangers with the approval of Traditional Owners. Although some of the male rangers had knowledge of fence construction (from previous employment in the cattle industry), they felt more comfortable hiring a contractor who had expertise in fence design and could also purchase the required materials and equipment, all of which the rangers found challenging being based in a remote community. Funding was conditional upon annual monitoring of ecological outcomes for 5 years.

In the early dry (July) and late dry (October) seasons of 2009 and 2010, the ecological features of three fenced and three nearby unfenced billabongs were monitored. A focus of this research was to include both

Indigenous and non-Indigenous participants in the design, implementation and interpretation phases of the monitoring project. 'Traditional' Indigenous observational analysis of change was facilitated by repeated visits, visual comparison of adjacent experimental exclosures and control areas (unfenced), and the oral interpretation of changes and transmission of knowledge. A 'Western' scientific quantitative monitoring methodology was instigated and included point intercept transect methods, water quality testing, visual estimates of water lily cover and photo points. These methods were chosen as they allowed incorporation of Indigenous values through agreed indicators of 'healthy' and 'damaged' billabongs; were not overly technical or scientific (to encourage uptake by rangers not trained in Western scientific methods) and involved a statistically robust design to promote scientific rigour.

Indigenous indicators of 'healthy' and 'damaged' billabongs were elicited through informal discussions with knowledgeable Indigenous rangers. The rangers stated that healthy billabongs with few feral animals had flat ground, lots of native grass and water lilies and clear water. They said that feral animal damage included buffalo, horse and pig tracks, buffalo wallows, pig diggings, muddy water and fewer lilies. Although these parameters are not uniquely Indigenous, they were of value to the rangers as they directly (e.g. water lilies) and indirectly (e.g. water quality that effects edible and

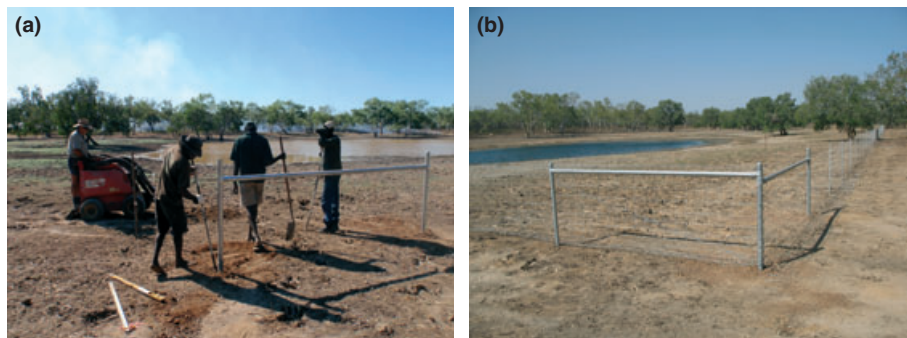


Figure 3. Photographs of Nalawan billabong when fences were erected in July 2009 (a) and 2 months after in September 2009 (b). (Left photograph: Emilie Ens; Right photograph: Elodie Fache).

useful flora and fauna) relate to culturally important species. The rangers had also previously received water quality testing training, so were keen to reapply these skills.

This information was converted to questions and answers in CyberTracker (see Ansell & Koenig 2011; Ens *in press*) data collection sequences, which removed the need for advanced numeracy and literacy skills. The sequences were uploaded onto touch-screen handheld computers (Trimble NOMAD), which the primary author initially borrowed from another ranger group, prior to acquiring funds to purchase new units. The first sequence was used to assess ground surface (e.g. buffalo wallow) and ground cover (e.g. grass) features at one metre intervals along each of three randomly placed 100-m transects situated above the water level. The second sequence was used to enter water quality data (temperature, pH, conductivity and turbidity) from five points around the edge of the billabongs using electronic water quality metres (which were also borrowed). Analysis of variance (ANOVA) statistical analyses of the data were conducted using SPSS software (Version 17.0; SPSS Inc. Chicago, IL, USA) by the non-Indigenous collaborator. Because of space restrictions, only some ground surface and ground cover data are presented here.

