Author/s:
Skroblin, A;Carboon, T;Bidu, G;Taylor, M;Bidu, N;Taylor, W;Taylor, K;Miller, M;Robinson, L;Williams, C;Chapman, N;Marney, M;Marney, C;Biljabu, J;Biljabu, L;Jeffries, P;Samson, H;Charles, P;Game, ET;Wintle, B

Title:
Developing a two-way learning monitoring program for Mankarr (Greater Bilby) in the Western Desert, Western Australia

Date:
2022-01-01

Citation:
Skroblin, A., Carboon, T., Bidu, G., Taylor, M., Bidu, N., Taylor, W., Taylor, K., Miller, M., Robinson, L., Williams, C., Chapman, N., Marney, M., Marney, C., Biljabu, J., Biljabu, L., Jeffries, P., Samson, H., Charles, P., Game, E. T. & Wintle, B. (2022). Developing a two-way learning monitoring program for Mankarr (Greater Bilby) in the Western Desert, Western Australia. Ecological Management and Restoration, 23 (S1), pp.129-138. https://doi.org/10.1111/emr.12543.

Persistent Link:
https://hdl.handle.net/11343/301792

doi: 10.1111/emr.12543

RESEARCH REPORT

# Developing a two-way learning monitoring program for *Mankarr* (Greater Bilby) in the Western Desert, Western Australia

**By Anja Skroblin, Tracy Carboon, Gladys Bidu, Muuki Taylor, Ngamaru Bidu, Waka Taylor, Karnu Taylor, Minyawu Miller, Leah Robinson, Carol Williams, Nganjapayi Chapman, Mulyatingki Marney, Carl Marney, Jakayu Biljabu, Levina Biljabu, Pamela Jeffries, Heather Samson, Phillipa Charles, Edward T. Game and Brendan Wintle**

***AnjaSkroblin*** *and* ***Brendan Wintle*** *are Western scientists based at the University of Melbourne (Parkville, Victoria, 3052, Australia; Email: anja.skroblin@unimelb.edu.au).* ***Tracy Carboon*** *is the Healthy Country Coordinator with Kanyirninpa Jukurrpa (PO Box 504, Newman, WA 6753, Australia)/* ***Gladys Bidu***, ***Muuki Taylor***, ***Ngamaru Bidu***, ***Waka Taylor***, ***Karnu Taylor***, ***Minyawu Miller***, ***Leah Robinson***, ***Carol Williams***, ***Nganjapayi Chapman***, ***Mulyatingki Marney***, ***Carl Marney***, ***Jakayu Biljabu***, ***Levina Biljabu***, ***Pamela Jeffries***, ***Heather Samson*** *and* ***Phillipa Charles*** *are Martu and rangers with Kanyirninpa Jukurrpa (Newman, WA 6573, Australia),* ***Edward T. Game*** *is Lead Scientist Asia Pacific with The Nature Conservancy (South Brisbane, QLD 4102, Australia). This project arose to support Martu in looking after Mankarr on their Country. This paper is part of the special issue 'Indigenous and cross-cultural ecology - perspectives from Australia' published in* Ecological Management & Restoration.

**Summary** Indigenous people are the custodians of knowledge systems that hold detailed awareness of the environment, including applications for monitoring and management to improve biodiversity and cultural outcomes. Indigenous communities are increasingly participating in programs to monitor populations of wildlife. There is a need for frameworks to guide how Indigenous priorities, aspirations and culture can be respected within monitoring programs, as well as case studies that demonstrate how Indigenous knowledge and practice can provide opportunities together with Western science practice to improve the rigour and outcomes of wildlife monitoring. Here, we describe the process of developing a monitoring program that was tailored to be carried out by Kanyirninpa Jukurrpa Indigenous ranger teams to assess the status, trend and response to the management of a threatened and culturally significant species *Mankarr* (Greater Bilby; *Macrotis lagotis*). We applied a collaborative two-way approach, using iterative consultations, elicitations and field trials involving Indigenous and non-Indigenous project partners to define monitoring objectives, record biocultural knowledge and tailor a sampling methodology to fit the requirements of Martu Traditional Owners. Our project focused on creating a method that would be engaging, accessible and useful for rangers who would carry out the program, and prioritized collection of relevant data for community decision-making regarding management. We outline our key learnings for co-design of wildlife monitoring programs on Indigenous lands. Our approach provides insights that will assist in designing other cross-cultural or participatory monitoring programs.

**Key words:** *biodiversity conservation, Indigenous land management, monitoring and evaluation, techniques and methodology, threatened species populations and communities.*

## Implications for managers

- Cross-cultural monitoring programs can work to combine place-based knowledge with Western scientific knowledge as a two-toolbox approach to managing declining species.
- Co-designing wildlife monitoring programs that are context specific for Indigenous rangers ensures programs are relevant and engaging, as well as culturally sound and logistically feasible.
- Monitoring programs can generate multiple types of data and experiences that are valuable to ranger teams, such as being on Country and intergenerational knowledge transfer, as well as data for Western science statistical analyses.

## Introduction

Globally, Indigenous peoples are the custodians of knowledge systems that hold detailed awareness of the dynamics that shape environmental diversity. This knowledge was traditionally used and is still highly relevant for monitoring patterns in wildlife populations and the effects of management practices (Moller *et al*. 2004; Jackson *et al*. 2015; Dobbs *et al*. 2016). Over the past decades, international policy (such as the Convention on Biological Diversity) and Australian initiatives (such as the Indigenous Ranger programs) are mandating the use of Indigenous knowledge to improve environmental monitoring and management (Mistry & Berardi 2016; Paltridge & Skroblin 2018).

