



Monitoring to Learn, Learning to Monitor: A Critical Analysis of Opportunities for Indigenous Community-Based Monitoring of Environmental Change in Australian Rangelands

NATHANAEL D. WISEMAN* and DOUGLAS K. BARDSLEY

Geography, Environment and Population, The University of Adelaide, Adelaide, SA 5005, Australia.

**Corresponding author. Email: nathanael.wiseman@adelaide.edu.au*

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Abstract

Indigenous community-based monitoring has been a central feature in many international attempts to improve monitoring of and local adaptation to environmental change. Despite offering much promise, Indigenous community-based monitoring has been underutilised in natural resource management in Australia, particularly within the remote, semi-arid rangelands. This paper discusses contextual social and environmental factors that may help to explain this apparent deficiency, before critically analysing key stakeholder perceptions of the roles for, and challenges of monitoring in the Alinytjara Wilurara Natural Resources Management region in the north-west of South Australia. The analysis guides a discussion of responses to better integrate monitoring in general, and Indigenous community-based monitoring in particular, into regional environmental management approaches. We argue that community-based monitoring offers a range of benefits, including: better coordination between stakeholders; a heightened ability to detect and respond to climatic trends and impacts; the effective utilisation of Indigenous knowledge; employment opportunities for managing and monitoring natural resources; and improved learning and understanding of rangeland socio-ecological systems. Identified opportunities for spatial and temporal community monitoring designed for the Alinytjara Wilurara region could be of value to other remote rangeland and Indigenous institutions charged with the difficult task of monitoring, learning from, and responding to environmental change.

KEY WORDS *Indigenous; community-based monitoring; rangelands; natural resource management; South Australia*

Introduction

Australian remote Indigenous communities remain largely marginalised from the wealth of the broader Australian society (SCRGSP, 2014). The lack of opportunities for Aboriginal communities is in large part linked to the inability of the dominant socio-economic system and associated institutions to recognise, value, and com-

pensate Aboriginal Australians for the cultural activities that they have or could provide. While that failure could be attributed to ignorance, prejudice, fear, or greed in the past, arguably a new era of socio-cultural recognition and self-determination sees the emerging challenges as largely linked to policy settings, governance, and institutional arrangements and funding

opportunities (Sutton, 2001; Robbins, 2010; Altman and Kerins, 2012; Gorman and Vemuri, 2012). The recent Federal review on *Overcoming Indigenous Disadvantage* notes that ‘Culture is a key aspect of Aboriginal and Torres Strait Islander wellbeing – not just knowledge and practice of culture by Indigenous Australians, but respect for that culture among the wider community’ (SCRGSP, 2014, p5.4). That situation presents a challenge to governments, businesses, and non-government organisations (NGOs) that are interested in overcoming social disadvantage and incorporating Indigenous cultural interpretations of country into environmental management in Australia. It also generates the need for the development and implementation of policy to compensate Indigenous Australians for the wealth of their cultural activities, including those biocultural activities that monitor and manage the environment within remote regions of the country (Maffi and Woodley, 2012).

Since the Council of Australian Governments (COAG) National Indigenous Reform Agreement (Closing the Gap) in 2008, a string of policy announcements by the Federal Government has been emphasising the necessity to overcome Indigenous disadvantage, in part through improved opportunities for training and employment (COAG, 2008). However, the application of comprehensive, caring policy to help guide sustainable futures for remote Indigenous communities remain highly problematic in Australia (Bardsley, 2015). Of immediate relevance to the focus of this paper, there has been an increased policy recognition of the importance of Indigenous natural resource management (NRM), and yet the links between such policies as the Indigenous Protected Areas programme and the associated Working on Country Ranger programme and improved socio-economic outcomes for remote communities remain uncertain, especially as Indigenous communities often struggle to access or maintain sufficient funding (URBIS, 2012; Bardsley and Wiseman, 2012a; Davies *et al.*, 2013; Commonwealth of Australia, 2014a; Moorcroft and Adams, 2014; Zander *et al.*, 2014). In just one relevant example, the majority of leadership roles in Indigenous Protected Areas in South Australia’s Anangu Pitjantjatjara Yankunytjatjara (APY) Lands are held by non-Indigenous staff (Bardsley and Wiseman, 2012a), despite the Federal programme’s primary goal to ‘Support Indigenous land owners to develop, declare and manage Indigenous Protected Areas on their lands’ (Australian Government, 2014).

Most recently, the Australian Government’s Direct Action Climate Plan through the Carbon Farming Initiative Amendment Bill 2014 identified a key role for carbon sequestration on Aboriginal Traditional Lands (Commonwealth of Australia, 2014b). Again, however, it remains unclear how the significant risks to Indigenous communities which sign contracts to biosequest carbon will function, given the regularity of wild-fires and droughts in their semi-arid landscapes. Improving livelihoods and NRM in remote Indigenous communities of Australia will require new forms of policy support, including the specific recognition of Aboriginal biocultural roles in environmental management based on a formal acknowledgement of the ongoing role of people in the interpretation and shaping of landscape (Sallenave, 1994; Bardsley *et al.*, 2015; Pert *et al.*, 2015).

One vital mechanism that could direct public and private funding to Indigenous communities for improvements in environmental outcomes is investigated here, namely Indigenous community-based monitoring of environmental change. It is within that broader governance context that this paper reviews the opportunities to support community-based monitoring to improve NRM in the semi-arid rangelands of the Alinytjara Wilurara (AW) NRM region in the north-west of South Australia (SA) (Figure 1). The AW region covers over a quarter of a million square kilometres and, as a result, there are relatively few people employed per area to manage the region’s natural resources (Robins and Dovers, 2007; AW NRM Board, 2013). Within the semi-arid region live approximately 3000 people, mostly of Pitjantjatjara, Yankunytjatjara, and Ngaanyatjaara descent, who refer to themselves collectively as Anangu, which translates as ‘people’ in Pitjantjatjara language, and will be the term used throughout this paper to refer to the local Indigenous population (ABS, 2011, AW NRM Board, 2011). The majority of the population lives in small remote towns in the relatively wetter north of the region (which receives 200–400 mm average annual rainfall), and to a lesser extent the coastal south. However, there is significant seasonal and cultural migration between communities and to other areas of Australia, particularly to Adelaide and Alice Springs, and to other communities in the Northern Territory and Western Australia, where Anangu territory has traditionally extended (Goddard, 2006). Between the North and South semi-arid sub-regions lies the more arid and sparsely populated Great

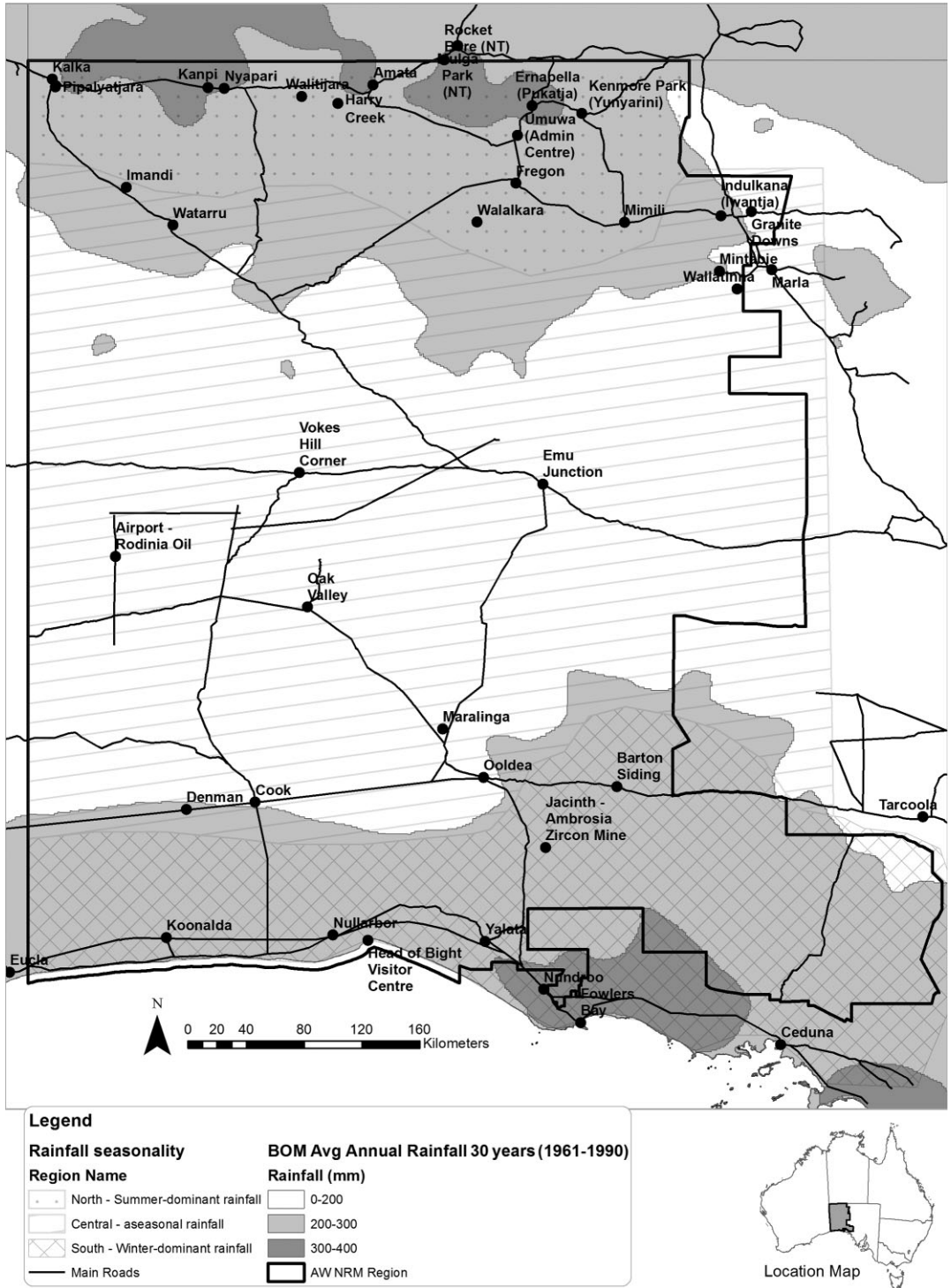


Figure 1 Map of the AW NRM region indicating mean annual rainfall, seasonal rainfall dominance, and major community locations.