Our results and their value

Since 2009, no feral animals have broken through or jumped over the upright fences. However, the force of the 2009–2010 wet season floodwater pushed two of the three fences (Costello and Namiliwirri) down along perimeters perpendicular to the water flow. The third enclosure (Nalawan) incurred minor damage from flood debris. Following the wet season, sections of the fences at Costello and Namiliwirri were not re-erected in a timely manner, which allowed some animals to enter. Despite the rangers having the best intentions to maintain the exclosures, they said they were too busy. From the non-Indigenous

perspective, lack of organisational capacity and local leadership appeared to be the most obvious reasons. However, after continued reflection, it became apparent that this assumption did not adequately acknowledge the complex historical, cultural, socio-economic and political factors that have influenced how the rangers understand, value and engage in work

and expect non-Indigenous people to engage with them (see McRae-Williams & Gerritson 2010). After acknowledging this different social environment, in the following 2010–2011 wet season, the non-Indigenous participants worked side by side with the rangers to repair the fence.

Two months after the fences were installed, there were visible signs

Table 1. Significant results from analysis of variance tests of the differences in ground feature variables (flat ground, all feral animal signs, bar ground and grass cover) between years, seasons and the fenced/unfenced condition at each site

Feature	Site	Significant terms	F _{1,16}	P value
Flat	Nalawan	Year × fence	90.31	<0.001
		Year × season	5.337	0.035
		Year	162.78	<0.001
		Season	5.34	0.035
		Fence	88.33	<0.001
All feral signs	Costello	Year	7.21	0.016
		Year × fence	8.75	0.009
		Year	16.37	0.001
		Fence	13.04	0.002
		Year	10.99	0.004
Bare ground	Namiliwirri	Year × season	9.98	0.006
		Year	7.058	0.017
Grass	Nalawan	Year × fenced	4.53	0.049
		Year	12.24	0.003
		Year × season	6.50	0.021



Figure 4. Fenced (left of image) and unfenced areas (right of image) at Nalawan, August 2010, showing more vigorous grass growth and less feral animal pugging when feral ungulates were excluded. (Photograph: Emilie Ens).

of water quality improvement, particularly at Nalawan (Fig. 3). Community members were surprised that the water went from being muddy to clear blue in only 2 months and asked whether fences could be erected around billabongs on their country. From the rangers' point of view, the project achieved rapid success in raising community awareness of feral animal impacts. After 2 years, billabong health (as measured in this study) at the fenced Nalawan site continued to improve as the fencing here most successfully excluded feral ungulates. Three-factor (Year, Fence, Season) ANOVA tests suggested that at Nalawan over 2 years, the ground within the fenced area (Year $\times$ Fence,

Table 1) became significantly flatter (going from 0 to 60%, Figs 4,5), had less feral animal damage (going from 40 to 0%, Figs 4,5) and more native grass cover (Figs 4,5) than the unfenced area (Table 1, Figs 4,5).

At the other two sites, Costello and Namiliwirri, the ANOVA showed that feral animals were entering the fenced area as much as the non-fenced area (Fig. 5). The analysis also showed that there were yearly and seasonal fluctuations in feral animal visitations and grass cover at these sites irrespective of the fence, suggesting the need for long-term monitoring to understand annual and seasonal changes. There was significantly less feral animal damage and more flat ground at

Costello in 2010 compared with 2009 and a Year $\times$ Season interaction effect for grass cover at Costello and bare ground at Namiliwirri (Table 1, Fig. 5).

Although these results of rapid recovery following feral animal exclusion were not surprising considering previous research (e.g. Braithwaite *et al.* 1984), they have raised community awareness about the impacts of feral ungulates, which was a primary research aim. Ranger confidence and skills have also been enhanced, and it was evident that the rangers were proud of this project through community feedback, their presentations at local ranger conferences and their article for the local Ngukurr newsletter.

