Case Study

Kakadu – vulnerability to climate change impacts

Background and context

The National Climate Change Adaptation Framework (COAG 2007) identified key strategies to build capacity to deal with climate change impacts and reduce vulnerability to key sectors and regions. Consistent with the Framework, the Australian Government Department of Climate Change undertook the National Coastal Vulnerability Assessment (NCVA) which aimed to assess the potential impacts and consequences of climate change for Australian coastal communities and to describe the benefits and costs of adaptation.

Six case studies across Australia were selected to demonstrate the range of issues and methods for analysis of vulnerability and adaptation responses. The identification of case studies was based on climate change variability, the significance of the systems at risk, the availability of existing data and the likely need for government intervention to ensure a timely and efficient adaptation response. Kakadu National Park in the Northern Territory was identified as one of the case studies within the NCVA.

Study area

The Kakadu case study focused on the wetlands and floodplains of the South Alligator River (SAR) system within the boundary of Kakadu National Park (Figure 1). The catchment of the SAR extends from the coastal floodplains in the north of Kakadu National Park, to the sandstone plateau in the south, covering 11 700 km^2. Located in the monsoonal zone of northern Australia, the area experiences annual extremes of the wet and dry cycle. The freshwater and saltwater systems of the South Alligator River exist in dynamic equilibrium, made complex by the relatively high tidal range, high seasonal rainfall and high natural variability (Figure 2). The tidal interface is subject to constant change caused by channel contraction and expansion.

Over the 15 years prior to the study, a large amount of scientific work on saltwater intrusion and other potential climate change impacts had been undertaken within Kakadu National Park. Several research papers and reports were available that indicated the vulnerability of Kakadu's low-lying wetlands to salt-water intrusion (Hare 2003, Gitay et al. 2001; Bayliss et al. 1997, and Eliot et al. 1999), with the Intergovernmental Panel on Climate Change (IPCC) (2007a) report predicting a loss of 80% of freshwater wetlands in Kakadu for a 30 cm sea level rise. However, these papers and reports also acknowledged that the estimates of predicted wetland loss are highly uncertain and highlighted the many assumptions and limitations that make predicting such losses difficult in a data-limited environment.

Figure 1: Case study location. Source: BMT WBM 2010. © Commonwealth of Australia, Department of Climate Change and Energy Efficiency, 2011.

Figure 2: Examples of wetland environments of the South Alligator River catchment: A) Tributary of the South Alligator River; B) Yellow Water; C) Billabong near Yellow Water. Photos: © Greg Fisk.

Park management

The traditional owners of Kakadu are the Bininj/Mungguy. It is estimated that the Bininj/Mungguy have occupied the Alligator Rivers region for up to 60,000 years, and at the time of European arrival in the area, many people hunted and gathered around the wetlands of the South Alligator River south of Nourlangie Creek.

Kakadu National Park is managed under a joint management arrangement; a partnership between Bininj/Mungguy and the Australian Government which enables Bininj/Mungguy to look after their country in cooperation with staff of the Kakadu National Park. This arrangement ensures the partners work together to solve problems, make decisions, and implement these in the management of the Park. It also ensures the respect and maintenance of traditional knowledge and skills associated with looking after culture and country, and cultural rules regarding how decisions are made (Kakadu National Park Management Plan 2016-2026).

The Park is managed through the implementation of the Kakadu National Park Management Plan, and strategies that sit under the Plan. The *Kakadu National Park Management Plan 2007-2014*, current at the time of the study, acknowledged the potential impacts climate change may have on the significant values of the Park, and also that further information is needed in a number of areas to be able to effectively undertake rehabilitation and protection measures. A draft Climate Change Strategy was also being prepared at the time of the study, and was finalised prior to the publication of the BMT WBM (2010) report. This strategy highlighted climate change impacts relevant to the whole Park (not just the SAR) and recommended management actions that were aligned with the Parks Australia Climate Change Strategic Overview 2009-2014. These Park planning timeframes were not considered in the establishment of the study timelines.

Study objectives and approach

The overall aim of the study was to model river system hydrodynamics to assess the risk of saltwater intrusion and extreme rainfall events on low-lying coastal wetlands of the South Alligator River catchment, and to discuss the implications of government planning, management and policy responses.