Victoria Desert, with average annual rainfall generally less than 200 mm per annum (see Figure 1).

The aim of this paper is to analyse the challenges of effective Indigenous community-based monitoring in the AW NRM region, and to identify opportunities for a broader role for local Indigenous communities to monitor, learn about, and guide future sustainable management of regional rangeland ecosystems. Previous work has identified the need for coordinated responses to effectively monitor and respond to the emerging socio-ecological risks to regional Indigenous communities and has helped to guide AW NRM planning (Bardsley and Wiseman, 2012a; 2012b; Wiseman and Bardsley, 2015). Accelerating global and local environmental risks, coupled with persistent social constraints necessitate broad, resilient responses to learning to manage changing ecological systems, and community-based monitoring needs to be seen a key part of that process. Therefore, the discussion on the roles of Indigenous community-based monitoring is developed in the context of environmental change, which has had and is projected to continue to have dramatic and non-linear impacts on local socio-ecosystems in the AW NRM region (Walker and Abel, 2002; Scheffer, 2009; Svenning and Sandel, 2013).

Indigenous community-based monitoring

Community-based monitoring of environmental change is increasingly being recognised as playing a vital role in strengthening knowledge, providing employment, and facilitating local adaptation efforts in Indigenous communities (Graham *et al.*, 2000; Danielsen *et al.*, 2005; Pelling and High, 2005; Berkes, 2012). Examples of comprehensive Indigenous community-based monitoring programmes have now been established in countries comparable to Australia, including New Zealand (Jollands and Harmsworth, 2007; Harmsworth *et al.*, 2011; Hughey and Booth, 2012) and Canada (Berkes *et al.*, 2007; Tremblay *et al.*, 2008; Gearheard *et al.*, 2011; Parlee *et al.*, 2012). Yet despite an expressed need for better integration of Australian Indigenous understandings and observations of environmental change (e.g. Petheram *et al.*, 2010; Prober *et al.*, 2011), documented examples of Australian Indigenous community-based monitoring programmes are uncommon, intermittent, and often limited in scope or duration. Where they do exist, these studies are predominantly focussed on monsoonal northern Austral-

ian ecosystems and associated communities (e.g. Robinson *et al.*, 2005; Ens *et al.*, 2012a; 2012b), while central desert/rangelands regions have been, by comparison, relatively poorly represented in the literature (for a notable exception, see Robinson *et al.*, 2003).

Where monitoring of environmental change does occur in remote Australia, it is typically characterised by large-scale remote sensing (e.g. Bastin and the ACRIS-MC, 2008; Lawley *et al.*, 2014) or small-scale and isolated expert field observations (e.g. Masters *et al.*, 2003; White *et al.*, 2012). These methods largely discount or ignore local and/or traditional knowledge, even though such knowledge is recognised as highly significant in rangeland environments (Stafford-Smith, 2008; Waudby *et al.*, 2013). As we have noted previously (Wiseman and Bardsley, 2015) and researchers such as Ens *et al.* (2012a; 2012b), Robinson and Wallington (2012), and Muller (2012; 2014) also highlight, where Indigenous people are included in monitoring, the focus has predominantly been on formal NRM goals in Australia, rather than opportunities to evolve policy and action to meet broader Indigenous cultural interpretations of landscape and ecology. That focus seems to assume that NRM planning and processes are sufficient for management of country, and that local Indigenous interpretations and management goals are secondary. There are considerable ethical and socio-ecological limitations of that assumption, and as Muller (2014, 132) rightly emphasises, it overlooks 'the need to respect and value both cultures and knowledges equitably in a spirit of mutual respect and trust, protecting and respecting both ways of learning'. Moreover, unique cultural interpretations of what constitutes effective environmental management are largely neglected by monitoring approaches that concentrate on scientific interpretations of places and systems (Coombes *et al.*, 2014). The central role Indigenous community-based monitoring can play in addressing these practical and ethical challenges is being recognised internationally, and we review those approaches with the aim of identifying how community monitoring could help to guide the evolution of environmental management within and for Indigenous communities of Australia, with a particular focus on the remote AW NRM region.

Approaches to Indigenous community-based monitoring

Participatory approaches to monitoring and managing natural resources acknowledge traditional

and/or local environmental knowledge as often providing valid complementary perspectives to Western science-driven knowledge (Gomez-Baggethun *et al.*, 2013; Waudby *et al.*, 2013; Staddon *et al.*, 2014; Tengö *et al.*, 2014). Not only is better information being derived from the recognition of local knowledge as a core component of any understanding of natural resource condition, but importantly, community-based monitoring aims to simultaneously empower local communities (Danielsen *et al.*, 2005). Vital human heritage associated with Indigenous adaptation to extreme environmental conditions, while sustaining complex cultures, can be championed, supported materially, and constantly regenerated through its use within environmental monitoring programmes (Graham *et al.*, 2000; Berkes, 2012). Such local involvement can be particularly important when it is necessary to generate local ownership and understanding of environmental change, and to facilitate the development of both autonomous and externally supported local climate change adaptation responses (Pelling and High, 2005; Bardsley and Rogers, 2011). Community-based monitoring aims to interpret change and guide responses to environmental issues as an integral and regular part of local management activities often through regular community practices such as hunting and gathering (Gearheard *et al.*, 2011; Ens *et al.*, 2012a; 2012b; Parlee *et al.*, 2012).

Yet community-based monitoring is not an uncontested or neutral concept. Participatory approaches to monitoring are extremely diverse in how they employ traditional, local, and scientific knowledge and in how monitoring and analysis are undertaken (Danielsen *et al.*, 2009). As a situated practice, community-based monitoring can exacerbate existing social differences, power relations, and inequalities according to whom is accorded authority and what counts as important knowledge for environmental management (Staddon *et al.*, 2014). The importance of collaboration and open participation in the design, development, implementation, and evaluation of the monitoring programme is essential if power struggles and inequalities are to be addressed through empowered and mutually respectful partnerships (Berkes *et al.*, 2007; Jollands and Harmsworth, 2007; Leonard *et al.*, 2013; Tengö *et al.*, 2014). Ultimately, trust between different stakeholders is essential in this process of shared learning and collaboration to inform decisions about management of Indigenous lands (Baland and Platteau, 1996; Pretty

and Ward, 2001; Olsson *et al.*, 2004). Moreover, institutions need to be open to the goals of environmental management changing to reflect the knowledge generated by Indigenous monitoring. Many of the challenges and complexities of community-based monitoring are enhanced within the remote, marginal conditions of the rangelands (Lynam and Stafford Smith, 2004; Gorman *et al.*, 2008; Eyre *et al.*, 2011; White *et al.*, 2012).

Challenges of monitoring in the rangelands

Ecosystems within semi-arid rangelands are dependent upon extremely variable rainfall events and consequent water flows (Ludwig and Tongway, 1997; Stafford-Smith *et al.*, 2009). This stochasticity both in space and in time presents difficulties for maintaining monitoring consistency and detecting significant changes or causal relationships (Ludwig and Tongway, 1996; Morton *et al.*, 2011; White *et al.*, 2012; Waudby *et al.*, 2013). A difference of days between observations before or after major rainfall events can mean the difference between a landscape that appears degraded and one that is lush and seemingly full of wildlife (Box *et al.*, 2008). The positioning of monitoring sites in the landscape can also give widely varying results depending on differences in local water flow and catchment-scale succession processes (Pringle *et al.*, 2006).

A number of social challenges also constrain community-based monitoring in rangeland environments. Human populations are typically sparsely distributed and distanced from centres of economic and political power (Reynolds *et al.*, 2007), making investment in long-term rangelands monitoring a low priority at the national level (White *et al.*, 2012). This disadvantage is especially true for remote Aboriginal communities due to a combination of political, socio-economic, and cultural marginalisation within the wider society (HORSCATSIA, 2004; Burgess *et al.*, 2005; Davies *et al.*, 2008; AW NRM Board, 2013): what Veland *et al.* (2013, 323) term the ongoing 'disaster of colonisation'. In many cases, the well-being of remote Indigenous communities could be seen to reflect the condition of country (Burgess *et al.*, 2005; Green and Minchin, 2014). Within the AW NRM region, the rangelands have changed dramatically since colonisation as a result of declining traditional fire management; loss of native biodiversity; pastoral activities; and spreading invasive species (AW NRM Board, 2011, EPA,

2013). It is highly likely that global climate change will exacerbate such existing risks (Maru *et al.*, 2012; Bardsley and Wiseman, 2012a). As well as having direct impacts on people through heat stress, reduced water supplies, and increased risk of disruptions to critical community infrastructure through fires and flooding, declining environmental quality has weakened traditional cultural ties to country (Wiseman and Bardsley, 2013).

Framing effective Indigenous monitoring of environmental change

Together, the environmental and social challenges outlined above conspire to both hinder the capacity for community-based monitoring in the rangelands and make learning from such environments slower and more difficult (Reynolds *et al.*, 2007). That situation leads to the need for a strong understanding of effective approaches for community monitoring of environmental change. Canadian, New Zealand, and Australian case studies of successful Indigenous community-based monitoring are reviewed and key themes identified that frame the approach taken according to what knowledge and technologies are utilised, who gathers and uses the data collected, and who is the primary beneficiary from the approach (Table 1). It is not the intention of this paper to attempt an exhaustive review of the literature on these monitoring typologies (see Danielsen *et al.*, 2014). Rather the review allows for the development of a framework of monitoring approaches, which is applied to critically review existing monitoring programmes in the AW region and to generate arguments on which particular monitoring approaches may be more or less appropriate.

To develop the critique, in 2013 information on community-based monitoring in the AW NRM region was accessed from published materials and interviews conducted with 14 regional stakeholders, including AW NRM staff (in both managerial and scientific/technical positions), AW NRM Board Members (elected Anangu representatives), and SA Government staff (scientific/technical positions) in 2013. After ethical approval through the University of Adelaide, respondents were chosen based on their knowledge of and involvement with existing monitoring programmes in the AW NRM region, or, in the case of AW NRM Board Members, to identify what future monitoring priorities they saw as important for the region. The discussion also draws from workshops held within Anangu com-

munities at Yalata, Kampi-Nyapari, Kenmore Park, Ernabella, and Umuwa in 2014 (see Figure 1). Importantly, this work was conducted at the request of the Indigenous AW NRM Board, to identify future monitoring priorities in the region, and to compare existing monitoring programmes with best-practice Indigenous community-based monitoring in other places. This project forms part of a longer participatory research agenda developed with Anangu communities and AW NRM staff on regional approaches to respond to environmental change (Bardsley and Wiseman, 2012b), which had identified that community-based monitoring of environmental condition remained a significant gap in regional capacity.