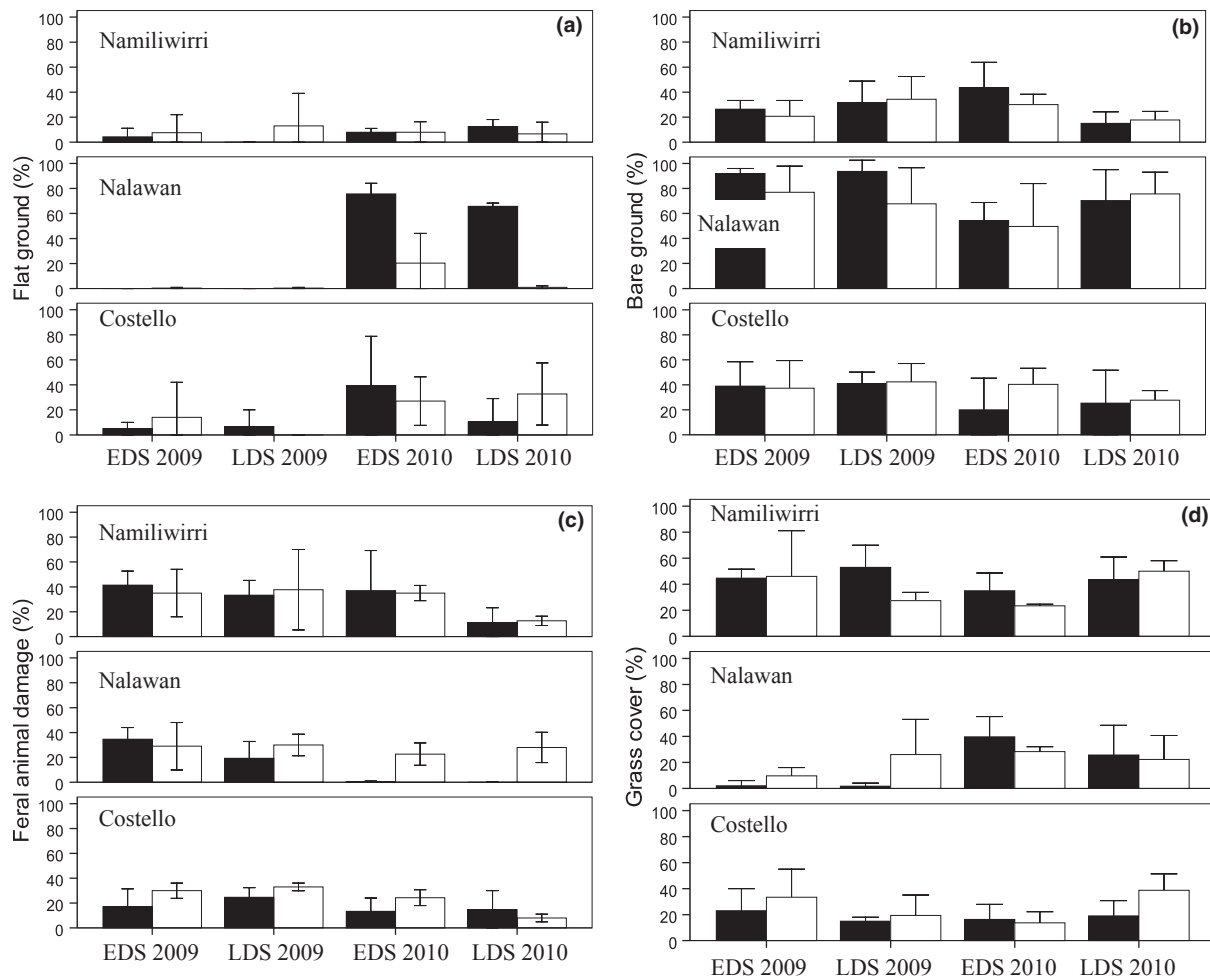


Figure 5. Mean percentages of flat ground (a), bare ground (b), total feral animal damage (c) and grass cover (d) at each of the fenced (black bars) and unfenced (white bars) sites (Namiliwirri, Nalawan and Costello) in the early (EDS) and late dry seasons (LDS) of 2009 and 2010. Error bars represent two standard errors.

Case study 2: two-way baseline data collection in the Warddeken Indigenous Protected Area

Background and aims

The Warddeken Indigenous Protected Area (IPA) covers 13 950 km² of western Arnhem Land (Fig. 2) and approximately half of the Arnhem Plateau bioregion. This bioregion has one of the highest levels of plant endemism in Australia with 172 plant species occurring nowhere else (Woinarski *et al.* 2006). Because of the paucity of herbarium plant records for Arnhem Land, most of the data for the bioregion have come from Kakadu National Park; hence, further research in the Warddeken IPA may detect even higher levels of endemism. According to the Warddeken IPA Technical Information document (Warddeken Land Management limited 2009), the Northern Territory (NT) Herbarium had records of 1238 vascular plant species from within the IPA boundary. Of these, 26% were represented by only 1 specimen and 63% by less than five. With so little known about the distribution of some taxa, further biological inventory of the Arnhem Plateau is regarded as a research priority (National Land and Water Resources Audit 2002).

