Mitig Adapt Strateg Glob Change
DOI 10.1007/s11027-016-9734-8

ORIGINAL ARTICLE

Local and Indigenous management of climate change risks to archaeological sites

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Received: 15 September 2016 / Accepted: 12 December 2016

Abstract Hundreds of thousands of significant archaeological and cultural heritage sites (cultural sites) along the coasts of every continent are threatened by sea level rise, and many will be destroyed. This wealth of artefacts and monuments testifies to human history, cosmology and identity. While cultural sites are especially important to local and Indigenous communities, a stall in coordinated global action means adaptation at a local scale is often unsupported. In response, this paper produces a practical climate change risk analysis methodology designed for independent, community-scale management of cultural sites. It builds on existing methods that prioritise sites most at risk from climate impacts, proposing a field survey that integrates an assessment of the relative cultural value of sites with assessment of exposure and sensitivity to climate impacts. The field survey also stands as a monitoring program and complements an assessment of organisational adaptive capacity. The preliminary field survey was tested by Indigenous land managers in remote northern Australia at midden and rock art sites threatened by sea level rise, extreme flood events and a range of non-climactic hazards. A participatory action research methodology—incorporating planning workshops, semi-structured interviews and participant observations—gave rise to significant modifications to the preliminary field survey as well as management prioritisation of 120 sites. The field survey is anticipated to have global application, particularly among marginalised and remote Indigenous communities. Well-planned and informed participation, with community control, monitoring and well-informed actions, will contribute significantly to coordinated global and regional adaptation strategies.

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Published online: 01 February 2017

Keywords Archaeology · Climate change · Adaptation · Community planning · Cultural heritage · Indigenous · Local planning · Risk assessment · Site prioritisation · Vulnerability assessment

1 Introduction

Since the early 1990s, archaeologists and cultural heritage managers have been expressing grave concern about the potential for climate change and sea level rise to impact the great many significant archaeological and cultural heritage sites (cultural sites) around the world (Rowland 1992). The conservation of those that can be saved or otherwise digitally documented should be a major topic in international adaptation planning and advanced as a major incentive to mitigate emissions.

Cultural sites hold a central position in the narratives and collective memories of societies and play a significant role in cultural identity, community cohesion and sense of place. Adger et al. (2013) argue that adaptation and mitigation responses will fail if they do not connect with the cultural values, including material values, of individuals and communities.

Cultural sites are especially important to Indigenous peoples (McIntyre-Tamwoy and Buhrich 2012). While this is particularly the case for colonised Indigenous communities in North America, Australia and New Zealand (Murray 2011), it is also the case for ethnic minorities in Asia (Xu 2007) and Africa (ICCROM 2008).

While a wide range of possible climate impacts and cultural resource vulnerabilities have been identified (Cassar and Pender 2005; Sabbioni et al. 2006; UNESCO 2006), increased coastal erosion remains the impact of greatest concern. In itself, coastal erosion is a major threat to cultural sites (Jones et al. 2008; Rick and Fitzpatrick 2012; Rowland and Ulm 2012). Because the sea has provided resources and a means of transport for millennia, a high proportion of significant cultural sites, perhaps numbering millions, are located near coastlines (Erlandson 2012). Rising sea levels will, however, extend the reach of storm surge (IPCC 2013), resulting in greater beach, cliff and sand barrier retreat and salt water inundation of floodplains, which in turn will increase rates of destruction of archaeological sites (FitzGerald et al. 2008; Murphy et al. 2009).

Internationally, archaeologists have begun developing methods to assess climate change risk to individual cultural sites. The general strategy has been to dedicate limited conservation resources to those determined to be most at risk of loss or damage. Approaches have been independently developed in England (English Heritage 2007), mainland and island states of the USA (Westley et al. 2011; Johnson et al. 2015; Reeder-Myers 2015), Scotland (Dawson 2015), France (Daire et al. 2012), Belgium (Dupont and Van Eetvelde 2013), Ireland (Daly 2014) and New Zealand (Bickler et al. 2013). The various approaches tend to be top-down, that is, designed primarily for implementation by government heritage managers and academic researchers. However, in some cases, citizen scientists from local communities have been invited to review prioritisation and contribute to monitoring and conservation plan implementation (e.g. ALeRT 2016; CITiZAN 2016; Shorewatch 2016) or to record threats to neglected sites on private property (Mazel et al. 2014).

UNESCO (2006) argued that involving local communities in the investigation of climate impacts on cultural sites and in developing adaptation strategies is fundamental if action is to be successful. Heritage resources are scarce, and when there is a lack of down-scaled climate projections, community experiences of extreme weather impacts become important sources of information (IPCC 2014). In an Indigenous context, cultural site custodians tend to have a greater exposure to the natural environment and are able to share vital traditional knowledge (IPCC 2014). Indigenous custodians in Australia, for example, are particularly concerned about the consequences of climate change for their cultural sites and regard managing impacts as an unfulfilled, priority need (Carmichael 2015).

Many communities, however, are not given the opportunity to participate in a cultural site adaptation program. Not because consultation is off the agenda, but simply because no program exists (Cassar et al. 2006). This is particularly the case for Indigenous communities. Socio-economic disadvantage, remoteness and political marginalisation increase vulnerability to climate change (Ford et al. 2006; Altman and Jordan 2008; Green et al. 2009). A lack of archaeological management resources and cross-scale heritage conservation support contribute to cultural vulnerability (Tacon and Marshall 2015).

In the continued absence of outside support, local and Indigenous land managers stand to benefit from planning tools or decision-support products aimed at guiding local management of climate impacts on cultural sites (Carmichael 2015; Carmichael et al. 2017).

In light of the above, the objective of this study is to develop a standard climate change risk-assessment methodology for cultural sites, suitable for practical use within adaptation planning processes controlled by local and Indigenous communities. It does so by reviewing the diversity of existing approaches in terms of suitability to a bottom-up planning process and synthesising a method likely suitable for independent community application. The synthesised method, an in situ field survey approach, was subsequently tested in two case study locations by Australian Indigenous natural resource managers and custodians of rock art and midden sites. These custodians' findings led to revised iterations of the tool, producing a final version significantly different to the progenitor. This paper reports on the modifications, as well as the prioritisation results it generated. It concludes with a discussion about the vital role of community managed adaptive measures within a global strategy for cultural sites, viewed through the lenses of Indigenous land management, cultural heritage and good climate adaptation practices.

2 Conceptual and methodological frameworks

2.1 Planning tools

Community stakeholder involvement is critical to successful adaptation (Jones and Preston 2011; Raiser 2014). Limited studies of Indigenous community adaptation make the same point (Bird et al. 2013; Leonard et al. 2013 Nursey-Bray et al. 2013).