International Indigenous community monitoring procedures utilise traditional knowledge to varying degrees. The programmes can be typified along a spectrum of methodologies and goals: with integrated monitoring providing depth and cultural context to established science-based assessments at one end of a spectrum, while at the other end, comprehensive community monitoring is initiated, developed, and implemented by local people to support their own learning and management interests (Jollands and Harmsworth, 2007; Danielsen *et al.*, 2009; Harmsworth *et al.*, 2011; Hughey and Booth, 2012). The other vital spectrum for categorisation relates to the potential for empowerment of local communities as defined by who benefits from the generation of the knowledge. The intersection of the two axes represents a blend of both local and external interests, and scientific and traditional knowledge. A small number of successful community-based monitoring projects are underway within the AW NRM region, which suggests that particular methods and techniques for community-based monitoring are being implemented within the regions' unique social and environmental contexts. These activities are framed in relation to the international case studies (Figure 2), and discussed in some detail in the fourth section, to highlight the need for some approaches which aim to empower through the use of traditional knowledge.

AW NRM examples of Indigenous community-based monitoring

Native biodiversity is currently being monitored in the AW NRM region, including culturally important species such as the Mallee Fowl (*Leipoa ocellata*), Black-footed Rock-wallaby (*Petrogale lateralis*), Sandhill Dunnart

Table 1 Indigenous community-based monitoring of environmental change.

#	Source	Description	Knowledge Used	Technology Used	Primary Data Gatherers	Primary Users	Who Benefits?
A	Parlee <i>et al.</i> (2012)	Mapping and documenting perceptions of ecological change by Cree people in Alberta, Canada	Blended TEK obtained through interviews and participatory mapping exercises	Observation and discussion	Primarily Indigenous people and secondly external researchers Analysis initiated externally	Indigenous people and external researchers	Cultural observation and understandings that have value for resilience within Indigenous communities, but there is no indication that the data led to livelihood improvements
B	Tremblay <i>et al.</i> (2008)	Monitoring ice and hunting trail conditions by Indigenous groups in Nunavik, Quebec	Blended TEK and scientific knowledge developed from local observation and trail mapping of risky areas	Workshops and interviews, ice monitoring stations and web-based ethno-cartographic processes	Integrated study with Indigenous people and external researchers Analysis initiated locally	Indigenous people and external researchers	Draws from cultural observations that have direct value for communities, as adaptation strategies are developed in association with researchers to facilitate better trail access, and improve climate-related information
C	Harmsworth <i>et al.</i> (2011)	Developing a cultural health index of river catchments in New Zealand and integrating this with scientific assessments of the same catchments	Blended TEK developed from local observation with other community and scientific knowledge	Observation-based data collection but integrated with community assessments and freshwater scientific research	Integrated study with Indigenous people and external researchers Cultural indices defined locally	Indigenous people and external researchers	Traditional knowledge and community observations used to determine the health of cultural attributes Mostly for external interests to test catchment condition, but leads to financial incentives and stronger representations of Indigenous values
D	Ens <i>et al.</i> (2012b)	Monitoring and controlling invasive feral animals around cultural sites in Arnhem Land, Australia, using both traditional and scientific observation techniques	Blended TEK with scientific knowledge	Observation data, oral interpretations; scientific transect, water quality, photo point analysis	Indigenous observation and scientific research undertaken by local Indigenous people, with external support	Indigenous people and external researchers	Funding was conditional upon annual monitoring of ecological outcomes. Aim was to protect key billabongs (wetlands) from invasive species for cultural purposes, particularly hunting and gathering, as well as for wider biodiversity, resources
E	Gearheard <i>et al.</i> (2011)	GPS monitoring of weather conditions, trail networks, hazards, rubbish, animals, etc., by Inuit hunters	Local observation given precedence – interpretations of what constitutes a 'hazard', for example, left up to local Inuit observers	PDA/GPS/mobile weather stations	Indigenous people (Inuit hunters) Monitoring indicators developed in collaboration among engineers, scientists, and Inuit hunters	Indigenous people (Inuit hunters), but currently requires support from external professionals to map and use information	Directly culturally relevant (mapping hunting trails, hazards, etc), but also of use to external researchers in monitoring environmental change through changes in seasonal trail use, etc.
F	Berkes <i>et al.</i> (2007) – western Arctic	Climate change monitoring in western Canadian Arctic by Inuit peoples, using locally developed indicators	Perceptions based on Indigenous hunters of change, including ability to predict weather patterns	Direct observation and note-taking	Indigenous people (Inuit hunters) Monitoring indicators developed by Indigenous people	Indigenous people, but also external help in producing communication media (video) and other documentation	In the interests of Indigenous people to demonstrate adverse impacts from climate change to local governments
G	Robinson <i>et al.</i> (2005)	Monitoring and managing feral animals based on cultural values of Jawoyn people, Kakadu National Park, Australia	Perceptions based on Indigenous understanding of ecosystem health and cultural values of introduced species	Direct observation	Indigenous people (Jawoyn) Monitoring indicators developed informally by Indigenous people	Indigenous people (Jawoyn)	Directly culturally relevant Indigenous understandings of 'good' versus 'bad' species sometimes conflicted with external national park managers Shared interest in controlling feral pigs

GPS, Global Positioning System; PDA, Personal Digital Assistant; TEK, Traditional Ecological Knowledge.

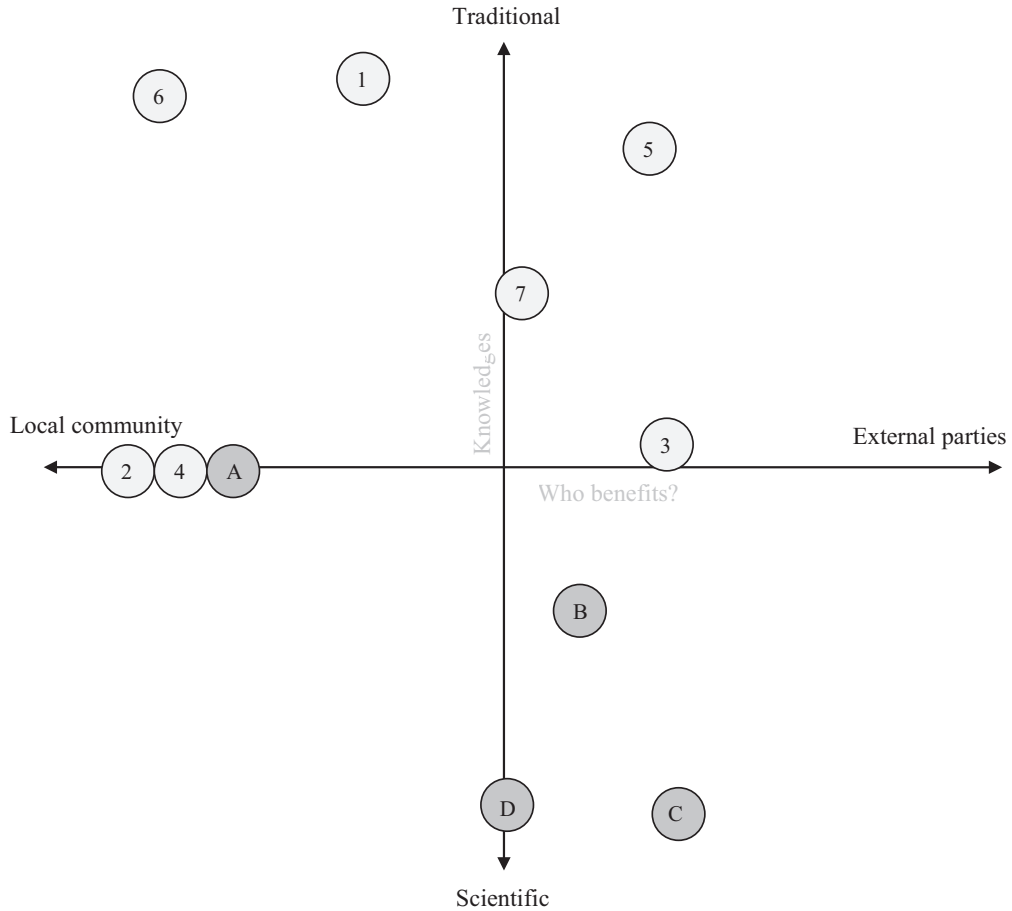


Figure 2 Comparison of effective Indigenous community-based monitoring activities with AW NRM projects according to knowledge and beneficiaries. 1= Parlee *et al.*, 2012 (Alberta, Canada; Cree); 2 = Tremblay *et al.*, 2008 (Nunavik, Canada; Inuit); 3 = Harmsworth *et al.*, 2011 (Motueka and Riwaka river catchments, New Zealand; Maori); 4 = Ens *et al.*, 2012b (Arnhem Land, Australia; Yugul Mangi and Manwurrk); 5 = Gearheard *et al.*, 2011 (Nunavut, Canada; Inuit); 6 = Berkes *et al.*, 2007 (Hudson Bay, Canada; Inuit, Cree); 7 = Robinson *et al.*, 2005 (Kakadu, Australia; Jawoyn). A = AW NRM, biodiversity monitoring; B = AW NRM, camel monitoring; C = AW NRM, Buffel grass monitoring; D = AW NRM, coastal monitoring.