Similarly, while considerable Indigenous ecological knowledge exists, it is in danger of not being passed on because of complex socio-economic and historical factors. Indigenous ecological knowledge is active knowledge that requires use to be kept alive, particularly if it is to be used in adaptive management of country (Berkes 1999). As Terrah Guymala, Chairman of the Warddeken Board stated:

‘Our old people are the most important resource that we have. More important than anything else. We need to work with them as much as we can, especially recording their knowledge, documenting it so it can be passed on. We must do this before it is too late. Because once they go then bonj, that’s the end. We can’t

bring them back.’ (Warddeken Land Management Limited 2010, p. 3).

Given this shortage of information from both sources, the main objective of this project was to add to the botanical baseline data by ‘looking back’ to seek existing information from other herbaria and local Indigenous knowledge sources and build on this to ‘to move forward’ through use of collaborative two-way (Indigenous and non-Indigenous) methods. A

complementary objective of this work was to promote two-way learning and capacity building through the exchange of non-Indigenous and Indigenous botanical knowledge and skills.

Collaborative approaches were, therefore, used to generate shared knowledge that all participants could understand; better inform local management planning and document Indigenous plant knowledge that is at risk of being lost as elders pass away.



Figure 6. Victor Garlmgarr mounting plant specimens as part of the Botanical Internship Program at the Australian National Herbarium, Canberra, 2011. (Photograph: Sam Bentley-Toon).

Our methods and achievements

The project was conducted over 10 field trips (1–2 weeks each) in the Warddeken IPA between September 2008 and November 2010. To build the two-way capacity of all collaborators, we embarked on an evolving, adaptive approach that explored combined Indigenous and non-Indigenous ways of building knowledge and skills, drawing on available resources and participants' interests. As a result, the project has involved a number of collaborative initiatives.

Development of a local herbarium collection involved taking the local Manwurrk Rangers and other community members out on country to places of their choosing and conducting training in non-Indigenous plant collecting techniques, specimen preparation and field data recording. For many participants, this was the first time they had systematically collected plants for the purpose of botanical assessment. Where possible, scientific and local language names (*Kundedjnjenghmi* and/or *Kunwinjku*) were recorded by non-Indigenous and Indigenous participants using available printed and electronic resources and through consultation with community elders. Pressed specimens were then mounted, labelled and placed into folders. In conjunction with the herbarium, a database was developed using FileMaker Pro (a software program already being used by the rangers) to create an electronic profile for each plant which, in addition to standard collection details, also included photographs and information on local customary use(s) and seasonal availability.

Plants that were unable to be identified in the field or at the ranger office at Kabulwarnamyo (Fig. 2) were taken to the Northern Territory Herbarium, National Herbarium of New South Wales or Australian National Herbarium for determination and then re-incorporated into the ranger collection. A number of specimens have also been (or are about to be) formally



Figure 7. On-country plant collecting trip. From left to right: Amy Namarnyilk, Mary Kolkiwarra, Gill Towler, Emilie Ens, Larissa Daylight, Emmanuel Namarnyilk and Joylene Cameron. (Photograph: Sam Bentley-Toon).