There can, however, be a disjunct between adaptation planning and adaptation theory (Preston et al. 2011). Many planning tools, including procedural frameworks or decision-support products, have therefore been developed to assist local communities plan (e.g. Dazé et al. 2009; UKCIP 2013; Hinkel et al. 2013). Where planning faces unique challenges, it is useful to produce tools focused on those demands (Preston and Stafford-Smith 2009).

The risk tool developed by this paper is conceived of as one component in a larger, five-step planning guide (Cultural Site Adaptation Guide) set out by Carmichael (2015). The five steps of the Cultural Site Adaptation Guide are as follows: (1) scoping, (2) risk analysis, (3) option analysis, (4) planning and implementation and (5) review. This paper focuses on the second step, risk analysis, while Carmichael et al. (2017) focuses on the scoping step.

2.2 Risk analysis and climate change

Traditional approaches to climate risk analysis combine measures of (a) the *likelihood* of a consequence with (b) the *magnitude* of the consequence (Willows and Connell 2003). An overemphasis on biophysical or hazard approaches has been criticised for failing to consider the system's social context and therefore its capacity to adapt (Smit and Pilifosova 2003). In response, a vulnerability approach to risk assessment conceptualises vulnerability in terms of degrees of *exposure* and *sensitivity* to climate hazards and, additionally, upon the system's *adaptive capacity* over time (IPCC 2001, 2014). A vulnerability approach has been used in assessing climate change impacts among Indigenous communities in the Canadian Arctic (Ford and Smit 2003), the Peruvian Amazon (Hofmeijer et al. 2013) and northern Australia (Bird et al. 2013).

2.3 Risk analysis, climate change and cultural sites

A limited number of archaeological studies have explored systematic climate change risk analysis for cultural sites. The most common approach prioritises sites on the basis of likelihood of impact alone (Table 1), in regard either to the site's proximity to the coast (Reeder-Myers 2015) or to hazard zones mapped on the basis of a climate change projection model (Westley et al. 2011; Dupont and Van Eetvelde 2013). These approaches are particularly useful for broad regional scale landscape assessment but can equally be performed at a local scale (Johnson et al. 2015).

Other studies have taken a traditional hazard or biophysical risk approach, considering the *likelihood* of damage or loss of sites, *sensitivity* to *exposure* and/or the *magnitude of the consequence*. Bickler et al. (2013), for example, used a remote geographic information system (GIS)-based analysis of likelihood of impact complemented by a standardised formula for the consequence of impact for particular site types. Daire et al. (2012) used a field survey to collect data in situ measuring a site's exposure and sensitivity to exposure. Dawson (2015) and English Heritage (2007) used remote GIS analysis and data collected in situ to assess likelihood of damage, combining results with an assessment of the relative archaeological significance of a site.

A third stream, represented by a single study (Daly 2014), engages with vulnerability literature, proposing a framework for an in situ, qualitative vulnerability approach based on *exposure*, *sensitivity* and *adaptive capacity.* An expert assessor interviews managers and local stakeholders to produce a qualitative vulnerability assessment based on stakeholder reactions to climate projections for the site's location.

2.3.1 Amenity to bottom-up planning

Models partly or entirely using remote mapping techniques and computer applications such as ArcGIS (e.g. English Heritage 2007; Westley et al. 2011; Bickler et al. 2013; Dupont and Van Eetvelde 2013; Dawson 2015; Johnson et al. 2015; Reeder-Myers 2015) do not readily avail themselves to independent use by non-professionals. A standardised field survey approach is, however, amenable to non-professional use (Daire et al. 2012; Mazel et al. 2014). Daire et al.'s approach (2012) requires surveyors in situ to choose from a range of given options corresponding to a set of fixed variables in order to generate a standardised score for each site.

Table 1 Review of methodologies for climate change risk assessment of cultural sites

	Reeder-Myers et al. (2015), Johnson et al. (2015), and Westley et al. (2011) *USA* Dupont et al. (2013) *Belgium*	Bickler et al. (2013) *New Zealand*	Daly (2014) *Ireland*	Dawson (2015) *Scotland* English Heritage (2007) *England*	Mazel et al. (2014) *England*	Daire et al. (2012) *France*	KNP-Djelk rangers (2017) *Australia*
Amenity to non-professional use					✓	✓	✓
Risk based on consequence of impact		✓					✓
Risk based on likelihood of impact	✓	✓		✓	✓		✓
Risk based on significance				✓			✓
Risk based on exposure and sensitivity			✓			✓	✓
Considers adaptive capacity			✓				✓
Includes non-climate impacts					✓	✓	✓

2.3.2 Mainstreaming

Mainstreaming climate change risk analysis into broader risk analysis makes practical action significantly more likely (Huq and Reid 2004; Smit and Wandel 2006). The field survey approach (Daire et al. 2012; Mazel et al. 2014) is unique in that it includes exposure and sensitivity to additional non-climate threats, avoiding a scenario in which a site rated as a low climate change priority is lost to another threat not considered.

2.3.3 Uncertainty and adaptation to current extremes

Approaches partly or wholly reliant on climate change projections (Westley et al. 2011; Dupont and Van Eetvelde 2013; Daly 2014; Johnson et al. 2015) are not ideal for local-level adaptation planning. At a local scale, detailed climate trend data and high-confidence, downscaled climate change projections are rarely available and, if so, entail a substantial degree of uncertainty. Local stakeholders, however, are likely knowledgeable as to the extent and impacts of past and recent extreme weather events (Reid et al. 2009). Given future climate change will see an increase in the frequency of extremes, practical expediency may necessitate reducing exposure and sensitivity to *present extremes* as a first step towards adaptation to future climate change (Smit and Pilifosova 2003; Hofmeijer et al. 2013; IPCC 2014).

2.3.4 Monitoring

Where data is scarce, one of the first options in managing climate change is developing appropriate monitoring systems (Rowland et al. 2014). While all the assessment systems not based on climate change projections avail themselves to a monitoring function, a field survey's in situ gathering of a fixed range of data and consideration of non-climate as well as climate exposure (Daire et al. 2012) recommends itself in this capacity also.

2.3.5 Significance

The importance of integrating an assessment of a site's archaeological significance with an assessment of the risk of damage or loss is acknowledged by four studies (English Heritage 2007; Bickler et al. 2013; Daly 2014; Dawson 2015). When immovable sites confront an impact such as sea-level rise, their loss may be inevitable (Cassar et al. 2006). The loss is likely to take place over a very short time period rather than by a slow degradation over an extended time (Bickler et al. 2013) or in a non-linear step process in response to discreet episodes of extreme conditions or changes (Giesen et al. 2013). The loss of one cultural site may be of far greater consequence than that of another. Only Dawson (2013) and English Heritage (2007) incorporate significance assessment into risk assessment. Dawson assesses each site in terms of 'rarity', 'period', 'condition', 'group value' and 'potential' (Dawson 2013; p. 80).