(*Sminthopsis psammophila*), Mulloway (*Argyrosomus hololepidotus*), whales, sea lions, and coastal birds. There are also regular surveys of many other animal and plant distributions, focussing on the northern APY lands, southern Yalata region, and central Oak Valley region (see Figure 1 for regions). The monitoring of animals employs a range of methods, including tagging of individuals, setting pit traps, recording animal tracks, and recording direct sightings using Cybertracker Global Positioning System (GPS) software, a digital, icon-based program which allows real-time spatial recording of field data within low-literacy populations (Ens, 2012; CyberTacker, 2014). For plants, a combination of direct field observation and remote-sensing is

used to determine the spatial extent of vegetation types. The frequency of such monitoring activities is generally low, with most monitoring programmes only repeating observations a few times a year or less. Anangu are involved in many of the current biodiversity monitoring programmes, helping to identify and record animal track sightings, and monitor species with important cultural significance (highlighted above). Many of these biodiversity monitoring programmes are highly popular with Anangu, offering opportunities to go out on country and maintain cultural connections to the land, as well as some paid employment. It also provides a sense of pride to Anangu that such work is valued and supported from a Western/scientific

perspective. As one respondent noted of a monitoring programme:

I think the reason this project works so well is that community members get really enthusiastic about going out to monitor – it is their animals, on their land, their country. They are proud to look after their country. (Respondent 6, 26/3/2013)

Past biodiversity surveys have also had strong Anangu involvement in on-ground monitoring, with close relationships formed between Western scientists and Anangu, resulting in rich cross-cultural experiences and knowledge generation (see Robinson *et al.*, 2003). The use of tools such as Cybertracker was identified in the interviews as useful for communities undertaking monitoring, particularly as photographs could be taken of land condition and shared with other community members who might not have gone out on country. For example, the AW NRM Dreamweaver program has been successful in supporting women to undertake rockhole maintenance and to guide mutual understanding of the importance of rockholes in the landscape (AW NRM Board, 2014). However, interview respondents suggested that while generating useful community engagement, the outcomes were less valuable for informing scientific NRM. There was a perceived difficulty in translating Indigenous perspectives of the environment into forms useful for integrating with scientific knowledge and to meet cultural as well as NRM policy goals.

We have the Dreamweaver program, which is doing some stuff around rockholes, women's sites and rockholes, getting people back to country, which is an outcome, and it is a land management outcome according to Anangu, and I agree with that. However, I think we could sort of 'upscale' that program so it provides a clear framework for consistent methods of monitoring rockholes, and strategic methods across the region, and that's where I want it to go. (Respondent 5, 26/3/2013)

What Caring for Country looks like to Aboriginal women may be very different from a scientific perspective. (Respondent 7, 15/4/2013)

Camel monitoring in the AW region includes assessing browsing impacts, aerial surveys of camel density, and recordings of camel move-

ment using satellite collaring. Anangu are employed to do survey work and mustering of camels in the APY Lands, both directly and through contractual agreements with third parties, but further south (Marlinga Tjarutja and Yalata) the process is more informal, with Anangu being asked to be involved in satellite monitoring work as it arises. There remains a significant gap between the understanding of camel numbers and impacts, and their management that largely aims to cull animals or remove them for meat.

I don't think we've adequately covered the monitoring needs at all. I think there are plenty of gaps. One is to, rather than trying to respond to the current situation, start looking at what the likely future holds. And we're not doing that in terms of camel density, camel habitat, and how climate change might affect both of those. (Respondent 4, 26/3/2013)

There is also a conflict between the goal of rangeland management to reduce camel numbers as much as possible and the goals of many local people to establish regimes of sustainable camel harvesting to obtain a regular income.

The problem we've got of course is particularly on Aboriginal communities is we're always weighing up impact with potential benefit. You know the fact that APY in particular a lot of people are receiving an income from camel management so it's always trying to convince them that the impact is significant, even if there is a benefit to be gained in addressing that impact by mustering. (Respondent 4, 26/3/2013)

Buffel grass monitoring has become much more important in the last five years with the growing recognition of the ecological and social impacts of this invasive species in the rangelands. As Buffel grass is highly rainfall dependent, current monitoring activities focus on identifying where rain has occurred in the region and conducting site visits to determine the extent of Buffel grass invasion, particularly in the south where Buffel is still not widespread. Rainfall data are obtained from weather stations in the region, from local radio reports, and direct observation through community/staff networks. Monitoring of Buffel grass includes mapping the current range of establishment using GPS with ArcPad or Cybertracker, and monitoring post-control growth and condition at regular intervals. At present, Anangu are contracted to do some

monitoring of Buffel grass through community-based monitoring programmes in Oak Valley and Yalata, using Cybertracker to locate Buffel grass sightings using GPS. Given the difficulties AW NRM staff have accessing such a large region with limited capacity, there are recognised opportunities to expand community involvement in monitoring Buffel grass:

[Communities are] there on-ground, they can do it every day of the week. And it's hard for us to predict what's happening up there. So I think that would be the key for them to be doing it, and then fielding things back to us, saying 'hey we had an inch of rain' or 'it's been dry', you know, just that communication about what they're doing. And we'll still continue the support. (Respondent 14, 24/4/2013)

The aim is to give communities the empowerment, the knowledge and the ability. That is very important, because at this stage it is the communities who are most at threat. (Respondent 8, 24/4/2013)

Coastal monitoring in the AW NRM region includes marine debris surveys, whale monitoring, shorebird monitoring, mulloway tagging, recreational fishing surveys, and marine mammal sampling and dissection. While there have been studies of cliff erosion and the link to climate change in the past, there is no current ongoing monitoring of cliff retreat. All coastal monitoring programmes involve Anangu in some form, whether through employment as data collectors, or in consultation to determine AW priorities along the coast. A new digital storytelling project aims to increase Anangu involvement by allowing communities to record their thoughts and ideas.

The communities purchase tablets, so we teach them the technology to use the tablets, and then skill those workers up through employment positions to capture the stories . . . through voice recording and film . . . [to see] if the community thinks that we're having an impact in the region and on the environment from management strategies. (Respondent 9, 24/4/2013)

The examples of Indigenous community monitoring are summarised using the same conventions as the other case studies (Table 2) and represented against the spectra generated in the context of the effective community-based monitoring activities.

Effective international and other national examples of successful Indigenous monitoring reviewed tend to use traditional knowledge comprehensively and either independently (e.g. Berkes *et al.*, 2007; Parlee *et al.*, 2012) or in conjunction with scientific knowledge (e.g. Tremblay *et al.*, 2008; Ens *et al.*, 2012b) to inform both local and external planning and action (Figure 2). In contrast, it can clearly be seen that AW NRM regional monitoring programmes prioritise scientific knowledge over local Indigenous knowledge, and generate that knowledge primarily for external interests and especially the institutional needs of the AW NRM Board itself. There are some exceptions to this general pattern; for example, biodiversity monitoring in the AW NRM region has utilised a blend of scientific and traditional knowledge, with strong benefits for local communities. Furthermore, some AW projects, such as Robinson *et al.*'s (2003) review of the regional ecology or the Dreamweaver project which supports Indigenous women's involvement in traditional NRM activities, clearly focus on utilising traditional knowledge for the benefit of local communities, and have worked closely with local Anangu in developing appropriate knowledge. Yet, just as clearly, the integration of Indigenous community-based monitoring is neither at the scale or scope necessary to generate regular engagement between traditional Anangu cultural knowledge and the management of country, or provide a mechanism for linking biocultural understanding and activities to regular employment.

Discussions with AW NRM stakeholders emphasised the problems with engaging with Indigenous communities for effective monitoring of environmental change, rather than the opportunities. Part of the problem lies in the lack of information on environmental conditions in the vast, remote region, such that baseline information on rangeland condition is not available.

We're trying to get a grip on what is 'normal', with the realisation that climate change didn't start last week when someone mentioned it! . . . So there's a lot of catching up to do, and I guess that's the difficulty of it at the moment is to try and determine where your baselines are from which you can then, you know, measure change. (Respondent 1, 5/3/2013)

Historically, there have been a number of strong ecological drivers of changing rangeland condition including changes to fire management, invasive species, grazing pressures, and climate

Table 2 Summary of local AW NRM monitoring activities.

#	Source	Knowledge Used	Technology Used	Primary Data Gatherers	Primary Users	Who Benefits?
A	AW NRM biodiversity monitoring	Mixture of Anangu and scientific perspectives	Direct observation, GPS mapping, on-ground and aerial surveys	A mixture – Anangu are involved in on-ground monitoring, external contractors involved in aerial monitoring	Anangu use knowledge of species directly from field work, and external institutions generally use mapped data	Anangu paid to undertake monitoring work through community-based contracts Work directly relevant to Anangu values and culture. Anangu paid to undertake monitoring work Work directly relevant to Anangu values and culture, but also potentially at odds with desire to muster for economic benefit
B	AW NRM camel monitoring	Mixture of Anangu perspective on camels and scientific perspectives	Direct observation, GPS mapping, aerial surveys	Mixture – Anangu involved in on-ground surveying, external contractors involved in aerial surveying	External institutions (state and national)	Anangu paid to undertake monitoring work Work directly relevant to Anangu values and culture, but also potentially at odds with desire to muster for economic benefit
C	AW NRM Buffel grass monitoring	Science-led eradication programme, with support from Anangu (concern over Buffel grass impact on native species)	GPS, site observations	Scientists/technicians with support from Indigenous communities	External institutions (AW NRM)	Anangu paid to undertake monitoring work, but in state/federal interest to undertake control work
D	AW NRM coastal monitoring	Currently science based	GPS tagging, field observations with GPS	Scientists/technicians with support from Indigenous communities	External institutions (regional, state)	Some programmes (e.g. mulfloway tagging) in community interest through employment, some benefit external institutions more Whale monitoring is culturally relevant.

AW, Alinytjara Wilurara; GPS, Global Positioning System; NRM, natural resource management.

change, so the attribution of variations to environmental condition to a particular cause is very difficult.

If we get the big fires, is that because there is a lack of a small fire mosaic, or is that a climate-induced thing, or is that a Buffel grass induced thing? So how do you then measure that and try and split it and pull it apart and say well this is a weather factor and this is a cultural factor and this is a new species introduced into the area factor – it's difficult! (Respondent 1, 5/3/2013)

Most respondents also raised the issue that they must constantly innovate to access funding as baseline funding is limited (AW NRM Board, 2013), which means that monitoring approaches are constantly in flux, making long-term comparisons difficult or impossible. Thus, any consistent, long-term monitoring at the community level cannot be supported via prevailing funding mechanisms.