The growing participation of Indigenous peoples in wildlife monitoring requires an extension of general monitoring frameworks (such as Lindenmayer & Likens 2010) to be responsive to Indigenous social, cultural and socioeconomic imperatives and priorities – not just conservation concerns – that often dictate management decisions on Indigenous lands (Sobrevila 2008; Hill *et al*. 2012; Mistry & Berardi 2016). It is increasingly clear that best practice approaches in the context of environmental monitoring or management on Indigenous lands encourage ownership and empowerment of local Indigenous knowledge holders in project design, delivery and evaluation (Lynch *et al*. 2010; Ens *et al*. 2015). There is increasing literature on cross-cultural monitoring programs globally (for instance Whitelaw *et al*. 2003; Danielsen *et al*. 2005; Lawrence *et al*. 2006; Conrad & Daoust 2008) including theory and examples of co-designed cross-cultural projects, especially in Australia (for instance Baker *et al*. 1990; Southgate & Moseby 2008; Brennan *et al*. 2012; Ens 2012; Ens *et al*. 2012). There is however a need for more cross-cultural monitoring programs that work to combine place-based knowledge with Western scientific knowledge as a two-toolbox approach to managing declining species.

In the deserts of Australia, reliable monitoring programs are critical to the conservation and recovery of the *Mankarr* (Greater Bilby, *Macrotis lagotis* Reid, 1837), a species of national significance (Bradley *et al*. 2015), which is culturally significant for many Aboriginal Australians (Walsh & custodians of the Bilby 2016). The Mankarr is the last surviving desert bandicoot. Once found across most of the arid inland of Australia, its distribution outside of fenced enclosures has decreased by 80% and to the north-western section of its former range (Woinarski *et al*. 2014). It is now primarily found in areas that are owned and managed by Aboriginal people. Aboriginal 'caring for Country' practices, such as careful burning at the right time of year and control of feral herbivores and predators, are vital to the persistence and recovery of the species (Commonwealth of Australia 2019). To Aboriginal people living in the deserts, small mammals such as the Mankarr form an integral part of culture and *Jukurrpa* (Dreaming and Law) and historically provided important sources of food (Walsh & custodians of the Bilby 2016). Aboriginal custodians of these species can hold knowledge of the species ecology, distributions, and the reasons for, and timelines of decline (Ziembicki *et al*. 2013).

In this reflective methods paper, we describe the how a cross-cultural team of Martu and Western scientists worked together to develop and tailor a monitoring project to investigate trends in *Mankarr* populations. The monitoring design needed to be context specific for Kanyirninpa Jukurrpa (KJ; a Martu organization) Indigenous ranger teams on Martu lands in the desert of Western Australia. We outline the participatory co-design process and present a monitoring framework intended to integrate Martu aspirations, knowledge, cultural and logistic constraints, along with Western monitoring program design protocols. We highlight Martu knowledge related to *Mankarr* and share our key learnings for co-design of wildlife monitoring programs on Indigenous lands that can be applied elsewhere.

## *Mankarr* Monitoring Project Development

This project was initiated in response to a concern held by Martu, the Traditional Owners of a vast expanse of deserts in Western Australia, about ongoing declines in *Mankarr* on their Country and a recognized need to improve the monitoring and management of the species. The project began in 2016 with the intent of creating a *Mankarr* monitoring system (method and supporting framework) that could be used as the basis for a monitoring program (i.e. set of monitoring, analysis and reporting activities) that integrated Martu priorities and approaches along with Western science methodologies. The project was carried out as a partnership between staff and ranger teams from KJ with non-Indigenous scientists who have backgrounds in monitoring and environmental management gained through the Western science and management practice.

## Understanding the Local Context

Martu are the traditional custodians of extensive parts of the Great Sandy, Little Sandy and Gibson Deserts, including Karlamilyi National Park (12,840 $km^2$), and have native title rights to over 136,000 $km^2$ referred to as the Martu Native Title Determination (Fig. 1). Apart from some limited road and mining activity, Martu lands have not been previously subject to significant development or other deliberate non-traditional land uses (Kanyirninpa Jukurrpa 2015). Caring for Country, loosely described as community-based activities that reinforce and support Indigenous peoples' relationships with their physical, cultural, social, economic and spiritual environment (Altman & Whitehead 2003; Kerins 2012; Woodward *et al*. 2020) is a priority for Martu who have deep connection to and knowledge of their Country (Veth 2005). Martu lands are among the most intact arid ecosystems anywhere on Earth. They provide one of the last havens for some of Australia's iconic but highly threatened desert species (Jupp *et al*. 2015), and are likely to contain one of the largest unfenced populations of *Mankarr* (Commonwealth of Australia 2019) (Box 1).

The objectives, relevance and success of any monitoring or management program on Martu lands needs to complement the unique social, cultural and socio-economic context that Martu ranger teams operate in (Walsh 2008). The activities of ranger teams, including monitoring of wildlife, is directed by a plan that outlines the future social, cultural, economic and environmental aspirations of Martu (Kanyirninpa Jukurrpa 2015). Men's and women's ranger teams focus on both cultural heritage and land management projects and operate out of four communities (Jigalong, Parnngurr, Punmu, Kunawarritji – see Fig. 1). Like other Aboriginal and Torres Strait Islander people, Martu custodial responsibilities shape who has responsibility for certain species and places; this influences the


**Figure 1.** The location of Martu Lands where the ranger teams that participated in this project are situated.

knowledge people hold, where certain activities may occur, and people (families, men or women) who may participate (Yunupingu & Muller 2009; Holmes & Jampijinpa 2013).