2.3.6 Adaptive capacity

Only Daly (2014) outlines a framework for cultural site climate change risk assessment that includes assessment of adaptive capacity. This vulnerability approach aims to address organisational barriers to adaptation and build resilience.

2.4 The preliminary model: a field survey incorporating cultural consequence

We propose that a field survey based on Daire et al.'s (2012) numerical ranking system incorporate significance assessment in light of Dawson's (2013) and English Heritage's (2007) approach and adaptive capacity in light of Daly's model (2014). The challenge is how to integrate all three approaches.

We find it expedient to assess the adaptive capacity of stakeholders separately from assessment of risks to sites. In a context where sites are being prioritised for management purposes, there is a danger that assessment of the adaptive capacity of stakeholders be confused with the adaptive capacity of sites, which in themselves have no adaptive capacity. Prioritised sites, in many instances, will need to be recorded before their demise. We propose that adaptive capacity assessment focus on workshops discussing stakeholder adaptive capacity, held during the first step, the scoping phase, in the Cultural Site Adaptation Guide. During the third step, the option analysis phase, participants can more clearly focus on ways to increase stakeholder adaptive capacity and thus their overall level of resilience. Hence, assessment of adaptive capacity is not part of the risk analysis phase of the Cultural Site Adaptation Guide presented in this paper.

2.4.1 Indigenous rangers assessing significance

Assessing significance is not without its own challenges. A field survey for non-professional application, for example, would have difficulties in replicating Dawson's (2013; p. 80) assessment of rarity, period, condition, group value and potential.

Absolute notions of scientific significance were abandoned in the post war period in favour of determining which sites best represent a range of archaeological variation (Briuer and Mathers 1996). Assessing the significance of Australian Indigenous sites, Bowdler considered a site's 'representativeness' and ability to 'answer timely and specific research questions' (Bowdler 1981; p. 1). In one of our case studies (see below), research has been prolific, but in the other, no comprehensive survey for each site type has been undertaken to date. This is likely to be the case in many Indigenous contexts internationally.

Although the relativistic approach acknowledges that significance is mutable and dynamic, it still sees significance residing in the physical fabric of the place, rather than something given to a place by those who value it (Little et al. 2005). However, as Sutton et al. (2013; p. 3) eloquently state:

> Values cannot be objectively identified within places, landscapes or objects; they originate and dwell within the hearts and minds of people.

A solution is to determine significance according to cultural values rather than scientific ones and then, where possible, invite archaeologists to review the results. This approach has merit in contemporary thinking on archaeological significance, which questions privileging archaeological significance over Indigenous values (Byrne et al. 2003; Little et al. 2005; Owen and Veale 2015).

Unfortunately, there is currently no rigorous methodology for assessing the cultural value of Australian Indigenous cultural sites (Brown 2008). The simplest solution, therefore, seemed to be for Indigenous land managers to ask Traditional Owners[1] or traditional custodians to rate relative cultural value during the field survey. The preliminary risk tool proposed asking

[1] The Aboriginal Land Rights Act (1976) describes 'traditional aboriginal owners' as local descent groups with primary spiritual responsibility for sites and land.

custodians if cultural sites were (a) very important, (b) quite important, (c) important, (d) a little important or (e) not important.

3 Case studies

Australian Indigenous rangers manage an Indigenous-owned and controlled estate that constitutes almost 20% of the Australian continent (Altman and Jordan 2008). Indigenous rangers undertake natural and cultural resource management including fire, feral animal and weed management. Two ranger groups took part in the project: Indigenous rangers from Kakadu National Park and rangers from the Djelk Indigenous Protected Area, both in far north Australia.

3.1 Kakadu National Park rangers (Fig. 1)

Kakadu National Park covers 19,804 km^2 (the approximate size of Wales, UK) within the Alligator Rivers region in the Northern Territory. Declared in 1979, the Park is inscribed on the UNESCO World Heritage List for both its exceptional natural and cultural values. While around 5000 rock art sites have been recorded, it is likely 10,000 to 20,000 remain unrecorded (Agnew et al. 2015). Occupation has been dated from at least 50,000 years (Clarkson et al. 2015; Roberts et al. 1990), and rock art reveals insights into Indigenous hunting, gathering, societal structure and rituals from 28,000 years until the present (David et al. 2013). The Park

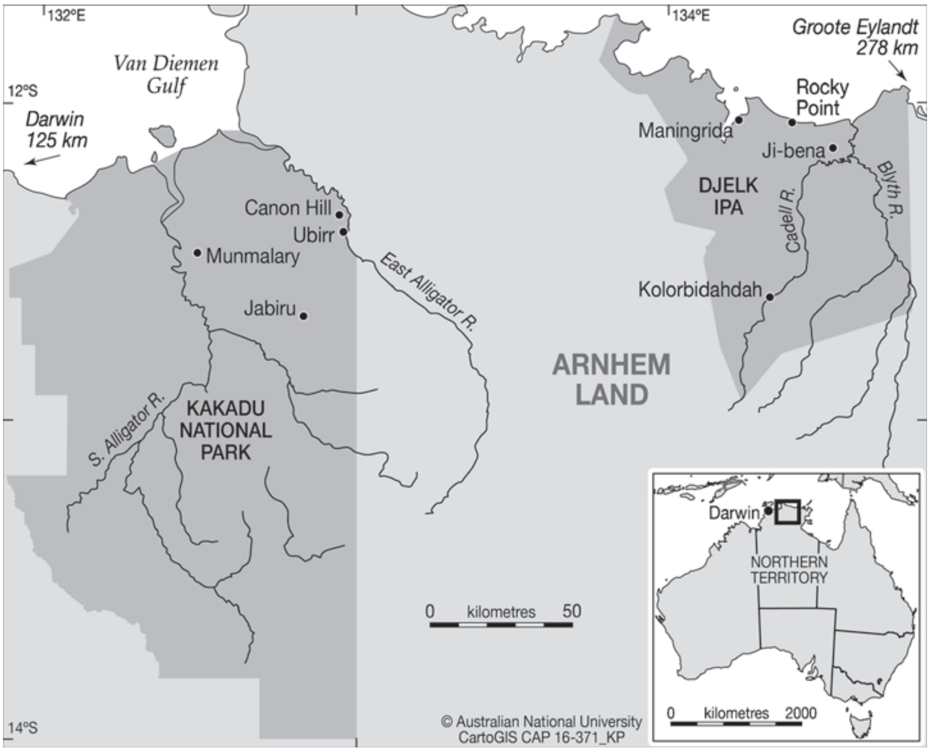

Fig. 1 The locations of the two case studies in the Northern Territory, Australia

database is extensive, reflecting intense survey over the years (e.g. Kamminga and Allen 1973; Jones 1985; Hiscock et al. 1992; Chaloupka 1993; Tacon and Brockwell 1995). Around a third of Kakadu's rangers are Indigenous men and women (Kakadu Board 2014). The Park has been administered jointly by the Australian Government and Traditional Owners since its inception, though all decisions must be ratified by the former.