Speaking purely from past experience, I used to find it really frustrating because it was very, very hard to get money for monitoring. State government basically wasn't interested in it . . . Quite often I was told when I was going for funding, I'd outline, trying to give them a lot of background of the project, and they'd just say 'oh no, we really need to see different projects'. So you'd have this situation where each year you had to come up with something new, which seemed a bit ridiculous. You had to be innovative. Which doesn't really work if you're trying to do long-term monitoring. (Respondent 2, 18/3/2013)

Indigenous people already engage with their country in the long term and so support for their involvement in generating and recording knowledge through remote community employment could avoid the short-term project-focus of much historical rangeland monitoring. As has also been found in Canada (Sallenave, 1994), if remote Indigenous communities can monitor local conditions regularly and over the longer term, remote data generation can improve and the costs of monitoring may actually decrease in relation to current monitoring approaches.

There is still a lack of a coordinated and integrated approach to monitoring across the large region, which makes it difficult to interpret and synthesise information and understand change. In particular, respondents suggested that resources are wasted due to repetition, overlapping activities, or major gaps in knowledge.

We don't have an overall monitoring strategy – it's severely lacking – everyone's doing their own little bit and they're fitting it in where they can. You know, it's the other 50% of the equation obviously, but I think we give it only about 5.5% value to the whole thing. I think it should be driving the purpose of doing what you're doing by measuring what you've achieved. Monitoring has always been the poor cousin to the operational action at the other end of the stick. (Respondent 1, 5/3/2013)

There are also conflicting opinions about what are the major priorities for management and monitoring. For example, conflicts exist between community goals, which may, for example, focus on the sustainable management of hunted animals that are important to local communities, and State and Federal priorities that aim for the conservation of endangered species. As a result of this mismatch, traditional knowledge is often conceptualised as secondary to the core issues of scientific data gathering, assessment, and management for specific NRM outcomes.

Are we introducing the little species, where maybe what we need to do is actually work on what the community want, which is to get the more common ones back [e.g. red kangaroos]? But then you don't get the funding to do that . . . because it's not a national priority – there's only so much money they can spend on things around Australia so they'll go for what they see as national priorities. (Respondent 3, 21/3/2013)

The mismatches in both management goals and in what knowledge is required to support those goals make translating traditional knowledge to inform science-based management difficult. On the other hand, monitoring programmes that focus on species important to both the AW NRM Board and to Anangu communities, such as the Mallee fowl, are well supported.

It may not be a monitoring activity per se, but the ability for old people to go out on country and see it, and say 'well this is looking alright' or 'this isn't looking alright' – the support for them to go out and do that has worked, but you don't necessarily end up with what's called a 'scientific' outcome. You end up with people saying 'yeah, yeah it was alright', or 'nah, we found some real issues out there; you mob of young kids have got to get out there and do a bit more'. (Respondent 3, 21/3/2013)

I think the reason this project works so well is that community members get really enthusiastic about going out to monitor – it is their animals, on their land, their country. They are proud to look after their country. (Respondent 6, 26/3/2013)

On occasions, mutual trust seems to be lacking between Anangu and management personnel. That situation raises important ethical and philosophical issues about the use and maintenance of different types of knowledge, particularly when it is sourced from people who are relatively disempowered within knowledge production and use systems. In fact, the incorporation of traditional biocultural knowledge into normalised knowledge systems risks devaluing the very difference that is core to the long-term socio-ecological value of Indigenous ways of knowing, understanding, and utilising environmental information (Muller, 2012; Bardsley and Wiseman, 2012a). Explicit concerns were raised about the outcomes of monitoring activities, including who subsequently owns or makes use of the information.

It's also what you do with the information: that's a critical outcome. Why should communities go out and collect information and give it to you if you're not going to help them do anything with it? So there's got to be an outcome from the collection of the data. . . . I think you need a long term strategy of how you get community involved – the 'what's in it for me?' outcomes have got to be there. (Respondent 3, 21/3/2013)

The appropriate sharing of information appears in some cases to be actively prevented due to lack of trust between people, which ultimately inhibits learning and collaboration. Even the marker to a piece of information, such as a reference and abstract, may be unobtainable due to cultural sensitivities, let alone the actual traditional knowledge in any comprehensive form. Clearly such barriers need to be in place to protect Indigenous culture, but respondents fear breaching intellectual property rights by using traditional ecological knowledge in formal assessments of rangeland condition.

How we end up with consistent long term data management strategies is a critical issue. [We need strategies] that have got the right level of protections on it for people, so that communities know that if they want to put information in there, it's going to be there, it's not

going to go walking away, and that they've got the intellectual property for it. (Respondent 3, 21/3/2013)

Projects such as Ara Irititja, a digital archive for Anangu focussing on the preservation of cultural heritage, show that it is possible to navigate this complex field of intellectual and cultural property rights while providing an important service to both Anangu and non-Aboriginal researchers interested in Anangu history and culture (Ara Irititja, 2014).

As Anangu elders who have direct experience of walking, understanding, and living off the semi-arid rangelands age and pass away, much of the complex and detailed traditional ecological knowledge they hold is lost with them (Bardsley and Wiseman, 2012a; Ara Irititja, 2014). Besides the immediate challenge that represents to Indigenous communities and cultures, such knowledge represents some of the most important remaining fragments of traditional biocultural heritage in Australia. Some traditional knowledge about local environments that was created and built upon over innumerable generations of living off country is being recorded and kept in a manner that suits the needs of both Indigenous people and western science, yet much is lost to contemporary and future managers of country. Formal education systems could act to bridge the gap between intergenerational knowledge, but at the moment the integration of school education, formal NRM, and traditional land use activities is weak.

I would say our links into the school curriculum needs to be a little bit more formalised . . . at the moment it's more ad-hoc: we have someone going up, they give the school a call before they go up and say 'hey, we're doing this', the school says 'yep, that's good', and it's all good. But in terms of longer-term career paths, we need to get better at getting it locked into a curriculum so there's a long-term strategy in place . . . [at the moment] it doesn't necessarily provide long-term career paths or that base understanding of NRM as a job. (Respondent 5, 26/3/2013)

All of these challenges suggest that it is vital now to develop or expand appropriate, ethical approaches to engage Indigenous communities for more mutually beneficial outcomes.

The aim is to give communities the empowerment, the knowledge and the ability. That is very important, because at this stage it is the

communities who are most at threat. (Respondent 8, 24/4/2013)

Arguably, if Anangu are going to become equal partners in the monitoring and management of rangelands, the journeys of building knowledge through social learning (field trips, sharing of stories, talking) are as important as the destinations that store and transmit that knowledge in data and reports (Muller, 2012). This distinction has clear similarities with Berkes' (2009, 153) emphasis on traditional knowledge as a process to 'teach what to look for and how to look for what is important'.

Future opportunities for monitoring in the AW NRM region

In order to develop a clear direction for future monitoring programmes and address respondents' concerns about a lack of cohesion, it will be necessary to have a shared discussion about what monitoring is important to all stakeholders to ensure that all goals are reflected, especially local community interests and needs (Zander *et al.*, 2014). By talking with Anangu across the AW region, it could be possible to develop a shared set of traditional and contemporary indicators of healthy/unhealthy ecosystems for all monitoring programmes. Increased levels of trust between Indigenous and non-Indigenous knowledge holders and users might also evolve through such a process. The indicators could involve particular targeted ecosystems or species for which there is mutual concern, or broader signs of landscape, ecosystem, or community health (Green and Minchin, 2014). By choosing a diversity of systems to monitor through the application of different participatory methodologies, it would be possible to integrate community monitoring into a broader process of experimentation and learning to adapt to changing socio-ecological circumstances in the rangelands (Argent, 2009; Stafford-Smith *et al.*, 2009). In light of the review above, reorganising, revaluing, and expanding old activities or introducing new monitoring programmes that aim to value and make use of traditional knowledge for local community benefit might focus such choices (top left quadrant of Figure 2).

Another element which appears to be under-represented in the AW programmes is the use of scientific knowledge for local community benefit (bottom left quadrant of Figure 2). A monitoring programme which focuses on identifying and monitoring local community hazards (flooding,

fire risk, food insecurity) could overcome this gap. Finally, the quadrant of utilising traditional knowledge primarily for external interests (top right quadrant of Figure 2) appears at first glance to represent an undesirable situation, given that it could involve either an exploitation or devaluing of Anangu understandings of place in relation to scientific data collection and analysis. However, rather than being a one-way extractive encounter, such approaches can provide employment while re-emphasising local communities' traditional knowledge as it comes under significant risk from intergenerational loss, and supporting institutional learning about culturally relevant NRM and long-term trends in resource condition. Traditional ecological knowledge could provide an alternative baseline for rangeland condition, but it is not formally recorded or accessible by other interested researchers and/or managers. By prioritising Indigenous involvement, traditional socio-cultural baselines could be utilised during assessments of current resource condition (Harmsworth *et al.*, 2011; Parlee *et al.*, 2012). Much of that baseline may remain largely inaccessible to western science unless the Indigenous knowledge owners provide specific permission, but by valuing and incorporating local Indigenous knowledge a baseline drawn from deep knowledge of an ancient relationship with a place could compensate for the relatively limited scientific knowledge of the vast, remote region.