## Building an 'Intercultural' Working Arrangement

To support Martu and KJ's aspirations for a *Mankarr* monitoring project, a University-based scientist (AS) was recruited to coordinate the design of the monitoring program. The first stage of the project focused on building a working relationship between the project partners. This required education of AS on Martu culture, protocols and priorities, and building of trust between Martu and AS, which was achieved through time spent in community with ranger teams and Elders. The activities of the University scientist were guided and facilitated by KJ staff (in particular TC). Throughout the project the partners followed community protocols: all on-Country work was guided by Martu and we attempted to include a broad representative group of Martu (Elders, Traditional Owners and rangers) and identify the right people to speak for Country. To facilitate strong participation by Martu, KJ employed more than 80 Martu who participated in some way over the course of the project. To ensure protections to Martu cultural and intellectual property rights, the project progressed within a data-sharing agreement, and we received approvals from the KJ board and the University of Melbourne Human Research Ethics (approval number 1646700.1). Martu who contributed to co-design and/or shared knowledge are listed as co-authors on this paper (Box 2).

## Defining Project Objectives and Approach to Co-design

The overall concept for the monitoring system and key success indicators for the co-design process (Box 3) were drafted during discussion-based meetings with rangers, Elders and KJ staff in early 2016. Following this, AS, TC and the ranger teams (defined as rangers and coordinators) facilitated collaborative planning, two-way knowledge sharing (sharing both Indigenous and Western knowledge) and community decision-making through community-based activities with Elders and rangers at four communities (Fig. 2) using the following four steps:

1 Workshops and consultations to discuss project objectives, Martu aspirations, logistics and survey protocols;

2 Collaborative field trials to iteratively update the field methodology and datasheets;

3 Informal discussions and feedback with community members and with KJ staff at other times, and

4 Semi-structured interviews with Elders (at Parnngurr and Punmu communities) focused on spatial information about *Mankarr* occurrence, *Mankarr* population trends, habitat associations and threats (Skroblin *et al*. 2021).

Through this co-design process, Martu shared a rich body of knowledge that was recorded by AS and TC for the KJ archives (overview in Skroblin *et al*. 2017). We cast both Martu and Western science lenses over the strengths and weaknesses of previous survey work carried out by KJ rangers (Paltridge 2008), and ascertained, through Martu guidance, which aspects of learnings from Western approaches to monitoring arid wildlife (for instance Southgate *et al*. 2005;

## Box 1 Martu connection to and knowledge of *Mankarr*

*Mankarr* features in Martu *Jukurrpa* (Dreaming and Law) and used to be hunted and eaten to some extent in *Pujiman* times (when Martu were walking Country before contact with non-Indigenous people). It is an important part of the ecosystem and an indicator about Country. *Mankarr* is particularly beloved as it is one of the last remaining small mammals on Martu Country. For Elders who remember these animals, they express a large sense of loss, which makes holding onto the *Mankarr* even more important.

Some Martu relate the declines in native mammals with Martu moving off their lands in 1960s and 1970s and the cessation of traditional practices including burning over this time. As Elder NC described in 2016:

> *When we were cooking up food in the mission [in Jigalong when people were moved off Country], there was no one cooking up food for all the animals [using fire to encourage food plants]. When we came back [to Country], all the animals were gone.*

Moseby *et al*. 2012) would best integrate with Martu ways of searching and understanding their Country. While the Western scientists provided advice, ultimate decision-making on all aspects of the monitoring program was held by KJ, for whom the program was being designed, with Western science knowledge and practice being applied where deemed of benefit.

## Reflections on the Co-design Process

To guide the co-design process, AS created a framework (expanding on Reynolds 2012) that built on the key principles that lead to better wildlife monitoring (Lindenmayer & Likens 2010) by integrating the objectives for a successful monitoring program as guided by KJ/Martu (Box 3 and Fig. 3). Monitoring *Mankarr* on Martu Country was subject to certain realities and constraints that needed to be navigated. There are ecological and logistical challenges to monitoring *Mankarr*: The species occurs in limited areas of suitable habitat across a very large and remote area. This potentially makes the species hard to find and monitoring costly in terms of resources and time. Ranger teams have limited resources to apply to monitoring (this is only one of many activities ranger teams are involved in), suggesting that effort (for instance number of sites, placement and revisits) needed to be optimized to achieve the objectives, as is the case for most monitoring programs (Lindenmayer & Likens 2010). Importantly, in the context of ranger-led monitoring on Indigenous lands, monitoring activities needed to adhere to cultural protocols including the involvement of particular people in certain activities, and the areas of Country that could be visited. Additionally, there was a need for flexibility in the co-design and in the resulting monitoring program as Martu have strong family obligations which influenced the timing of work trips and availability of key individuals. Furthermore, the methodology needed to be accessible to Martu who varied in their English and literacy skills (Box 4).

**Figure 2.** Ranger teams from four communities participating in co-design of the monitoring program during workshops and field trials on County.