3.2 Djelk rangers (Fig. 1)

The Djelk Indigenous Protected Area[2] (Djelk IPA) covers over 14,000 km^2 of land and sea country. It too contains exceptional natural and cultural values, including 12 separate language groups. Remoteness and a lack of formal scientific exploration have meant that site documentation has been limited (Brandl 1988; Meehan 1982; Brockwell et al. 2005). The Djelk rangers began operating in 1991 with the IPA being declared in 2009. Djelk employs over 30 men and women full time, almost all of whom are Traditional Owners. As a subsidiary of Bawinanga Aboriginal Corporation (BAC), Djelk is directed by an Indigenous executive committee. Djelk receives funding under the Australian Government's 'Caring for our Country' initiative (Kerins 2012, Australian Government 2013), as well as through sales of carbon credits from broadscale fire management.

3.3 Climate change projections for the case studies

Ranger perceptions of climate related impacts are consistent with climate change projections for Australia's monsoonal north (Carmichael 2015). These projections (Moise et al. 2015) are as follows:

- Mean sea level will continue to rise (*very high confidence*).
- Height of extreme sea-level events (storm surge) will increase (*very high confidence*).
- Intensity of extreme rainfall events will increase (*high confidence*).
- Tropical cyclones will be fewer but more intense (*medium confidence*).
- Total rainfall changes are possible but unclear.
- Average temperatures will continue to increase (*very high confidence*).
- Numbers of hot days and warm spells will increase (*very high confidence)*.

In 2011, sea-level rise off the northern Australian coast was averaging 8.6 mm per year at Darwin and 9.0 mm per year at Groote Eylandt (National Tidal Centre 2011), with rates significantly above global averages.

4 Methods

4.1 Participatory action research

This study used a participatory action research (PAR) methodology. PAR is initiated by a group, organisation or community to solve an immediate problem that members themselves experience.

[2] Indigenous land owners nominate their estates as IPAs, which are subsequently recognised as part of the National Reserve System and attract government resourcing.

Members of an organisation use an iterative cycle of investigation that aims to develop better work practises, often developing best-practice guidelines (Lewin 1946; Stringer 2014).

Preliminary trips were made to three potential case study areas. Semi-structured interviews were conducted with community leaders, rangers, Traditional Owners and organisational support staff to determine if climate change impacts on cultural sites had been perceived, and if so, whether addressing them was a priority need. Respondents in the current two case studies were keen to address their strong perceptions of rapid sea-level rise and increased inland flooding impacting cultural sites (Carmichael 2015). Respondents in a third case study perceived climate changes, but no resulting impacts on cultural sites.

The main body of fieldwork began with the testing of the scoping phase of the Cultural Site Adaptation Guide. Participants were either self-selected or selected by the ranger groups. The scoping workshops included discussion of several methodological options. Site-based risk analysis was selected by participants in both case studies as the primary mode of investigation, with organisational adaptive capacity an additional priority. As one ranger put it:

> That's the good one: risk analysis … for future generations; so [X, a Traditional Owner] can pass that information [i.e. sites assessed as most at risk] on to his kids.

Further workshops were conducted during development of the risk analysis tool and during analysis of adaptation options. Seven workshop and result-reporting meetings took place with Djelk rangers. These involved 35 participants, of which four were female. Five focus group and result-reporting meetings took place with Kakadu National Park (KNP) Indigenous rangers. These involved ten participants, one of whom was female. The workshops lasted between 1.5 and 2.5 h.

Semi-structured and informal interviews took place throughout all phases of the research. Multiple interviews with Djelk rangers, support staff and Traditional Owners involved 12 participants, of whom three were female. Interviews with KNP Indigenous rangers, support staff and Traditional Owners involved 16 participants, of whom 11 were female.

Identification of site types perceived as in danger, their general locations and the nature of the climate change threats impacting them, took place in the workshops cited above. These perceptions were then investigated in the field. Site types in locations of concern were visited and assessed using the preliminary risk analysis tool. Observations of participant use of the tool, their difficulties, concerns and suggested modifications were recorded via field notes and voice recordings. Field testing of the risk analysis tool involved six Djelk and seven KNP Indigenous rangers, selected during scoping workshops.

4.2 Data analysis

Workshop and interview audio recordings and audio recordings of participant observations were transcribed and, along with field notes, organised digitally according to participant and date using NVivo 10 qualitative data analysis software. Content analysis framed by the scoping and risk analysis frameworks was performed to identify themes relating to impacts, goals, methods, resources, barriers, leadership and ownership, as well as field survey variables for cultural value, site exposure and site sensitivity. Strategies to manage potential biases in data collection included reports back to participants and reviews of manuscripts and of quoted dialogue by participants and support staff. Cross-referencing of narratives obtained in the workshops with interviews and participant observation enabled assessment of consistency and credibility of findings.

4.3 Ethics

The study followed standard ethical norms, including obtaining university ethics approval (Australian National University no. 2014-342, Charles Darwin University no. H14022), eliciting informed consent from all study participants, reviewing results with and presenting results back to communities prior to publication and not divulging the locations of 'sacred' sites.

5 Results

Three sets of results are presented: (a) confirmation of rangers' perceptions of the types of cultural sites impacted, the impacts and the locations of these sites; (b) changes made to the preliminary field survey; and (c) the prioritisation of sites produced by the tool.

5.1 Confirmation of perceptions and establishing exposure units

During research for the Scoping phase of the Cultural Site Adaptation Guide, rangers identified site types they perceived to be at risk, the climate change impacts such sites were being exposed to and the types of land forms in which such sites might be found (Carmichael et al. 2017). During field explorations, the following sites were found that provided confirmation of these perceptions.