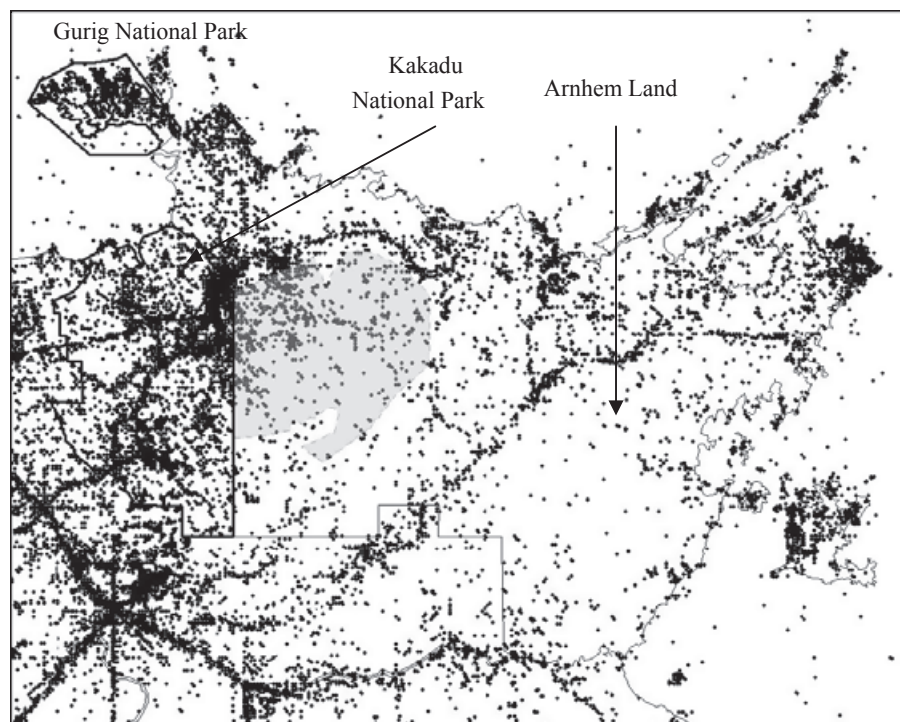


Figure 8. Herbarium specimen locations (dots) in Arnhem Land, adjacent National Parks (bold lines) and the Warddeken Indigenous Protected Area (shaded area). Data from the Australian Virtual Herbarium, March 2011.

lodged at these institutions with the permission of Traditional Owners.

To further reciprocate the cross-cultural exchange of information and training that the rangers had offered the non-Indigenous participants in Arnhem Land, in early 2010, the non-Indigenous participants hosted two Manwurrk Rangers at the Royal Botanic Gardens and National Herbarium of New South Wales in Sydney. This visit involved a guided tour of the botanical collections and discussions about the function of herbaria and value of having plant collections as resources for scientists, land managers and historians. The rangers were very proud to see some of the Warddeken specimens in the herbarium with the Indigenous plant name and their names, as collectors, pointed on the specimen label. A conscious aim of this work was to recognise the contributions of Indigenous plant collectors to redress the historical lack of acknowledgement (Clarke 2008). In 2011, we continued the herbarium visit initiative by supporting the involvement of two other Manwurrk Rangers in the Student Botanical Internship Program at the Australian National Herbarium in Canberra (Fig. 6). The rangers participated in the first 2 weeks of the 7-week programme, as these were deemed to be most appropriate in terms of content and training. Subject areas included Australian flora, principles of plant identification, curation of botanical collections (including mounting and handling plant specimens), plant collecting techniques, field data recording and map reading.

In addition to the development of a local herbarium and plant database, Indigenous and non-Indigenous participants also filmed elders speaking about local plants and their customary uses, in language and sometimes in English. In late 2010, we visited three places with Mary Kodjdan Kolkiwarra, a senior elder of Kabulwarnamyo community, to learn about *Kunwinjku* names and uses of plants and place-centred stories (Fig. 7). On each occasion, the group of

participants included between five and 15 community members (aged between five and about 70) and three non-Indigenous scientists. This work was designed to situate and record the practice of Indigenous knowledge as directed by elders of the community.

Following the field work, non-Indigenous and Indigenous participants edited the film footage at the ranger office using existing Apple iMac computers and iMovie software. Together, the participants interpreted language, selected film footage, added scientific names and added Indigenous names and uses using a local ethnobotanical reference (Garde *et al.* 2003). The end product was a 29-min video documenting the names and uses of 30 local plants and bush products found at the onset of the tropical wet season (*Kunumeleng*). About 50 copies of this film were made for community members.