## Developing the Monitoring Framework

As with any monitoring program, a vital step was deciding on what to measure (the metric and habitat indicators) and how to measure. Wildlife monitoring in the arid zone was often carried out using 2-ha plot surveys where animal presence was recorded through detection of tracks, scats, burrows and other traces (following methods of Southgate & Moseby 2008; Moseby *et al*. 2012). However, the ranger teams were disengaged with 2-ha plots (having applied them between 2008 and 2015) and interested in exploring alternatives. AS compiled potential survey methods from the literature for discussion (see Appendix 1 for details). From a ranger team perspective, sign-based surveys appeared to be the most suitable method

## Box 2 Martu aspirations for *Mankarr*

Martu have extensive knowledge of *Mankarr* and hold strong aspirations to continue their cultural practices and maintain populations of *Mankarr* and other native wildlife on their Country. Some reasons why caring for *Mankarr* is important (as told using Martu ways):

- Keeping *Mankarr* on Martu Country:

  *We need to look after Mankarr because it's the only one left. Those other animals they are all gone. Martu, we know where Mankarr are, and how to look after them* (GB).

- Enacting caring for Country practices

  *We need to do this work to look after Mankarr and the other animals because my father told me we need to look after them* (HS).

- Continuing intergenerational knowledge transfer

  *It's important for us to take kids out and show them the animals, to sit down and share stories* (PJ).

- Interacting with Country

  *We found a Mankarr burrow. Some ladies had never seen one. I showed them the Mankarr and they were really happy*! (CW).

as they encouraged and utilized Martu traditional tracking skills. However, from a Martu perspective there were shortcomings with the available methods and opportunities for improvements (see Table A2). As a result, the project partners decided to co-design a modified survey method with a data-recording protocol that was tailored to Martu.

### *Mankarr* search method

Iterative field trials were carried out with ranger teams across four communities in 2017. Here, the search method, habitat indicators and design of data collection methods (data sheets and protocols) were trialled and updated based on the feedback of Martu. The resulting search method was based on Martu ways of reading the landscape and searching for animal presence (utilizing Martu tracking skills akin to hunting) (Fig. 4) combined with a timed search (20 min). . The method included a data-recording protocol that used environmental variables that reflected Martu ways of describing/defining Country (habitat type, vegetation communities, bush foods, Martu fire categories and *Mankarr* demographics), which were not recorded in conventional sign survey methodology (Southgate & Moseby 2008; Moseby *et al*. 2012). In particular, *mirrka* (bushfoods) was recorded during surveys to tell Martu if a site was good for *Mankarr*, as the plants growing at a site can tell Martu about the *waru* (fire history) and guide management.

Martu directed the design of field resources (tick-sheets to record animals, and datasheets) which were supported by protocol documents. All resources were designed to have as many Martu words and images as possible to make the method user-friendly and possibly reduce errors in recording (Fig 5). The tick-sheets were pictorial and bilingual, and made of laminated paper, so that each ranger could have one to fill out while surveying, with the intent of helping rangers to learn and carry out the methodology. The method allocated time after the search was completed where the ranger teams came together to discuss what everyone saw, and talk about whether the site needed management or other relevant points while filling in the site datasheet (Skroblin *et al*. 2019). The datasheet was on paper as Martu felt that this was more accessible to all rangers rather than using an App (such as CyberTracker). The method by design enabled two types of interpretation of survey sites: (i) Martu talking together encouraged community learning and intergenerational knowledge transfer, interpretation of Country and decision-making following Martu ways, and (ii) the collection of animal presence and site data allowed for statistical analyses that could inform broad-scale patterns across the region. To make the monitoring program self-standing for KJ, AS designed a data management system using Microsoft Excel where ranger teams could input data into a preformatted worksheet that included automatic processes to generate basic analyses such as a yearly proportion of sites with animal or plant detections, or changes in habitat. The resulting graphics were designed to be used for reporting.

### Where to monitor and how many sites

Careful monitoring design is key to meeting the objective of detecting trends in *Mankarr* populations over time. In this case, we needed to consider optimal site positioning and stratification, and the resources needed while keeping in mind the ongoing local constraints (Southwell *et al*. 2019). In our approach, ranger teams from each community nominated priority monitoring areas based on their knowledge of *Mankarr* occurrence and the location of suitable habitat. This assured that locations were culturally appropriate and logistically feasible to visit. AS then used power analysis and a simulation tool to test the ability of this design to detect declines in *Mankarr* populations of different magnitudes, as

## Box 3 Objectives of the monitoring program

The aims of the monitoring program as defined by KJ and Martu were to:

1 Assess the status and trends of *Mankarr* on Martu Country, and

2 Help Martu make sure *Mankarr* populations continue to stay healthy.

Directed by KJ and Martu, the objectives for a successful monitoring program were outlined as:

- A sustainable program that KJ staff can feasibly enact year after year.
- The way the project was to be conducted, and the methods generated needed to be accepted as culturally appropriate and scientifically sound.
- Martu knowledge and ways of doing must form the foundation of the methodology.
- Create tools and strategies that support monitoring activities of ranger teams.
- Deliver information that is useful to make management decisions and demonstrate benefits of management efforts.
- Increase engagement in monitoring, knowledge sharing and skills acquisition by rangers.

well as to investigate the optimal number of sites to visit and the number of repeats needed. Carrying out an *a priori* power analyses can inform land managers (including Traditional Owner and rangers) about how well alternative monitoring designs are likely to perform, and thereby reduce the risk of using substantial resources on a monitoring program that does not meet expectations (Wintle 2018).