In recent research involving community workshops with the AW NRM Board with Indigenous communities at Yalata, Ernabella, Kenmore Park, and Kanpi-Nyapari, two important specific opportunities emerged – one spatial, the other temporal – for monitoring environmental change in the region (Wiseman and Bardsley, 2015). A spatial example of Indigenous community-based monitoring in the north of the AW NRM region could be the development of a managed bushfoods zone, where hunting is controlled and threatening processes such as invasive species (e.g. Buffel grass, camels) are managed. Such an area was identified by Ernabella community residents in workshops as being an important refuge area for valued bushfood species due to the denser tree cover (Figure 3). Concerns were also raised about hunting pressures leading to a decline in the availability of favoured game animals, particularly kangaroo. By monitoring and managing bushfood species within the zone, as well as recording hunting effort and yield, Anangu could better understand threats to

Ernabella Bushfood Zone

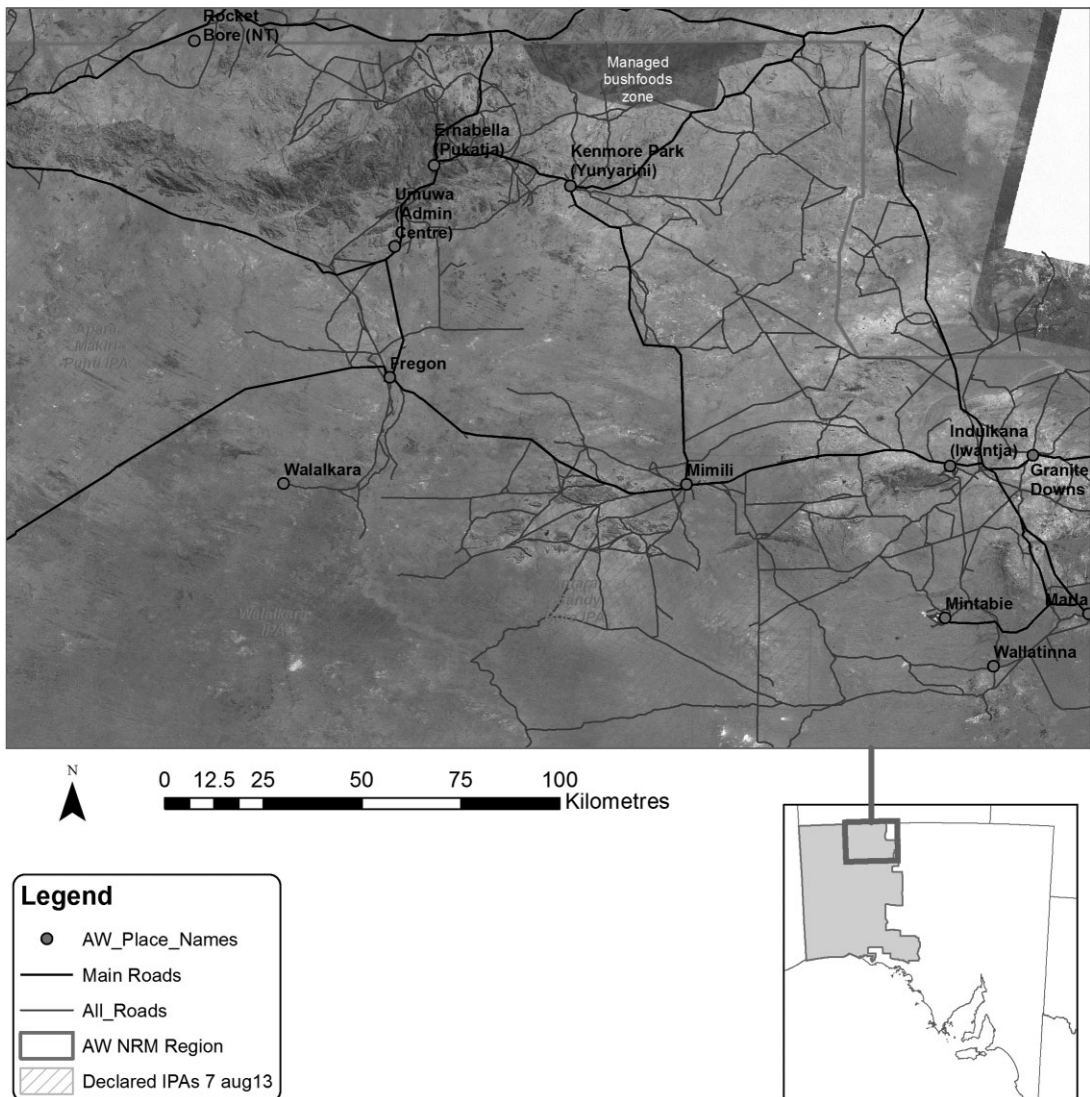


Figure 3 An example of a managed bushfood zone developed with the Ernabella community.

favoured species that would help to establish sustainable management programmes.

Much greater use could also be made of collating seasonal phenomena important to Anangu such as flowering, breeding, migrating, hunting, and harvesting times to act as temporal indicators of change (see Berkes *et al.*, 2007; Prober *et al.*, 2011; Parlee *et al.*, 2012). The focus of monitoring in the AW NRM region to date has been primarily on spatial phenomena (where things are located in space and in what densities), but an equal emphasis is needed on temporal phenom-

ena (what happens at certain times). One approach to achieving regular monitoring of systems could aim to integrate traditional knowledge of seasonal phenomena with scientific observation techniques (e.g. using Cybertracker), with Anangu paid to do regular monitoring of valued habitats or species.

Community-based monitoring of seasonal events could play an important role in observing gradual shifts in seasonal phenomena as a result of climate change, as well as providing a living record of phenomenological events and a

practical application of traditional ecological knowledge (see Figure 4). Seasonal calendars are important tools in Indigenous NRM as well as having potential for climate change adaptation (Prober *et al.*, 2011; Woodward *et al.*, 2012). These calendars could be used to record important locally observed phenomena for each cycle of the seasons (e.g. flowering times of plants, hibernation of animals, floods), and over the years, serve as a tool to analyse longer-term change and to facilitate intergenerational sharing of traditional knowledge.

Unless Indigenous community-based monitoring approaches are well designed and implemented over the long term, the risk remains that they will be ineffective for all stakeholders or perceived as tokenistic, and as a result, are unlikely to be integrated into broader environmental management activities or provide support for local livelihoods (Green *et al.*, 2012). Respondents recognised that the most successful monitoring occurred when Anangu were monitoring things they personally connected with, rather than for externally driven needs (see also Staddon *et al.*, 2014). For example, during and after field trips, much monitoring and consolidation of learning could occur simply by taking and organising photos and recording activities and observations in a manner that could be made available to communities and kept for future studies of an area or system (Tremblay *et al.*, 2008; Gearheard *et al.*, 2011). Coombes *et al.* (2014) similarly emphasises that Indigenous research would ideally be drawn from the goals of the communities themselves. In this case, tying monitoring to explicit, locally desired outputs such as hunting *kuka* (game), harvesting *mai* (wild/bush foods), or maintaining important cultural sites such as water holes (see Robinson *et al.*, 2005; Ens *et al.*, 2012a; 2012b) incentivises monitoring and ensures it passes the test of relevance to local communities. However, there is also increasing space for NRM to work with Indigenous communities in new ways to provide mutual benefits that would include paid employment for Anangu as monitors of rangeland conditions to develop new knowledge and management approaches.

Conclusion

If Australian academia and governance systems are to work with Indigenous society in the serious attempt to sustain the country's ancient biocultural heritage, that heritage needs to be further recognised, supported, and strengthened.

Indigenous community-based monitoring offers one way to achieve these goals, while at the same time improving learning about changes to country. Other countries have well-established, formal programmes to support NRM stakeholders, Indigenous community members, anthropologists, ecologists, and others to work together in processes of shared learning about environmental change. To achieve that goal in Australia, monitoring projects within remote Indigenous communities will need to extend beyond the relatively straightforward processes of interviewing stakeholders or running intermittent workshops or field trips to discuss local Indigenous perceptions of rangeland condition. Rather, community monitoring will need to become a regular and ongoing part of everyday activities, and the approaches should draw from the knowledge of, and lead to ongoing benefits for, all stakeholders. The knowledge generated from such projects can be effectively integrated into NRM policy and action, but it requires institutions to evolve the concept of environmental management to allow for unique cultural interpretations of place. AW NRM practitioners are recognising the need for community-based knowledge to be incorporated into planning and action, but without a broader national framework for Indigenous monitoring and comprehensive methodologies for engagement, approaches are limited in scope.

Given that Indigenous monitoring will remain a fluid and changing concept depending on the circumstances, no single definition emerges from the research to characterise the concept, but a strong argument emerges for greater inclusivity of Indigenous approaches, perceptions, interpretations, and actions to inform environmental monitoring. Rather, the themes that emerged from the interviews and workshops suggest that the variety of approaches would include efforts to: improve coordination between stakeholders; improve the ability to detect and respond to climatic trends; utilise Indigenous knowledge more effectively; and improve learning through better communication and sharing of findings. The use of the spectra of monitoring approaches within a formal regional monitoring strategy, with a particular emphasis on under-represented sectors, such as the use of traditional knowledge for local community benefit, would generate a range of complementary approaches to monitoring. Such a formal monitoring programme that recognises the value of biocultural knowledge to Australian environmental management also has