From the diverse cross-cultural botanical surveys conducted so far, we have collected information on 180 species. Interrogation of the Australian Virtual Herbarium database by the non-Indigenous participants found that 8172 specimens, representing 1327 vascular and 57 non-vascular plant species, had been collected from within what is now the Warddeken IPA (Fig. 8) and lodged in Australian herbaria by non-Indigenous scientists. This national data search added a further 258 species to the Warddeken plant list. Records of a further 18 vascular plant species have been documented through collaborative research by Garde *et al.* (2003). It is likely that more species occur within the IPA, as large tracts of land have not yet been surveyed (Fig. 8). In fact, Figure 5 shows that for most of Arnhem Land, there are large gaps in documented plant diversity and distribution knowledge, especially when compared to adjacent Kakadu National Park (~19 804 km²) where 37 422 specimens have been lodged in national herbaria, documenting over 2000 plant taxa (AVH data, accessed March 2011).

Lessons Learned and Suggestions for the Way Forward

These case studies demonstrated how Indigenous rangers and non-Indigenous scientists have collaboratively explored ways to build baseline data and ecological monitoring capacity as a prelude to the future monitoring of Indigenous land management outcomes. Monitoring of ecological values, threats and work effort is not only beneficial for acquiring funding, reporting and demonstrating accountability to external stakeholders, but it is also requested by Indigenous rangers for local skill development, increased employment opportunities, adaptive management and accountability to local communities. Such projects could also address concerns about national biodiversity and ecological monitoring gaps (ANZEC & BDAC 2001), particularly for remote parts of Australia. Furthermore, by incorporating Indigenous knowledge systems and elements of 'Western' science, we have developed locally meaningful approaches to recording and using valuable but threatened cultural knowledge in contemporary land management.

To promote Indigenous control, ownership and engagement with the monitoring programmes detailed in the case studies, use of terms and methods that were of interest and importance to the Indigenous rangers was integral (see also Barbour & Schlesinger 2012). The two case studies employed different combinations of Indigenous and non-Indigenous knowledge, skills and methods. Successful engagement and interest in these projects by the rangers was demonstrated by their communication of the results within the local and broader community. Increased communication about the outcomes of Indigenous ranger effort will also contribute to greater cross-cultural awareness and understanding that is often raised as a constraint to the development of the Indigenous

NCRM sector more broadly (Roughley & Williams 2007).

It is important to note that, in case study 2, Indigenous participants preferred to use their own plant nomenclatural system, reflecting commitment to their culture. Indigenous differentiation of 'species' can differ to Western scientific classifications. For example, *Kundedjnjenghmi* speakers split what Western science calls *Buchanania obovata* into two species (*andudjmi* and *anwodberr*), which are distinguished by tree height (Garde *et al.* 2003) and require different fruit harvesting methods. However, many participants also wanted to learn more about Western systems of classification and botany, as evidenced by interest in herbarium visits and participation in the Botanical Internship Program. Furthermore, the non-Indigenous participants were very interested in learning about Indigenous botanical knowledge and language names as evidenced by their frequent use of the latter in conversation with Indigenous participants. An important feature of this work was the reciprocal sharing of not only knowledge, skill and expertise but also of place. Our sharing of place not only facilitated sharing of situated knowledge, which is an important part of Indigenous learning (Sithole & Hunter-Xenie 2007), but it also helped build trust and understanding between collaborators. Use of both knowledge systems strengthened and enriched the two-way capacity building, botanical data collection and facilitated cross-cultural awareness, the last of which is often documented as a substantial constraint to effective cross-cultural research (Roughley & Williams 2007; Sithole & Hunter-Xenie 2007; Hoffmann *et al.* 2012).

This research also promoted the inter-generational transfer of Indigenous knowledge through on-country trips with young and older people. Indigenous participants were most interested and engaged in learning about and documenting plant diversity and distributional information when it was being told by elders, actively used

on country (e.g. digging up yams and cooking them), and in combination with cultural and historical stories. We also found that this form of on-country learning facilitated the uptake of other methods of baseline data collection, such as the herbarium collections, videos, still photography and use of computers, especially by younger people (Fig. 1).