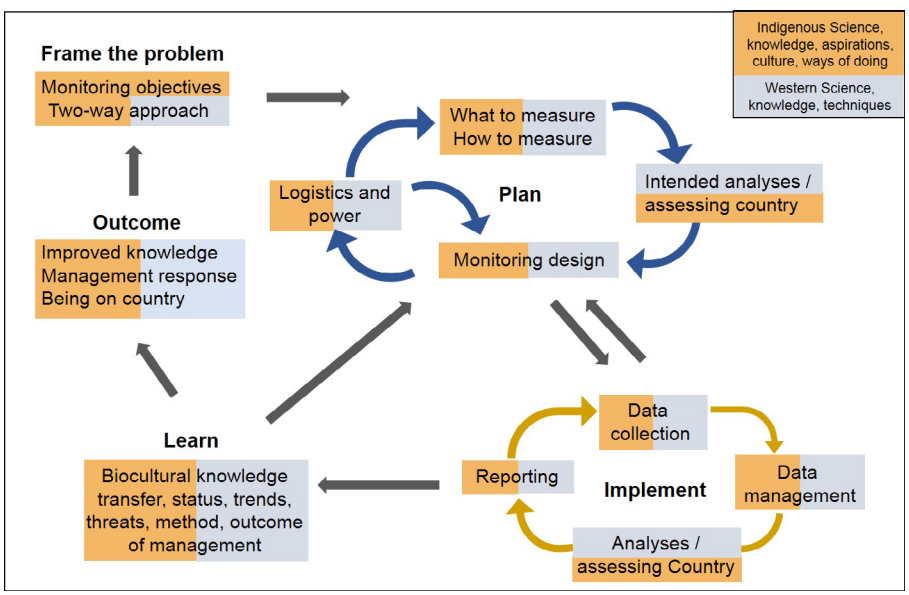


**Figure 3.** Framework of the *Mankarr* monitoring program, showing how Martu (orange) and Western science (blue) knowledge and practice feed into the program actions. The problem is framed when objectives are set; context-specific design is generated in the 'planning' cycle; implementation, evaluation and reporting take place in the 'doing' cycle; while reviewing and improvement happen under the 'learning' process (Adapted from: Reynolds 2012).

The analyses suggested that the monitoring design focused on places that Martu considered a priority could perform sufficiently well at detecting decreases in *Mankarr* presence over time, and that a minimum of 20 sites were needed (at least biannually) to be visited by each ranger team. Our experience suggested that the creation of bridges between conventional Western science tools (like power analysis) and Indigenous approaches requires direct engagement of Western scientists and Indigenous knowledge holders rather than intermediaries, and that the Western science analyst must be able to translate outputs into useful products for community interpretation.

## Final Products

The outcome of the project was a monitoring system that included:

1 A survey method using Martu language and search approaches that included culturally informed datasheets and field resources that were tailored to Martu;

2 A plan of where to monitor (Skroblin *et al.* 2019);

3 A data management system; and

4 An archive of Martu knowledge (Skroblin *et al.* 2017).

The *Mankarr* monitoring program was rolled out in 2018. There have been positive responses from ranger teams on use of the program. In addition to being used for animal monitoring, the *Mankarr* search method was used by the KJ Punmu ranger team in 2020 to help teach the *jijikaja* (children) about *Mankarr*, interpret signs and identify *mirrka* (bush foods important to Mankarr and Martu) (Fig. 6). The method thereby provided an opportunity to practice English and Martu environmental vocabulary and share knowledge with children while on Country, which can help support the conservation of traditional language and culture (Wilder *et al.* 2016).

## Lessons Learnt

Key to carrying out our co-design process for monitoring wildlife was a respectful

## Box 4 Martu knowledge in the monitoring program

Martu applied their extensive knowledge and skills to provide guidance on all aspects of the monitoring framework (Fig 3.). Martu are experts in understanding *Mankarr* on their Country:

> *We know places that bilbies live. We look at Country, explore, know that this isn't the place Mankarr come. We know.* (HS Jigalong 2018).

During the project, Martu intellectual property was shared and created (now stored in KJ archives) for the development of the monitoring program, including:

- Maps drawn by Elders of where Mankarr had been observed (spatial occurrence data) and maps of where Mankarr have declined over the previous 50 years (see Skroblin *et al.* 2021)
- Quotes from Martu explaining Mankarr habitat associations and location of habitat, including the influence of fire and stages of post-fire regrowth, along with associated Language terms.
- Quotes from Martu explaining the influence of threats like 'wrong- way' *waru* (fire), predation by feral cats and foxes and competition from rabbits (see Skroblin *et al.* 2017).
- Tracking skills that formed the basis of the Mankarr search method

**Figure 6.** The Kanyirninpa Jukurrpa rangers are teaching children how to find *Mankarr*; here a child points to a *Mankarr* digging.

**Figure 4.** Kanyirninpa Jukurrpa rangers find a fresh *Mankarr* tracks and use datasheets from the *Mankarr* search method to record site information.

**Figure 5.** Kanyirninpa Jukurrpa ranger carrying out the *Mankarr* search method using the 'tick-sheet' to record animal sign.

and collaborative relationship between Indigenous and non-Indigenous partners. This required willingness and openness from all partners, but especially time for the new collaborator to spend within the community; immerse themselves in the culture and work to the local protocols (Paltridge & Skroblin 2018; Woodford *et al.* 2020). We found it useful to use a modified version of the Western 'planning, doing and learning' monitoring framework (Reynolds 2012) as a foundation to guide the steps involved in the broader co-design process (Fig. 3). Participatory design was encouraged through on-Country discussions and field trials, and it was important to work across all KJ Martu ranger teams and communities to ensure that the final design was broadly applicable and widely supported. For instance, we needed to capture the full representation of relevant language terms used for wildlife and Country between communities and account for different training needs or approaches in protocols. By building bridges between Martu and Western approaches (Hill *et al.* 2012), we found that the monitoring program could be designed to generate multiple types of data or experiences that have value to ranger teams. This included being on Country, opportunities for intergenerational knowledge transfer and on-Country learning, as well as information that is applied in detecting declines (through statistical analysis), or data that can contribute at the regional or national monitoring scale.