5.1.1 Riverine rock art

Djelk rangers investigating rock art sites on the upper Cadell River, south of Kolorbidahdah (Fig. 1) found five sites within 5 m of the river, less than 5 m above it and in sections of the river that pass through narrow gorges. At one of these sites, white-ochre paintings of kangaroos in x-ray style were almost entirely faded below a distinct line horizontally dissecting them. The location of the paintings on a rock face inaccessible to buffalos confirmed that the line dissecting the paintings did not represent the height limit of feral-animal rubbing. Flood debris caught on an adjacent elevated rock outcrop at the same level as the art work confirmed that the dissecting line resulted from an extreme flood event or events. The presence of water-compacted, fine-grade leaves and twigs among large logs suggested that the flood event was quite recent. Another four sites in close proximity to the river also had fine-grade flood debris in the stems of immature saplings at heights level with the art. While heavily faded red-ochre art was present at levels below those of the flood debris, no white ochre art work existed below these lines.

5.1.2 Floodplain rock art

KNP Indigenous rangers found floodplain-fringing rock art at close proximity to and at a low elevation above a floodplain near a creek inflow south of Ubirr (Fig. 1). A large log, likely flood debris, was stranded on a rock outcrop at a height less than 2 m below an adjacent rock art painting.

5.1.3 Coastal middens

In the Djelk IPA, in the vicinity east of Rocky Point (Fig. 1), severely eroded coastal middens on beaches fronting dune barriers were located. At a severely eroded coastal river mouth in the vicinity of Rocky Point, rangers located a site at which cyclonic storms only months earlier

(Tropical Cyclone Nathan, March 2015) had cut a visible swathe 20 m wide through riparian trees, destroying all traces of a river- and beach-based midden complex observed intact by rangers in the months prior to the cyclone.

5.1.4 Floodplain middens

KNP Indigenous rangers also found evidence of erosion from extreme flooding at floodplain midden sites. A very large, 50 m × 50 m, deflated earth midden was located on a slight rise within the South Alligator River floodplain north of Munmalary (Fig. 1). The substantial midden had substrate flood erosion at its perimeter. It was located very close to a channel, along which new colonisation by mangroves was taking place. Mangrove encroachment in freshwater areas is an evidence of salt water intrusion (Winn et al. 2006). Deflation of the midden had exposed human skeletal remains of two individuals, numerous stone artefacts, a stone axe head and the ochre cache perhaps of an ancestral artist.

5.2 Changes to the preliminary model

The preliminary field survey was therefore applied to and modified to accommodate the characteristics of (a) floodplain and riverine rock art and (b) coastal and floodplain middens. The preliminary model contained *ten exposure and sensitivity variables*, each with *five assessment options* from which surveyors could choose. The changes, discussed in the following sections, resulted in a revised model (Table 2) that replaced these with 15 *exposure and sensitivity variables*, each with *three assessment options*. The preliminary significance assessment contained *five assessment options*; the revised significance assessment method replaced these with *three assessment classes*.

5.2.1 Reduction of the range of assessment options

The preliminary model required surveyors to choose one of five possible assessment options for each variable. Qualitatively assessed variables, such as that for biological hazards, required the surveyor to choose from either ‘very active’, ‘active’, ‘moderately strong’, ‘weak’ or ‘almost inactive’. Rangers, however, found distinguishing between the options difficult. We experimented with binary options of either ‘yes’ or ‘no’, but in variables concerned with qualitative assessment of impacts, rangers were confronted with sites at which a midway measure was required. The range of options was finally changed to three: ‘strong’, ‘some’ or ‘none’ (Table 2). Wherever possible, however, strong, some or none were replaced with questions specific to rock art and middens. For example, the sensitivity of rock art was gauged on the basis of the painting’s ochre type: ‘red’ stood in for ‘strong’; ‘yellow’ for ‘some’; and ‘black/white/wax’ for (almost) none (Wesley et al. 2014). Similarly, the sensitivity of middens was gauged by the solidity of the structure: ‘solid’ stood in for strong, ‘soft’ for some and ‘scattered’ for none.

To be consistent, quantitative assessment options, mainly the proximity of hazards, were also reduced to three (see Table 2). The three increments of proximity used were chosen on the basis of local conditions. Rangers observed dune systems extending up to 400 m from the tidal edge. Because the Arnhem Land coast generally has a very shallow incline, with a slope value of <6°, we rated sites up to 100 m from the tidal edge as being the most exposed and those beyond 400 m as the least.

Table 2 A methodology for local-scale, climate change risk assessment of Indigenous cultural sites

A—Exposure				
Hazard types	Variables	Assessment options		
		Option A	Option B	Option C
Human	Proximity of township or outstation	Township <4 km	Outstation <4 km	Neither <4 km
	Proximity of tourism or hunting/gathering	Tourism <4 km	Hunt/gather <4 km	Neither <4 km
	Proximity of graded road or track	Graded road <4 km	Track <4 km	Neither <4 km
Climate change and extremes	Proximity to tidal edge/river	<100 m	100 to 400 m	>400 m
	Height above tidal edge/river	<2 m	2 to 6 m	>6 m
	Geomorphology:	Narrow gorge	Wide gorge	None
	◦ *Rock art*—gorge: location and breadth	<100 m	100 to 400 m	>400 m
	◦ *Floodplain midden*—proximity of channel	<100 m	100 to 400 m	>400 m
	◦ *Coastal midden*—proximity of river mouth			
Biological	Feral animals and weeds—impact	Strong	Some	None
	Native flora/fauna—impact	Strong	Some	None
	Fire hazard—vegetation and detritus build up	Large	Some	None
Natural weathering	◦ *Rock art*—fading	Very faded	Some fading	None
	◦ *Midden*—degree of deflation	Completely flat	Minor elevation	Steep sided
B—Sensitivity				
Sensitivity factors	Variables		Assessment options	
		Option A	Option B	Option C
Nature of remains	◦ *Rock art*—ochre type	Red	Yellow	Black/white/wax
	◦ *Midden*—structure	Solid	Soft	Scattered
Nature of substrate	◦ *Rock art*—rock hardness	Hard	Soft	Crumbling
	◦ *Midden*—doil type	Clay	Soil	Sand
Natural protection	◦ *Rock art*—rock overhang	Deep rock shelter	Some overhang	No overhang
	◦ *Midden*—tree consolidation	Strong	Some	None
Built protection	Fence—effectiveness	Well maintained	Unmaintained	None
Legal protection	Site is (a) on Indigenous owned land or (b) listed under heritage protection legislation	Both (a) and (b)	Either (a) or (b), but not both	Neither (a) nor (b)

5.2.2 Additional exposure and sensitivity variables

The height of a site above the tidal edge or river was a concern. While the Arnhem Land coast generally has a shallow incline and unconsolidated sediment, cliffs do exist and rangers recorded some middens within metres of the tidal edge but atop relatively high consolidated cliffs. At the same time, cyclone-derived storm surge can potentially extend very great distances in areas where there is an exceptionally low coastal slope, putting low lying shell middens more than 400 m from the tidal edge at an accentuated risk.