Need for ongoing support by non-Indigenous collaborators

As other research (e.g. Roughley & Williams 2007) has elucidated, local communities can lack the necessary degree of local organisational and governance capacity to maintain long-term projects, suggesting an ongoing requirement for non-Indigenous involvement. Although each ranger group in our research requested these specific projects, it became evident that their organisational capacity was not strong enough to develop and consistently implement the required activities independently. In the first case study, for example, the Yugul Mangi Rangers relied on the non-Indigenous collaborators to complete the funding application forms, organise the fencing contractor and instigate the fence repairs. We suggest that it was not the inability of the rangers that inhibited effort, but rather different perceptions and expectations around work and roles of Indigenous and non-Indigenous collaborators (McRae-Williams & Gerritson 2010). The methodology also required continued input from a non-Indigenous ecologist for the analysis of the CyberTracker data. While it is envisaged that local rangers may take more of an interest in 'the numbers' as skills and interest increases over time, we consider it important that sustained commitment remains a consideration for scientists if they intend working with Indigenous rangers in remote parts of Australia to collect long-term data that is meaningful to local communities as well as external stakeholders. Similarly in the Warddeken IPA, after the initial enthusiasm

for learning herbarium skills, use of video cameras and film making, the rangers still relied on the non-Indigenous collaborators to instigate much of the continued work, even though they said that this was an important project for them. These examples showed that there was a need for enhanced organisational capacity to support Indigenous rangers as well as increased recognition of the role of non-Indigenous staff and collaborators who are often an integral part of on-ground work effort. Therefore, we suggest that respectful bottom-up, collaborative approaches to monitoring that fundamentally incorporate local interests and skills, similar to those described in the case studies, are needed to support Indigenous rangers and their aspirations to create strong, self-sufficient organisations that promote Indigenous culture while concomitantly addressing external stakeholder expectations and contributions to national conservation objectives.

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References

- Altman J. C., Buchanan G. J. and Larsen L. (2007) *The Environmental Significance of the Indigenous estate: Natural Resource Management as Economic Development in*