## Conclusion

Co-design approaches can provide a way for Indigenous groups to create wildlife monitoring programs where there may not be in-house expertise to create a program that tracks trends in wildlife populations. Fundamentally, monitoring programs need to have value to the local Indigenous community and provide meaningful findings. To be relevant and successful within the context of Indigenous caring for Country, monitoring programs need to value and incorporate Traditional Knowledge, practices and aspirations under the guidance and advice of the community and ensure that intellectual property is protected. We

need to continue to explore approaches where non-Indigenous views and methods do not dominate but are used to support Indigenous knowledge and aspirations. This can be achieved through respectful, bottom-up collaborative approaches that incorporate local skills and interests and assist Indigenous groups to meet their needs, as well as the needs of external funding requirements.

## Acknowledgements

We acknowledge and are grateful to Martu and Kanyirninpa Jukurrpa staff who have supported this project, shared knowledge and time with us and provided data. The project is a collaboration between the traditional owners of the Martu Determination through Kanyirninpa Jukurrpa (KJ) Ranger program and researchers at the University of Melbourne, it is supported by the Australian Government's National Environmental Science Program through the Threatened Species Recovery Hub, BHP, The Nature Conservancy, Department of Prime Minister and Cabinet, Parks and Wildlife Services, and Rangelands NRM WA. The study was approved by the Kanyirninpa Jukurrpa board. The authors have no conflict of interest to declare.

## References

Altman J. C. and Whitehead P. J. (2003) Caring for country and sustainable Indigenous development: opportunities, constraints and innovation. CAEPR Working Paper 20. Australian National University, Canberra, ACT.

Baker L., Richards E., Tjikadu B. *et al*. (1990) Tjunguringkula Waarkaripai: working together. *Wildlife Australia* **27**, 24–27.

Bradley K., Lees C., Lundie-Jenkins G. *et al*. (2015) *Greater Bilby Conservation Summit and Interim Conservation Plan: an Initiative of the Save the Bilby Fund*. IUCN SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Brennan K. E. C., Twigg P. J., Watson A. *et al*. (2012) Cross-cultural systematic biological surveys in Australia's Western Desert. *Ecological Management & Restoration* **13**, 72–80.

Commonwealth of Australia (2019) *Draft Recovery Plan for the Greater Bilby*. https://www.awe.gov.au/environment/biodiversity/threatened/recovery-plans/comment/draft-recovery-plan-greater-bilby

Conrad C. and Daoust T. (2008) Community-based monitoring frameworks: increasing the effectiveness of environmental stewardship. *Environmental Management* **41**, 358–366.

Danielsen F., Burgess N. and Balmford A. (2005) Monitoring matters: examining the potential of locally based approaches. *Biodiversity and Conservation* **14**, 2507–2542.

Dobbs R. J., Davies C. L., Walker M. L. *et al*. (2016) Collaborative research partnerships inform monitoring and management of aquatic ecosystems by Indigenous rangers. *Reviews in Fish Biology and Fisheries* **26**, 711–725.

Ens E. J. (2012) Monitoring outcomes of environmental service provision in low socio-economic Indigenous Australia using innovative CyberTracker technology. *Conservation and Society* **10**, 42–52.

Ens E. J., Pert P., Clarke P. A. *et al*. (2015) Indigenous biocultural knowledge in ecosystem science and management: review and insight from Australia. *Biological Conservation* **181**, 133–149.

Ens E. J., Towler G. M., Daniels C., Yugul Mangi Rangers and The Manwurrk Rangers (2012) Looking back to move forward: collaborative ecological monitoring in remote Arnhem Land. *Ecological Management & Restoration* **13**, 26–35.

Hill R., Grant C., George M., Robinson C. J., Jackson S. and Abel N. (2012) A typology of indigenous engagement in Australian Environmental Management: implications for knowledge integration and social-ecological system sustainability. *Ecology and Society* **17**, 23.

Holmes M. C. C. and Jampijinpa W. (2013) Law for country: the structure of Warlpiri ecological knowledge and its application to natural resource management and ecosystem stewardship. *Ecology and Society* **18** (3), 19. https://doi.org/10.5751/ES-05537-180319

Jackson M. V., Kennett R., Bayliss P. *et al*. (2015) Developing collaborative marine turtle monitoring in the Kimberley region of northern Australia. *Ecological Management & Restoration* **16**, 163–176.

Joseph, L. N., Field, S. A., Wilcox, C. and Possingham, H. P. (2006) Presence–absence versus abundance data for monitoring threatened species. *Conservation biology*, **20** (6), 1679–1687.

Jupp T., Fitzsimons J., Carr B. and See P. (2015) New partnerships for managing large desert landscapes: experiences from the Martu Living Deserts Project. *The Rangeland Journal* **37**, 571–582.

Kerins S. (2012) Caring for country to working on country. *In: People on Country, Vital Landscapes, Indigenous Futures*, (eds J. C. Altman and S. Kerins) pp. 26–44. Federation Press, Sydney.

Kanyirninpa Jukurrpa (2015) . *Martu Kanyirninpa Ngurrara Plan: A Plan for Healthy Country*. Newman, WA.

Lawrence A., Paudel K., Barnes R. and Malla Y. A. M. (2006) Adaptive value of participatory biodiversity monitoring in community forestry. *Environmental Conservation* **33**, 325–334.

Lindenmayer D. B. and Likens G. E. (2010) The science and application of ecological monitoring. *Biological Conservation* **143**, 1317–1328.