The height of rock art above rivers and floodplains was also a concern. While rangers documented rock art located very close to rivers, some sites were relatively high on the rock face and probably out of reach of even the most extreme floods.

We therefore complemented the variable of *proximity to* tidal or river edge, with a second climate change hazard exposure variable, *height above* tidal or river edge (see Table 2). Sites more than 6 m above the tidal or river edge were rated as the least sensitive and those less than 2 m above it as the most sensitive.

Observations of particular geomorphological risk factors at sites prompted addition of a third climate change risk variable, geomorphology. The assessment was modified to account for the location of: (a) rock art in a gorge, where a bottleneck-effect extenuates the height of flooding; (b) a floodplain midden's proximity to a channel, where water moves at speed; and (c) a coastal midden's proximity to a river mouth, where salt water flooding can be accentuated by simultaneous fresh water flooding.

The catch-all variable of 'biological' hazards was another issue for rangers. They indicated that the field survey should account for extreme damage done by feral buffalos and pigs observed at many shell midden and rock art sites. Rangers also related instances of damage to sites from fire, and many sites were observed to have a significant build-up of detritus and vegetation, sometimes exotic. Rangers concluded that the hazard of vegetation burning should be distinguished from the threat of mechanical damage (rubbing) to a site by vegetation animated by wind. The biological hazard variable was therefore divided in three: (a) feral animals and weeds, (b) fire and (c) native flora and fauna.

By the same token, it was noted that the best preserved coastal middens often had trees growing in them and that rock overhang at rock art sites also leant protection to rock art sites. A new sensitivity variable was therefore added: natural protection.

5.2.3 Cultural significance assessment options

Initially, rangers asked Traditional Owners to rate sites as either (a) very important, (b) quite important, (c) important, (d) a little important or (e) not important. Invariably, however, all sites were described as 'very important'. Shell mounds and middens in the Djelk IPA have a wide range of age and dimensions. We dated a small, shallow midden with burnt shell deposits, without an associated Dreaming story[3] or surface implements, at 149 cal. BP (Wk-42262). In contrast, a shell mound Dreaming site over 4 m tall and 40 m in diameter with stone tools on its surface was dated at 789–467 cal. BP (ANU-2021 Brockwell et al. 2009); its age at ground level might be considerably more, but no older than the establishment of the chenier beach ridge, with which it is associated, at c. 1000 years BP (Brockwell et al. 2005). Both these

[3] The term 'Dreaming' represents many Australian Indigenous cosmologies in which the land was once inhabited by ancestral figures, often of heroic proportions or with supernatural abilities.

middens, however, were described as 'very important sites' by their respective Traditional Owners.

In rethinking the issue, it was found that other studies documented similar difficulties. Sutton learnt that when asked, Indigenous Traditional Owners insisted that 'all our sites are of high significance' (Sutton et al. 2013; p. 9). The context of Sutton's inquires was destructive development (coal mining), a context in which an Indigenous statement of relative cultural significance might save a site or doom it to destruction. Yet, in a conservation context, Djelk and KNP rangers and Traditional Owners expressed the same very important evaluation of all sites.

The International Council on Monuments and Sites (ICOMOS) in Australia defines 'cultural significance' in terms of 'aesthetic, historic, scientific, social or spiritual value' (Australia ICOMOS 2013). 'Social' is defined in terms of 'group' or 'community identity'. There is, however, little in the way of detailed guidance in assessing site cultural significance beyond this. During the scoping phase, rangers and Traditional Owners discussed why cultural sites were important to them, without reference to the five ICOMOS categories. The explanations provided, however, were broadly in keeping with three of the five ICOMOS indicators of cultural significance (Table 3). Notably, no aesthetic or scientific explanations of value were provided.

Accordingly, questions were developed (Table 4) to gauge the cultural significance of sites in terms of three priority *classes* of evaluation rather than a scale, i.e. group identity value, historic value, and spiritual value. As middens and rock art sites are the focus of the climate change project, cultural significance questions specific to these site types were developed.

The schema therefore assumes *all sites* are very important from the outset: Group identity value is taken as a given for all middens and rock art and is the default position. If a site was not classified as culturally significant in terms of historical value but culturally significant in terms of spiritual value, it was rated class three. The schema was workshopped and discussed individually with rangers and Traditional Owners. All respondents were happy to prioritise the

Table 3 Ranger explanations of cultural significance allotted to ICOMOS significance categories

ICOMOS categories of significance	Example statements from interviews and workshops with Indigenous rangers from KNP and Djelk IPA
Group identity	◦ 'It's very important because I think a lot of those sites they may not define a single person, but they define a whole clan group, sometimes they make a clan group who they are'. ◦ 'Sites are who I am'; ◦ 'They are in our blood, all those sacred sites … our body and Spirit';
Historic	◦ 'The stories are about how we lived off the land, and some of them may point to how we still need to care for the land'; ◦ 'If we lose these sites then a lot of us will lose connection to land'; ◦ 'How will we know what to paint if the rock art goes?'
Religious	◦ '[If] I see everything damaged I might feel myself bad, and I might see the country dying, slowly; all that Dreamtime there, that country, you have to keep it healthy. If that all gone, then we lose everything. We will probably lose our Song Lines if all that country gets damaged'; ◦ 'For our ancestors, we have to look after [sites] for our ancestors. We have to keep going back and checking it. Keep talking, keep talking to the Spirit, making it settle down, making it good'.
Scientific	◦ Nil
Aesthetic	◦ Nil

Table 4 A method for assessing Indigenous values for cultural sites

Value type	Questions for Traditional Owners and Caretakers about midden and rock art sites	Cultural significance class
Group identity value	No questions: ◦ Group identity value is a given for all midden and rock art sites.	One
Historic value	Does the midden or rock art site contain or have: ◦ a name, traditional or modern? ◦ tools (or tool impacts, such as grind holes), which show us how old people lived on country? ◦ pictures that show us: how old people looked, hunted, gathered, fought, their tools, and what they noticed about white fellas? ◦ pictures good for showing us how to paint things?	Two
Spiritual value	Does the midden or rock art site have: ◦ a Dreaming story? ◦ a burial (bones) in it or nearby? ◦ a ceremony site at it or nearby? ◦ secret or 'dangerous' knowledge? ◦ pictures showing spirits, half-animal half-people beings, sacred animals, or a ceremony?	Three

three classes, with spiritual value as the highest priority and group identity value as the foundational priority but both *within* the overall category of very important.