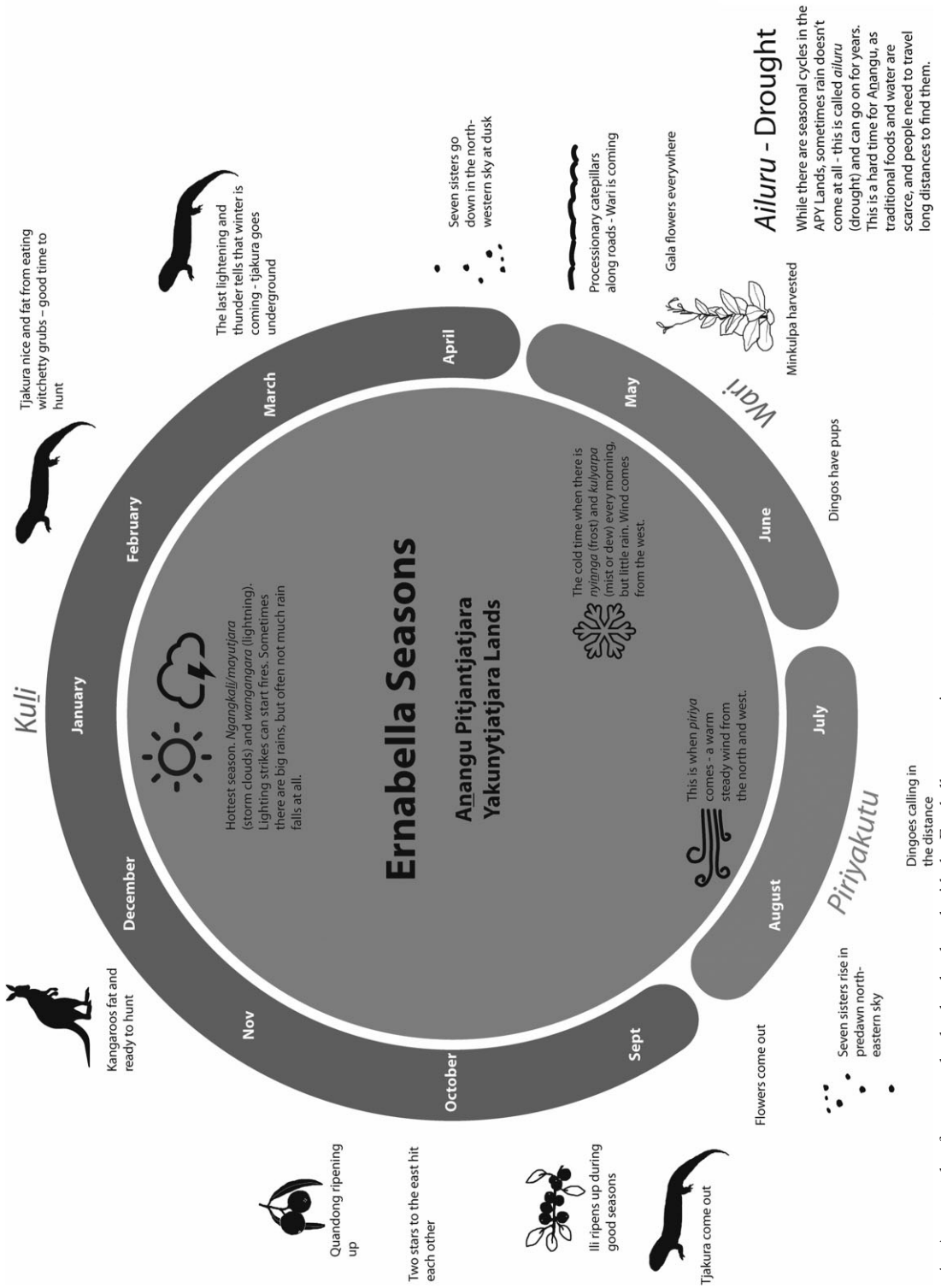


Figure 4 An example of a seasonal calendar developed with the Ernabella community.

the potential to direct financial benefits to remote Indigenous communities on a sustainable basis.

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REFERENCES

- Australian Bureau of Statistics (ABS), 2011: Census 2011. Retrieved: 8 January 2014 from <<http://www.abs.gov.au/websitedbs/censushome.nsf/home/data>>.
- Altman, J.C. and Kerins, S. (eds), 2012: *People on Country: Vital Landscapes, Indigenous Futures*. Federation Press, Sydney.
- Ara Irititja, 2014: Ara Irititja digital archive. Retrieved: 6 February 2014 from <<http://www.irititja.com/index.html>>.
- Argent, R.M., 2009: Components of adaptive management. In Allan, C. and Stankey, G.H. (eds) *Adaptive Environmental Management: A Practitioner's Guide*. Springer Science + Business Media B.V., Dordrecht and CSIRO Publishing, Collingwood, 11–32.
- Australian Government, 2014: Indigenous Protected Area webpage. Retrieved: 3 December 2014 from <<http://www.environment.gov.au/indigenous/ipa/index.html>>.
- AW NRM Board (Alinytjara Wilurara Natural Resources Management Board), 2011: *Alinytjara Wilurara Regional NRM Plan*. Government of South Australia, Adelaide.
- AW NRM Board (Alinytjara Wilurara Natural Resources Management Board), 2013: *Amendments to the Regional Natural Resources Management Plan of the Alinytjara Wilurara, Natural Resources Management Board*. Government of South Australia, Adelaide.
- AW NRM Board (Alinytjara Wilurara Natural Resources Management Board), 2014: Dreamweaver: rockhole maintenance. Retrieved: 30 November 2014 from <<http://www.naturalresources.sa.gov.au/alinytjara-wilurara/projects/dreamweaver-rockhole>>.
- Baland, J. and Platteau, J., 1996: *Halting Degradation of Natural Resources: Is there a Role for Rural Communities?* Food and Agriculture Organization of the United Nations, Rome.
- Bardsley, D.K., 2015: Navigating the roles of the social learning researcher: a critical analysis of a learning approach to guide climate change adaptation. *Australian Geographer* 46, 33–50.
- Bardsley, D.K. and Rogers, G.P., 2011: Prioritizing engagement for sustainable adaptation to climate change: an example from natural resource management in South Australia. *Society and Natural Resources* 24, 1–17.
- Bardsley, D.K., Weber, D., Robinson, G.M., Moskwa, E. and Bardsley, A.M., 2015: Wildfire risk, biodiversity and peri-urban planning in the Mt Lofty Ranges, South Australia. *Applied Geography* 63, 155–165.
- Bardsley, D.K. and Wiseman, N.D., 2012a: Climate change vulnerability and social development for remote Indigenous communities of South Australia. *Global Environmental Change* 22, 713–723.
- Bardsley, D.K. and Wiseman, N.D., 2012b: *It depends which way the wind blows: an integrated assessment of projected climate change impacts and adaptation options for the Alinytjara Wilurara Natural Resources Management region*. AW NRM Board/Government of SA, Government of Australia, Adelaide.
- Bastin, G. and the Australian Collaborative Rangelands Information System Management Committee (ACRIS-MC), 2008: *Rangelands 2008 – Taking the Pulse*. National Land & Water Resources Audit, Canberra.
- Berkes, F., 2012: *Sacred Ecology*, third edn. Routledge, New York.
- Berkes, F., 2009: Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand* 39, 151–156.
- Berkes, F., Berkes, M.K. and Fast, H., 2007: Collaborative integrated management in Canada's North: the role of local and traditional knowledge and community-based monitoring. *Coastal Management* 35, 143–162.
- Box, J.B., Duguid, A., Read, R.E., Kimber, R.G., Knapton, A., Davis, J. and Bowland, A.E., 2008: Central Australian waterbodies: the importance of permanence in a desert landscape. *Journal of Arid Environments* 72, 1395–1413.
- Burgess, C.P., Johnston, F.H., Bowman, D.M.J.S. and Whitehead, P.J., 2005: Healthy country: healthy people? Exploring the health benefits of Indigenous natural resource management. *Australian and New Zealand Journal of Public Health* 29, 117–122.
- Commonwealth of Australia, 2014a: Working on Country. Retrieved: 30 November 2014 from <<http://www.environment.gov.au/indigenous/workingoncountry/>>.
- Commonwealth of Australia, 2014b: *Carbon Farming Initiative Amendment Bill 2014*. Commonwealth of Australia, Canberra.
- Coombes, B., Johnson, J.T. and Howitt, R., 2014: Indigenous geographies III: methodological innovation and the unsettling of participatory research. *Progress in Human Geography* 38, 845–854.
- COAG (Council of Australian Governments), 2008: National Indigenous Reform Agreement (Closing the Gap). Retrieved: 30 November 2014 from <https://www.coag.gov.au/closing_the_gap_in_Indigenous_disadvantage>.
- CyberTacker, 2014: CyberTracker website. Retrieved: 15 November 2014 from <<http://www.cybertracker.org/>>.
- Danielsen, F., Burgess, N.D. and Balmford, A., 2005: Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 14, 2507–2542.
- Danielsen, F., Burgess, N.D., Balmford, A., Donald, P., Jones, J., Alviola, P., Balet, D., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjelds, J., Holt, S., Hubertz, H., Jensen, A., Jensen, P., Massao, J., Mendoza, M., Ngaga, Y., Poulsen, M., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jorgensen, E. and Yonten, D., 2009: Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* 23, 31–42.
- Danielsen, F., Pirhofer-Walz, K., Adrian, T.P., Kapijimpanga, D.R., Burgess, N.D., Jensen, P.M., Bonney, R., Funder, M., Landa, A., Levermann, N. and Madsen, J., 2014: Linking public participation in scientific research to the indicators and needs of international environmental agreements. *Conservation Letters* 7, 12–24.
- Davies, J., White, J., Wright, A., Maru, Y. and LaFlamme, M., 2008: Applying the sustainable livelihoods approach in Australian desert Aboriginal development. *The Rangeland Journal* 30, 55–65.