Lynch A. J. J., Fell D. G. and McIntyre-Tamwoy S. (2010) Incorporating Indigenous values with 'Western' conservation values in sustainable biodiversity management. *Australasian Journal of Environmental Management* **17**, 244–255.

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. A. and Hines, J. E. (2006) *Occupancy modeling and estimation*. Academic, San Diego, CA.

Mistry J. and Berardi A. (2016) Bridging indigenous and scientific knowledge. *Science* **352**, 1274–1275.

Moller H., Berkes F., Lyver P. O. and Kislalioglu M. (2004) Combining science and traditional ecological knowledge: monitoring populations for co-management. *Ecology and Society* **9** (3), 2. http://www.ecologyandsociety.org/vol9/iss3/art2/

Moseby K., Nano T. and Southgate R. (2012) *Tales in the Sand; A Guide to Identifying Australian Arid Zone Fauna Using Spoor and Other Signs*. Ecological Horizons, South Australia.

Paltridge R. (2008) The Martu Mankarr Tracking Project. Threatened Species Network, Sydney.

Paltridge R. and Skroblin A. (2018) Threatened species monitoring on Aboriginal land: finding the common ground between Kuka, Jukurrpa, Ranger Work and Science. *In: Monitoring Threatened Species and Ecological Communities*. (eds. S. Legge, D. B. Lindenmayer, N. Robinson, B. Scheele, D. Southwell, B. A. Wintle) pp. 321–332. CSIRO Publishing, Clayton South, Australia.

Reynolds J. H. (2012) *An Overview of Statistical Considerations in Long-Term Monitoring*. Cambridge University Press, Cambridge.

Skroblin A., Carboon T. and Martu (2017) *Martu Knowledge of Mankarr (Greater Bilby): Distribution, Habitat, Management*. National Environmental Science Program; Threatened Species Hub, Canberra, ACT.

Skroblin A., Carboon T. and Martu (2019) *KJ Guide to Mankarr monitoring Using the Mankarr Survey Method*. National Environmental Science Program; Threatened Species Hub, Canberra, ACT.

Skroblin A., Carboon T., Bidu G. *et al*. (2021) Including Indigenous knowledge in species distribution modelling for increased ecological insights. *Conservation Biology* **35**, 587–597.

Sobrevila C. (2008) *The Role of Indigenous Peoples in Biodiversity Conservation: the Natural but Often Forgotten Partners*. The World Bank, Washington, DC.

Southgate, R. & Moseby, K. (2008). Track-based monitoring for the deserts and rangelands of Australia. Prepared for the Threatened Species Network at WWF Australia, Sydney.

Southgate R., Paltridge R., Masters P. and Nano T. (2005) An evaluation of transect, plot and aerial survey techniques to monitor the spatial pattern and status of the bilby (Macrotis lagotis) in the Tanami Desert. *Wildlife Research* **32**, 43–52.

Southwell D. M., Einoder L. D., Lahoz-Monfort J. J., Fisher A., Gillespie G. R. and Wintle B. A. (2019) Spatially explicit power analysis for detecting occupancy trends for multiple species. *Ecological Applications* **29**, e01950.

Veth P. (2005) *Between the Desert and The Sea: Archaeologies of the Western Desert and the Pilbara Regions*. National Museum of Australia, Canberra, ACT.
Walsh F. J. (2008) *To Hunt and to Hold: Martu Aboriginal People's Uses and Knowledge of Their Country, With Implications for Co-management in Karlamilyi (Rudall River) National Park and the Great Sandy Desert, Western Australia*. The University of Western Australia, Crawley WA.
Walsh F. J. and custodians of the Bilby (2016) Bilby is part of this country and for everybody: cultural report about Bilbies and the Ninu Festival Kiwirrkura, 2016. Report to Central Desert Native Title Services, Alice Springs, 70 pp.
Whitelaw G., Vaughan H., Craig B. and Atkinson D. (2003) Establishing the Canadian community monitoring network. *Environmental Monitoring and Assessment* **88**, 409–418.
Wilder B. T., O'Meara C., Nabhan G. P. and Monti L. (2016) The importance of indigenous knowledge in curbing the loss of language and biodiversity. *BioScience* **66**, 499–509.
Wintle B. A. (2018) Why, what, how much, and is it worth it? Questions to answer before spending a penny on monitoring. *In: Monitoring Threatened Species and Ecological Communities* (eds S. Legge, N. Robinson, D. Lindenmayer, B. Scheele, D. M. Southwell, B. A. Wintle), pp. 211–216. CSIRO Publishing, Clayton South, Australia.
Woinarski J. C., Burbidge A. A. and Harrison P. L. (2014) *The Action Plan for Australian Mammals 2012*. CSIRO Publishing, Melbourne.
Woodward E., Hill R., Harkness P. and Archer R. (2020) Our knowledge our way in caring for country: indigenous-led approaches to strengthening and sharing our knowledge for land and sea management. Best Practice Guidelines from Australian Experiences, Cairns, Australia, NAILSMA and CSIRO.
Yunupingu D. and Muller S. (2009) Cross-cultural challenges for Indigenous sea country management in Australia. *Australasian Journal of Environmental Management* **16**, 158–167.
Ziembicki M. R., Woinarski J. C. Z. and Mackey B. (2013) Evaluating the status of species using Indigenous knowledge: novel evidence for major native mammal declines in northern Australia. *Biological Conservation* **157**, 78–92.