- Remote Australia. CAEPR Discussion Paper No. 286, The Australian National University, Canberra.
- Ansell S. and Koenig J. (2011) CyberTracker: an integral management tool used by rangers in the Djelk Indigenous Protected Area, central Arnhem Land, Australia. *Ecological Management & Restoration* **12**, 13–25.
- Australian Government. (2011) *Caring for our Country Business Plan 2011–2012*. Australian Government, Canberra.
- Australian National Audit Office. (2008) *Regional delivery model for the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality*. Audit Report No. 21 2007–2008. Australian Government, Canberra.
- ANZEC (Australian and New Zealand Environment) and BDAC (Conservation Council and Biological Diversity Advisory Committee). (2001) *Biodiversity Conservation Research: Australia's Priorities*. Commonwealth of Australia, Canberra.
- Barbour W. and Schlesinger C. (2012) Who's the boss? Post-colonialism, ecological research and conservation management on Australian Indigenous lands. *Ecological Management & Restoration* **13**, 36–41.
- Bayliss P. and Yeomans K. M. (1989) Distribution and abundance of feral livestock in the 'Top End' of the Northern Territory (1985–1986), and their relation to population control. *Australian Wildlife Research* **16**, 651–676.
- Berkes F. (1999) *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. Taylor and Francis, Philadelphia.
- Blanch S. (2008) Steps to a sustainable Northern Australia. *Ecological Management & Restoration* **9**, 110–115.
- Braithwaite R. W., Dudzinski M. L., Ridpath M. G. and Parker B. S. (1984) The impact of water buffalo on the monsoon forest ecosystem in Kakadu National Park. *Australian Journal of Ecology* **9**, 309–322.
- Carter J. L. (2008) Thinking outside the framework: equitable research partnerships for environmental research in Australia. *Geographical Journal* **174**, 63–75.
- Clarke P. A. (2008) *Aboriginal Plant Collectors: Botanists and Australian Aboriginal People in the Nineteenth Century*. Rosenberg Publishing, Kenthurst.
- Ens E. J. (in press) Monitoring outcomes of environmental service provision in low socio-economic Indigenous Australia using innovative CyberTracker technology. *Conservation and Society*.
- Ens E. J., Cooke P., Nadjamerrek R., Namundja S., Garling V. and Yibarbuk D. (2010) Ecological impacts of feral water buffalo on perennial freshwater springs of the Aboriginal owned Arnhem Plateau, Australia. *Environmental Management* **45**, 751–758.
- Fitzsimons J., Russell-Smith J., James G. et al. (2012) Insights into the biodiversity and social benchmarking components of the Northern Australian fire management and carbon abatement programmes. *Ecological Management & Restoration*, **13**, 51–57.
- Garde M., Russell-Smith J. and Namok W. (2003) *A Preliminary List of Kundedjnjanghmi Plant Names*. Report to Warddeken Land Management Limited, Kabulwarnamyo.
- Hoffmann B. D., Roeger S., Wise P. et al. (2012) Achieving highly successful multiple agency collaborations in a cross-cultural environment: experiences and lessons from Dhimurru Aboriginal Corporation and partners. *Ecological Management & Restoration* **13**, 42–50.
- Horstman M. and Wightman G. (2001) Kaparti ecology: recognition of Aboriginal ecological knowledge and its application to management in north-western Australia. *Ecological Management & Restoration* **2**, 99–109.
- Hunt J., Smith D., Garling S. and Sanders W. (2008) *Contested governance: Culture, Power and Institutions in Indigenous Australia*. ANU EPress, Canberra.
- Kennett R., Robinson C., Kiessling I., Yunupingu D., Mununguritj M. and Yunupingu D. (2004) Indigenous initiatives for co-management of Miyapunu/Sea turtle. *Ecological Management & Restoration* **5**, 159–166.
- Luzar J. B., Silvius K. M., Overman H., Giery S. T., Read J. M. and Fragoso J. M. V. (2011) Large-scale environmental monitoring by Indigenous peoples. *BioScience* **61**, 771–781.
- McConvell P. and Thieberger N. (2001) *State of Indigenous languages in Australia – 2001*. Australian State of the Environment Second Technical Paper Series (Natural and Cultural Heritage). Department of the Environment and Heritage, Canberra.
- McRae-Williams E. and Gerritson R. (2010). Mutual incomprehension: the cross-cultural domain of work in a remote Australian Aboriginal community. *The International Indigenous Policy Journal* **1**, Article 2.
- Moorcroft H., Ignjic E., Cowell S. et al. (2012) Conservation planning in a cross-cultural context: the Wunambal Gaambera Healthy Country Project in the Kimberley, Western Australia. *Ecological Management & Restoration*, **13**, 16–25.
- Muller S. (2008) Accountability constructions, contestations and implications: insights from working in a Yolngu cross-cultural institution, Australia. *Geography Compass* **2**, 395–413.
- National Land and Water Resources Audit. (2002) *Australia's Natural Resources: 1997–2002 and beyond*. Commonwealth of Australia, Canberra.
- OECD. (2002) *Agri-Environmental Policy measures: Overview of developments*. Unclassified Report COM/AGR/CA/ENV/EPOC (2002)95/FINAL. Organisation for Economic Cooperation and Development, Paris.
- Robinson C. J., Smyth D. and Whitehead P. (2005) Bush tucker, bush threats and bush pets: cooperative management of feral animals in Australia's Kakadu National Park. *Conservation Biology* **19**, 1385–1391.
- Roughley A. and Williams S. (2007) *The engagement of Indigenous Australians in Natural Resource Management: Key Findings and Outcomes from Land and Water Australia Funded Research and the Broader Literature*. Land and Water Australia, Canberra.
- Russell-Smith J., Lucas D., Gapindi M. et al. (1997) Aboriginal resource utilisation and fire management practice in western Arnhem Land, monsoonal northern Australia: notes for prehistory, Lessons for the future. *Human Ecology* **25**, 159–195.
- Russell-Smith J., Whitehead P. and Cooke P. (2009) *Culture, Ecology and Economy of Fire Management in North Australian Savannas: Rekindling the Wurrk Tradition*. CSIRO Publishing, Canberra.
- Sithole B. and Hunter-Xenie H. with 16 others. (2007) *Aboriginal Land and Sea Management in the Top End: A Community Driven Evaluation*. CSIRO: Darwin.
- Warddeken Land Management Limited. (2009) *Warddeken IPA Technical Information Document*. Warddeken Land Management Limited, Kabulwarnamyo.
- Warddeken Land Management Limited. (2010) *Warddeken Annual Report 2009–2010*. Warddeken Land Management Limited, Kabulwarnamyo.
- Woinarski J. C. Z., Hempel C., Cowie I. et al. (2006) Distributional pattern of plant species endemic to the Northern Territory, Australia. *Australian Journal of Botany* **54**, 627–640.