- Davies, J., Hill, R., Walsh, F.J., Sandford, M., Smyth, D. and Holmes, M.C., 2013: Innovation in management plans for community conserved areas: experiences from Australian Indigenous protected areas. *Ecology and Society* 18, 14.
- 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., Finlayson, M., Preuss, K., Jackson, S. and Holcombe, S., 2012a: Australian approaches for managing 'country' using Indigenous and non-Indigenous knowledge. *Ecological Management & Restoration* 13, 100–107.
- Ens, E.J., Towler, G.M., Daniels, C. and the Yugul Mangi Rangers and the Manwurrk Rangers, 2012b: Looking back to move forward: collaborative ecological monitoring in remote Arnhem Land. *Ecological Management & Restoration* 13, 26–35.
- EPA (Environmental Protection Authority), 2013: *State of the Environment South Australia 2013*. Government of South Australia, Adelaide.
- Eyre, T.J., Fisher, A., Hunt, L.P. and Kutt, A.S., 2011: Measure it to better manage it: a biodiversity monitoring framework for the Australian rangelands. *The Rangeland Journal* 33, 239–253.
- Gearheard, S., Aporta, C., Aipellee, G. and O'Keefe, K., 2011: The Igliniit project: inuit hunters document life on the trail to map and monitor arctic change. *The Canadian Geographer* 55, 42–55.
- Goddard, C., 2006: *Pitjatjantjara/Yakunytjatjara to English dictionary*. Institute for Aboriginal Development Press, Alice Springs, NT.
- Gómez-Baggethun, E., Corbera, E. and Reyes-García, V., 2013: Traditional ecological knowledge and global environmental change: research findings and policy implications. *Ecology and Society* 18, 72.
- Gorman, J. and Vemuri, S., 2012: Social implications of bridging the gap through 'caring for country' in remote Indigenous communities of the Northern Territory, Australia. *The Rangeland Journal* 34, 63–73.
- Gorman, J., Person, D. and Whitehead, P., 2008: Assisting Australian Indigenous resource management and sustainable utilization of species through the use of GIS and environmental modeling techniques. *Journal of Environmental Management* 86, 104–113.
- Graham, B., Ashworth, G.J. and Tunbridge, J.E., 2000: *A Geography of Heritage: Power, Culture and Economy*. Arnold, London.
- Green, D. and Minchin, L., 2014: Living on climate-changed country: indigenous health, well-being and climate change in remote Australian communities. *Ecohealth* Jan 2014.
- Green, D., Niall, S. and Morrison, J., 2012: Bridging the gap between theory and practice in climate change vulnerability assessments for remote Indigenous communities in northern Australia. *Local Environment* 17, 295–315.
- Harmsworth, G.R., Young, R.G., Walker, D., Clapcott, J.E. and James, T., 2011: Linkages between cultural and scientific indicators of river and stream health. *New Zealand Journal of Marine and Freshwater Research* 45, 423–436.
- HORSCATSA (House of Representatives Standing Committee on Aboriginal and Torres Strait Islander Affairs), 2004: *Many Ways Forward: Report of the Inquiry into Capacity Building and Service Delivery in Indigenous Communities*. Parliament of the Commonwealth of Australia, Canberra.
- Hughey, K.F.D. and Booth, K.L., 2012: Monitoring the state of New Zealand rivers: how the River Values Assessment System can help. *New Zealand Journal of Marine and Freshwater Research* 46, 545–556.
- Jollands, N. and Harmsworth, G., 2007: Participation of Indigenous groups in sustainable development monitoring: rationale and examples from New Zealand. *Ecological Economics* 62, 716–726.
- Lawley, E.F., Lewis, M.M. and Ostendorf, B., 2014: Evaluating MODIS soil fractional cover for arid regions, using albedo from high-spatial resolution satellite imagery. *International Journal of Remote Sensing* 35, 2028–2046.
- Leonard, S., Parsons, M., Olawsky, K. and Kofod, F., 2013: The role of culture and traditional knowledge in climate change adaptation: insights from East Kimberley, Australia. *Global Environmental Change* 23, 623–632.
- Ludwig, J.A. and Tongway, D.J., 1996: Rehabilitation of Semi-arid Landscapes in Australia. II. Restoring vegetation patches. *Restoration Ecology* 4, 398–406.
- Ludwig, J.A. and Tongway, D.J., 1997: A landscape approach to rangeland ecology. Chapter 1. In Ludwig, J., Tongway, D., Freudenberger, D., Noble, J. and Hodgkinson, K. (eds) *Landscape Ecology, Function and Management: Principles from Australia's Rangelands*. CSIRO Publishing, Melbourne, 1–12.
- Lynam, T.J.P. and Stafford Smith, M., 2004: Monitoring in a complex world – seeking slow variables, a scaled focus, and speedier learning. *African Journal of Range & Forage Science* 21, 69–78.
- Maffi, L. and Woodley, E., 2012: *Biocultural Diversity Conservation: A Global Sourcebook*. Routledge, London.
- Maru, Y.T., Chewings, V. and Sparrow, A., 2012: Climate change adaptation, energy futures and carbon economies in remote Australia: a review of the current literature, research and policy. CRC-REP Working Paper CW005. Ninti One Limited, Alice Springs.
- Masters, P., Dickman, C.R. and Crowther, M., 2003: Effects of cover reduction on mulgara *Dasyurus cristicauda* (Marsupialia: Dasyuridae), rodent and invertebrate populations in central Australia: implications for land management. *Austral Ecology* 28, 658–665.
- Moorcroft, H. and Adams, M., 2014: Emerging geographies of conservation and indigenous Land in Australia. *Australian Geographer* 45, 485–504.
- Morton, S.R., Stafford Smith, D.M., Dickman, C.R., Dunkerley, D.L., Friedel, M.H., McAllister, R.R.J., Reid, J.R.W., Roshier, D.A., Smith, M.A., Walsh, F.J., Wardle, G.M., Watson, I.W. and Westoby, M., 2011: A fresh framework for the ecology of arid Australia. *Journal of Arid Environments* 75, 313–329.
- Muller, S., 2012: 'Two ways': bringing indigenous and non-indigenous knowledges together. In Weir, J. (ed.) *Country, Native Title and Ecology*. ANU ePress, Canberra, 59–79.
- Muller, S., 2014: Co-motion: making space to care for country. *Geoforum; Journal of Physical, Human, and Regional Geosciences* 54, 132–141.
- Olsson, P., Folke, C. and Berkes, F., 2004: Adaptive comanagement for building resilience in socio-ecological systems. *Environmental Management* 34, 75–90.
- Parlee, B.L., Geertsema, K. and Willier, A., 2012: Social-ecological thresholds in a changing boreal landscape: insights from Cree knowledge of the Lesser Slave Lake Region of Alberta, Canada. *Ecology and Society* 17, 20.
- Pelling, M. and High, C., 2005: Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Global Environmental Change* 15, 308–319.
- Pert, P.L., Hill, R., Maclean, K., Dale, A., Rist, P., Schmider, J., Talbot, L. and Tawake, L., 2015: Mapping cultural ecosystem services with Rainforest Aboriginal peoples:

- integrating biocultural diversity, governance and social variation. *Ecosystem Services* 13, 41–56.
- Petheram, L., Zander, K.K., Campbell, B.M., High, C. and Stacey, N., 2010: Strange changes': indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia). *Global Environmental Change* 20, 681–692.
- Pretty, J. and Ward, H., 2001: Social capital and the environment. *World Development* 29, 209–227.
- Pringle, H., Watson, I. and Tinley, K., 2006: Landscape improvement, or ongoing degradation – reconciling apparent contradictions from the arid rangelands of Western Australia. *Landscape Ecology* 21, 1267–1279.
- Prober, S.M., O'Connor, M.H. and Walsh, F.J., 2011: Australian Aboriginal peoples' seasonal knowledge: a potential basis for shared understanding in environmental management. *Ecology and Society* 16, 12.
- Reynolds, J.F., Smith, D.M.S., Lambin, E.F., Turner, B.L., Mortimore, M., Batterbury, S.P.J., Downing, T.E., Dowlatabadi, H., Fernández, R.J., Herrick, J.E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M. and Walker, B., 2007: Global desertification: building a science for dryland development. *Science* 316, 847–851.
- Robbins, J., 2010: A nation within? Indigenous peoples, representation and sovereignty in Australia. *Ethnicities* 10, 257–274.
- Robins, L. and Dovers, S., 2007: NRM Regions in Australia: the 'Haves' and the 'Have Nots'. *Geographical Research* 45, 273–290.
- Robinson, A.C., Copley, P.B., Canty, P.D., Baker, L.M. and Nesbitt, B.J., 2003: *A Biological Survey of the Anangu Pitjantjatjara Lands, South Australia, 1991–2001*. Department for Environment and Heritage, South Australia.
- Robinson, C.J. and Wallington, T.J., 2012: Boundary work: engaging knowledge systems in co-management of feral animals on Indigenous lands. *Ecology and Society* 17, 16.
- Robinson, C.J., Smyth, D. and Whitehead, P.J., 2005: Bush tucker, bush pets, and bush threats: cooperative management of feral animals in Australia's Kakadu National Park. *Conservation Biology* 19, 1385–1391.
- Sallenave, J., 1994: Giving traditional ecological knowledge its rightful place in environmental impact assessment. *Northern Perspectives* 22, 16–19.
- Scheffer, M., 2009: *Critical Transitions in Nature and Society*. Princeton University Press, Princeton.
- SCRGSP (Steering Committee for the Review of Government Service Provision), 2014: *Overcoming Indigenous Disadvantage: Key Indicators 2014*. Commonwealth of Australia, Canberra.
- Staddon, S.C., Nightingale, A. and Shrestha, S.K., 2014: The social nature of participatory ecological monitoring. *Society and Natural Resources* 27, 899–914.
- Stafford-Smith, D.M., 2008: The 'desert syndrome' – causally-linked factors that characterise outback Australia. *The Rangeland Journal* 30, 3–14.
- Stafford-Smith, D.M., Abel, N., Walker, B. and Chapin, F.S., 2009: Drylands: coping with uncertainty, thresholds, and changes in state. In Folke, C., Kofinas, G.P. and Chapin, F.S. (eds) *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York, 171–195.
- Sutton, P., 2001: The politics of suffering: indigenous policy in Australia since the 1970s. *Anthropological Forum* 11, 125–173.
- Svenning, J. and Sandel, B., 2013: Disequilibrium vegetation dynamics under future climate change. *American Journal of Botany* 100, 1266–1286.
- Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P. and Spierenburg, M., 2014: Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. *Ambio* 43, 579–591.
- Tremblay, M., Furgal, C., Larrivee, C., Annanack, T., Tookalook, P., Qiisik, M., Angiyou, E., Swappie, N., Savard, J. and Barrett, M., 2008: Climate change in northern Quebec: adaptation strategies from community-based research. *Arctic* 61, 27–34.
- URBIS, 2012: Assessment of the social outcomes of the working on country program: report 2012. Retrieved: 30 November 2014 from <<https://www.environment.gov.au/indigenous/workingoncountry/publications/woc-social.html>>.
- Veland, S., Howitt, R., Dominey-Howes, D., Thomalla, F. and Houston, D., 2013: Procedural vulnerability: understanding environmental change in a remote Indigenous community. *Global Environmental Change* 23, 314–326.
- Walker, B. and Abel, N., 2002: Resilient rangelands: adaptation in complex systems. In Gunderson, L.H. and Holling, C.S. (eds) *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington., 293–314.
- Waudby, H.P., Petit, S. and Robinson, G., 2013: Pastoralists' knowledge of plant palatability and grazing indicators in an arid region of South Australia. *The Rangeland Journal* 35, 445–454.
- White, A., Foulkes, J.N., Sparrow, B.D. and Lowe, A.J., 2012: Biodiversity monitoring in the rangelands. In Lindemayer, D. and Gibbons, P. (eds) *Biodiversity Monitoring in Australia*. CSIRO publishing, Canberra, 179–190.
- Wiseman, N.D. and Bardsley, D.K., 2013: Climate change and indigenous natural resource management: a review of socio-ecological interactions in the Alinytjara Wilurara NRM region. *Local Environment* 18, 1024–1045.
- Wiseman, N.D. and Bardsley, D.K., 2015: *Adapting to Climate Change on Country. Climate Change Addendum – Technical Report for the Alinytjara Wilurara Regional Management Plan*. Government of South Australia/Australian Government, Adelaide.
- Woodward, E.L., Jackson, S., Finn, M. and Marrfurra McTaggart, P., 2012: Utilising Indigenous seasonal knowledge to understand aquatic resource use and inform water resource management in northern Australia. *Ecological Management & Restoration* 13, 58–64.
- Zander, K.K., Austin, B.J. and Garnett, S.T., 2014: Indigenous peoples' interest in wildlife-based enterprises in the Northern Territory, Australia. *Human Ecology* 42, 115–126.