5.3 Prioritisation outputs

In the original model conceived by Daire et al. (2012), the five assessment options are each represented by a numerical score: very active = 1, active = 0.8, moderately strong = 0.6, weak = 0.4 and almost inactive = 0.2. In our revised model, strong = 1, some = 0.6, and none = 0.2. As in the original model, the exposure scores were added together to create a score for total exposure, as were the sensitivity scores to create a score for total sensitivity. The total score for sensitivity was deducted from the total score for exposure to produce a total score for likelihood of loss or damage. Unlike the original model, we were then able to combine likelihood of loss or damage and cultural significance (consequence) scores for each site in a management priority matrix, giving rise to one of five possible management priorities: 'very low', 'low', 'medium', 'high' or 'very high'.

It should be noted that combining the potential impact components of vulnerability assessments (exposure and sensitivity) in this way, as a proxy for 'likelihood' of loss, with an independent and innovative assessment of 'consequence' of loss, provides a natural and practical reconciliation between the traditional risk assessment method (e.g. Willows and Connell 2003) and the climate vulnerability methods and thus combines the advantages and insights of both approaches.

As an example, rangers assessing a site near a creek in the Canon Hill area of Kakadu National Park (Fig. 1) gave it a very high management priority (Table 5). Firstly, its likelihood of loss or damage score equalled 2.6. Secondly, it was assessed as 'class three' cultural significance, due to paintings depicting spirits and ceremony and the site's associated Dreaming story. In the field survey's management priority matrix, a likelihood of loss or damage score greater than 2 and a cultural significance score of 3 converge on a very high management priority rating.

Table 5 Prioritisation case study: a rock art site in Kakadu National Park. Management priority: 'very high'

Likelihood of loss or damage				Consequence	
EXPOSURE	score				
Town/outstation	.6				
Tourism/hunting	.2				
Graded road/track	.6				
From tidal zone	1				
Above tidal zone	.6	**SENSITIVITY**	score		
Gorge	.2	Ochre type	1		
Feral damage	.2	Rock hardness	.6		
Native damage	.6	Rock overhang	.6	**CULTURAL SIGNIFICANCE**	score
Fire hazard	1	Fence	.2		
Weathering	.6	Legal gazette	.6	Pictures of spirits/ ceremony; site has a Dreaming story	**class 3**
Total Exposure	**5.6**	**Total Sensitivity**	**3.0**		
score for **Likelihood of loss or damage = 2.6** (Total Sensitivity subtracted from Total Exposure)				score for **Consequence = 3**	

		Management priority		
Likelihood of loss or damage	> 2	medium	high	very high
	1-2	low	medium	high
	< 1	very low	low	medium
		1	**2**	**3**
		Consequence		

Using this process, over 120 sites were assessed by rangers across the two study areas (Table 6). Of these, 13 sites are rated as a very high management priority and 25 a high priority. These preliminary assessments are a very small fraction of total sites within each ranger group's domain. The majority of the shell middens and many of the rock art sites assessed were formally recorded for the first time. It is beyond the scope of this paper, however, to provide a detailed analysis of these results.

6 Discussion and Conclusion

Despite extensive discussion of global warming, rising seas and coastal erosion, there has been relatively little global recognition of the perils facing possibly millions of cultural resources along the world's coastlines.

This study contributes to a small but growing body of scholarship examining practical responses to this grave issue (English Heritage 2007; Westley et al. 2011; Daire et al. 2012;

Table 6 Prioritisation results for Djelk IPA and Kakadu National Park cultural sites

	Exposure/ sensitivity score			Cultural significance class			Management priority rating				
	Low	Med	High	One	Two	Three	Very Low	Low	Med	High	Very High
No. of rock art sites (25 in total)	6	7	12	2	2	21	0	2	7	6	10
No. of midden sites (101 in total)	2	8	91	76	22	3	1	5	73	19	3
Total	8	15	103	78	24	14	1	7	80	25	13

Bickler et al. 2013; Dupont and Van Eetvelde 2013; Daly 2014; Dawson 2015; Johnson et al. 2015; Reeder-Myers 2015). The majority of this scholarship has been conducted in relation to non-Indigenous heritage, and as such, the focus on adaptive approaches to Indigenous cultural sites by Indigenous custodians in our study contributes some unique insights. These insights have significant values at various levels—locally in the case study areas themselves, more generally to Indigenous heritage locations around Australia and more broadly again in international/global approaches and strategies. As our study combined several disciplines, the insights can also be viewed through these lenses—particularly for Indigenous land management, for archaeological heritage studies and for climate adaptation approaches.

6.1 Local case study insights

Lack of local-scale support for Indigenous custodians necessitates the development of tools for independent risk analysis and responses.

This study identified a field survey approach to risk assessment as the most appropriate for local application. A preliminary field survey considered non-climate as well as climate impacts, allowing under-resourced communities and ‘citizen scientists’ to integrate assessment of climate change threats to cultural sites, with general threats.

The overly generic approach of the preliminary field survey, originally designed to assess potential impacts on everything from Neolithic burial tombs to post Medieval and twentieth century military features, was problematic. Indigenous land managers had a relatively narrow focus—rock art and middens. Nevertheless, they had the organisational capacity to significantly modify the preliminary model and ultimately allot sites to one of five management priority rankings. Reducing the range of assessment options from five to three greatly improved the consistency between independent assessments. Indigenous land managers also added two additional variables for climate change threats: geomorphology and height above hazard. Tourist activity in one of the case studies justifies the inclusion of the three separate human impact variables: proximity of township or outstation, proximity of tourism or hunting/gathering and proximity of graded road or track. However, the remoteness of the locations and their propensity for monsoonal climatic extremes warranted a greater weighting to climatic impacts. The additional variables are considered in some GIS-based models: geomorphology by Dawson (2015) and Reeders-Myer (2015) and height above hazard by Reeders-Myer (2015) by way of coastal slope.

Indigenous land mangers’ concerns about fire damage to cultural sites are supported by studies underlining fire’s destructive potential for rock art (e.g. Gunn 2011). Further studies also suggest that fire regimes in northern Australia are impacted, indirectly, by climate change (e.g. Russell-Smith and Edwards 2008). Similarly, the IPCC (2007) and others (e.g. Sheppard et al. 2008) argue that climate change will increase the spread of feral-animals and weeds, hence the importance of this research.

The cultural assets at threat from changing climatic conditions considered here are highly valued and vital to identity and ongoing cultural practice. Assessing risks and planning for future impacts must take the cultural value of sites into consideration. The research identified this as a deficit in the field survey approach, modifying the survey to include a novel assessment of cultural significance in line with broad cultural significance categories. Although these categories were derived from the world body tasked with setting standards for cultural conservation, ICOMOS, they proved applicable at the local level.