## Appendix 1

### What to Measure (The Metric and Habitat Indicators)

Martu indicated they preferred methods that encouraged learning and looking and reading country, sharing of knowledge between generations (especially with children), trips out to country and provided hunting/gathering opportunities. Track-based surveys (searching for sign of animals) which can be used to assess the presence/absence were regarded as the best survey method to monitor status of bilbies across the landscape while fitting with the interests of Martu. Occupancy or landscape usage has been proposed as a useful state variable for various large-scale monitoring programs (MacKenzie *et al*. 2006), and occupancy declines are of interest when dealing with species of conservation concern (MacKenzie *et al*. 2006).

While information on abundance is more powerful to assess population trends over time (Joseph *et al*. 2006) the methods to assess abundance are labour and time intensive (DNA from scats and trapping), and these methods were, therefore, not considered feasible to monitor bilbies at a landscape scale in this context (Table A1).

### How to Measure (The Survey Methodology)

Sign surveys, which were the chosen method for the monitoring program, had previously been used by KJ rangers between 2008 and 2015. Surveys had been conducted by searching a 2-ha area for signs (including tracks, scats, diggings and burrows) to indicate the recent presence of animal species including mankarr (following methods of Southgate & Moseby 2008; Moseby *et al*. 2012). During consultations with ranger teams, issues regarding the utility of these previous methods were raised, and plans were made to trial modifications to the sign survey method to make it more relevant, accessible and engaging to Martu (Table A2).

**Table A1.** Informal assessment of field methods to monitor bilbies by Kanyirninpa Jukurrpa, as applicable to the effort available and feasibility constraints

| | Presence/ absence | Detectability | Local abundance | No special equipment | Many rangers involved | Martu skills used | Little post-processing | Info at landscape scale | Time per site |
|---|---|---|---|---|---|---|---|---|---|
| Sign surveys | ✓ | OK | | ✓ | ✓ | ✓ | ✓ | ✓ | 30 min |
| Transects counting sign | ✓ | OK | ✓ | ✓ | ✓ | ✓ | ✓ | | Clearing tracks + counting |
| Camera trapping | ✓ | ? Low | | | | | | | Deploy + retrieve |
| DNA from scats | ✓ | ? | ✓ | ✓ | ✓ | | | | ~2 days |
| Trapping | ✓ | Low trap success | ✓ | | ✓ | | ✓ | | >2 days |

**Table A2.** Feedback from Kanyirninpa Jukurrpa ranger teams on using 2 ha track-based surveys to survey for mankarr, the action the project took to resolve feedback and the outcome. Feedback was collected during semi-formal and informal discussions with Parnngurr, Punmu and Jigalong ranger teams in 2016, and 3-day field trial in Punmu 2016

| Theme | Feedback given | Action to remedy | Outcome following trial of changes |
|---|---|---|---|
| How to survey | The method needs to more engaging to how Martu search the landscape (a 2-ha plot is seen as an unnatural shape and people do not understand why it is used) | Trial searching with no boundary for 20 min (30 min was considered too long). Rangers use knowledge to direct search path. | 20-min search method preferred by 7/7 ranger teams. |
| | When there is a large group, there can be too many people searching in the small 2-ha area | Trial a search method not confined to a 2-ha plot and people can spread out. | Use of 20 min search method, and record number of people. |
| What to record | The country should be described in terms that Martu understand (the previous method was not relevant and interpretable). | Martu generate terminology to describe country, and ground cover using language. | Changes made to protocol. |
| | Bush foods are an important part of habitat suitability and should be recorded | Martu indicate the correct bush-foods to include. Field resources are created to support this. There is a positive response to field trial. | Changes made to protocol. Field resources created. |
| | Fire should be described using Martu terms | Martu indicate what fire terms to use. | Changes made to protocol. |
| | Rangers do not like disregarding sign that is not within the 2-ha plot | Trial search method not confined to 2-ha plot. | Use of 20 min search method; all mankarr sign recorded. |
| Using Martu knowledge | Martu know how to tell the number of individual mankarr from tracks. Can we include this? | Trial modification of Paltridge method (pers. Comm.) to assign age class based on mankarr tracks. | Field resource created and changes made to protocol. |
| | There needs to be enhanced opportunity to learn, share knowledge and culture | Trial giving rangers time to discuss the site at the end of the survey. | Protocol incorporates time at the end of the survey for rangers to talk. |
| Inclusiveness | Field resources and datasheets need to be tailored to Martu, and can be filled in by rangers | Trials of using Martu language and tailored field resources. | Tick-sheets created to support field work in Martu language. |
| | More rangers should be involved in data recording | Consultations and trials to create field resources (tick datasheet) that can be filled in by more people. | Field resources created, and verbal group reporting of findings at end of survey. |
| | A data app (this instance Cybertracker™ ) is only accessible to some people | Consultation and trials to create field resources (tick datasheet) that can be filled in by more people. Creation of new app. | Field resources to record data. Option of paper datasheets or a new design app. |
| Where to survey | Rangers do not want to use random way of positioning sites. Rangers want to survey the places where they think have suitable habitat, and not survey where the habitat is not suitable | Martu identify the places that are a priority for them to monitor. Power analysis shows that sampling in Martu priority places provides good power. | Surveys are focused on Martu priority places. |
| | Rangers do not like going back to the same area to do repeats surveys within the one year (reluctance to participate in repeat visits leads to no measure of detectability) | Martu identify the places that are a priority for them to monitor. Multiple independent surveys can happen during the same visit to assess detectability. | Surveys are focused on Martu priority places. Multiple surveys happen at subset of sites during one visit. |
| Management | These surveys should inform management practices | Trial having rangers talk about management the site requires at end of the survey. | Survey findings help decisions about burning. |