The innovations and improvements that emerged organically from field testing, and the usability of the outcomes, confirm the utility of the participative action research approach used. Results also represent an early affirmation of the high adaptive capacity of Indigenous land managers, not only in terms of conducting independent risk assessments but also in terms of formally recording previously undocumented sites and undertaking a monitoring process. Results also evidence the potential of Indigenous land managers within those locations to advance to the next stages of site management. These include an option analysis phase in which adaptive capacity is overtly workshopped and plans developed for capacity building and delivery of adaptation actions.

6.2 Broader insights

6.2.1 Indigenous land management

Insights from this study have implications for global responses, not only just in terms of Indigenous stakeholders but also for independent endeavours among any local community bereft of professional, state or non-government organisation (NGO)-based cultural site management coordination. Furthermore, where there *is* a context of regional coordination, there are implications for increasing local ownership and influence over policy development and planning.

Further testing of the risk survey tool in different contexts might result in the accumulation of variants on the model for different site types. These variants could conceivably be shared among a community of users, regionally, nationally and globally. The testing and use of the field survey by land managers at inland riverine cultural sites mean that its application can go beyond a purely coastal application and have more widespread application around Australia and elsewhere.

The cultural significance assessment component of the field survey developed here was not inclusive of the aesthetic and scientific classes of significance outlined by ICOMOS. In other contexts, these factors might be seen as important, and the survey accordingly reconfigured to include them.

The success of the field survey developed here recommends it to digitalisation and application in GPS-controlled tablets that are designed to log natural resource management data. Such devices have been taken up by Indigenous land managers across northern Australia and by other Indigenous land managers elsewhere in the world (NAILSMA 2014). Digital application of the risk tool has the potential to seamlessly incorporate assessment of impacts on cultural sites into the broader workflow of local land managers. If digitalisation is successful, making these relatively inexpensive devices available to local and Indigenous land managers might be a priority for governments and NGOs globally.

6.2.2 Archaeology, cultural heritage and climate studies

The study confirms that a global strategy for addressing climate change impacts on cultural sites cannot be focused exclusively on measuring impacts, it must also highlight the value of what is at risk. Article 8 of the COP21 Paris Agreement introduced a notion of residual climate risks and climate impacts, dubbed ‘loss and damage’. There is now a need to address the valuation of loss and damage to cultural sites for the purposes potential recompense.

Lessons learnt and experiences gained by local people adapting sites to climate impacts, particularly Indigenous people battling economic marginalisation, represent the development of skills valuable not just to their own communities but also to the global community. Indigenous land managers may be able to develop and provide adaptive heritage services worthy of financial support on the basis of supplying a valuable public good, as they do in terms of natural resource management (Altman 2009). Their cultural sites are, after all, of value to the world community.

Work in this area must entail publicising the impacts and potential losses that local communities highlight not just in order to attract support for cultural site adaptation but also to inspire greater global efforts to mitigate greenhouse gas emissions.

6.2.3 Climate adaptation approaches

Our study has shown that many of the principles and approaches developed and applied in other climate change adaptation contexts (e.g. Webb and Beh 2013; pp. 16–19) can be equally and usefully applied to less studied, remote Indigenous environments. Examples include the following:

- Incorporation of non-climate as well climate driven risks into the process, consistent with preferred ‘mainstreaming’ approaches and ‘integrated solutions’ to adaptation
- Locally driven and owned approaches consistent with ‘community-based adaptation’ approaches, with high levels of local engagement and leadership that can reflect local values, knowledge and capacities. Such ‘bottom-up’ approaches are a crucial starting point that can be complemented by ‘top-down’ approaches (e.g. regional coordination or expert archaeological review of cultural significance assessment) in subsequent stages
- The importance of understanding both social and institutional contexts, noting, for example, the distinction between the two case studies with whom the research described here was undertaken, and a third in which there was a lack of perceptions of climate change impacts on cultural sites
- Building an approach that facilitates reflexive learning and continued iteration, which can continue through the field survey’s ongoing monitoring process as well as continued improvement and modification of the field survey itself
- The applicability of standard risk and vulnerability assessment approaches as a cornerstone of local community adaptation practice.

Further to the latter point, it was found that by using consistent and practical definitions of key concepts, it was possible to effectively use and completely reconcile risk management and vulnerability methodologies. This is counter to the view often expressed in the literature and practice that concepts such as *likelihood of damage or loss* and *vulnerability* are alternative or even competing paradigms.

6.3 Conclusion

The multiple insights and outcomes from our study support the view that practical and rigorous approaches can be taken to climate adaptation of cultural heritage sites even where resources are likely to be severely constrained.

The development of global strategies to combat climate impacts on local and world heritage has stalled since first steps were taken at the beginning of the millennium (UNESCO 2006). Renewed efforts need to adopt standard climate change risk terminology for cultural sites; facilitate risk analysis across global, regional and local scales; and create links between those working independently at a local scale in order to share knowledge and insights born of empirical experience. Future reports of the IPCC and programs of the UN Framework Convention on Climate Change need to increase incorporation of archaeological resources and research.

Work in the field of Indigenous community adaptation to climate change is also in its infancy, and there remains a need for practical and accessible adaptation planning pathways for Indigenous peoples in general. Essential for further work in this area is the integration of communities and Indigenous organisations that combine local knowledge, experience and scientific practice, with global planning efforts to confront climate change.

Acknowledgements The authors would like to thank the following for their generous assistance: Djelk and KNP Traditional Owners including rangers Patricia Gibson, Darryl Redford, Obed Namirrik, Alfie Galaminda, Bobbie-Sheena Wilson, Felina Campion, Simon Dempsey, Jackie Cahill, Jonathan Nadji, Natasha Nadji, Jeffrey Lee, Bobby Maranlgurra and Kadeem May; KNP cultural heritage manager Gabrielle O'Loughlin; Djelk support staff Dominic Nicholls, Alys Stevens, Anthony Staniland and Ricky Archer; and for the critical feedback, Apolline Kohen, Colin Pardoe, Rolf Gerritsen and Jack Fenner. Fieldwork was supported by the Australian Research Council (Linkage Project LP110201128 and Discovery Project DP120100512), the Australian National University and Charles Darwin University.

Compliance with ethical standards The study followed standard ethical norms, including obtaining university ethics approval (Australian National University no. 2014-342, Charles Darwin University no. H14022), eliciting informed consent from all study participants, reviewing results with and presenting results back to communities prior to publication and not divulging the locations of 'sacred' sites.

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