In meeting the above aim, the study sought to provide:

- a multi-disciplinary methodology that can be used to assess like environments in the context of future climate change impacts such as sea level rise
- a desktop assessment of potential climate change impacts on the values of the South Alligator River catchment that will be of use to Parks Australia and other users and stakeholders in future management of the Kakadu National Park.

The specific study objectives were to:

- identify the key physical processes and ecological, cultural and socio-economic values of the South Alligator River catchment
- develop and model river system hydrodynamics with associated catchment (rainfall) and coastal (storm surge) inputs from additional modelling for existing and projected climate change under 2030 and 2070 scenarios
- assess the potential impacts on the key physical processes and ecological, cultural and socio-economic values
- assess the risks of projected climate change for 2030 and 2070 scenarios
- identify and evaluate adaptation options including the relative costs of implementing such measures against a 'do nothing' approach: this part of the assessment is described further below.

For the purpose of conducting the study, the Australian Government provided the two climate scenarios and sea level rise predictions to be used. These were:

- 2030: IPCC emission scenario A1B, 95th percentile – giving a sea level rise of 143 mm
- 2070: a high emissions scenario based on the latest science at the time – giving a sea level rise of 700 mm.

Rainfall scenarios were based on the percentage change figures for Darwin, as published by the IPCC (IPCC 2000, 2007b) and interpreted by the CSIRO in Climate Change in Australia (CSIRO 2007). Also included were predictions of changes in cyclone intensity and frequency, with 2030 representing a 10% increase in intensity (only) and 2070 representing a 20% increase in intensity and 10% increase in frequency (Appendix J, BMT WBM 2010).

The study specifically addressed climate change-induced impacts related to the projected rise in sea level, statistical increase in cyclone intensity and frequency (i.e. storm surge related to changes in cyclone intensity and frequency), and rainfall changes. The scope of the study did not include other climate change factors, such as temperature increase (including increase of water temperature), fire frequency or intensity.

Consultation

As part of the broader study consultation strategy, consultation with traditional owners and Aboriginal people associated with Kakadu National Park (specifically the SAR catchment) was undertaken to:

- engage key stakeholders in order to gather information
- empower key stakeholders to provide input into the study
- provide a forum to present study results to key stakeholders.

Additionally, the consultation fulfilled the conditions of the research permit granted by Kakadu National Park, for which Traditional Owner consultation was advised by the Northern Land Council. The Kakadu Board of Management requested that the project was aligned with other climate change projects in the region in order for Parks Australia North to build on regional knowledge and to avoid duplication in Traditional Owner consultation. For the same reasons, Park staff were involved with the consultation process and given full access to the information obtained.

Consultation was undertaken in two main stages:1) initial consultation to provide stakeholders with information regarding the study, and to seek information on the ecological, cultural and socio-economic values of the study area. This stage of the consultation was undertaken in the form of meetings at ranger stations; visits to outstations, homes, businesses and Aboriginal associations; workshops at Park headquarters; telephone calls; and simple information sheets; and 2) a Risk Assessment and Adaptation Options Workshop which was used to present preliminary findings from the modelling and impact assessment stages of the study, and use an expert/stakeholder elicitation process to jointly determine and assess the risks and adaptation options available.

Assessment of implementation of adaptation options vs 'do nothing' approach

The final step in the study approach was a multiple criteria analysis that was undertaken to assess the performance of proposed adaptation options against the 'do nothing' approach. Criteria such as cost of implementation, level of risk mitigated, efficacy, feasibility to implement and benefits to regional economy were identified to enable the measurement of the performance of options.

Qualitative information was used to score the performance of options against the criteria, as data to accurately estimate the performance of each option was not available for the study, and instead orders of magnitude were applied to the assessment.

A trade-off matrix was then used to determine how each option performed in comparison to other options. Following conversion of the trade-off matrix to a ranking matrix, options were prioritised based on their aggregate score.

Outputs and outcomes

The main aim of the study was to provide a multi-disciplinary methodology that can be used to assess similar environments in the context of future climate change impacts such as sea level rise. The methodology was documented in detail in the BMT WBM (2010) report.

In addition, the study provided an assessment of potential climate change impacts on the values of the South Alligator River catchment, and identification and assessment of potential adaptation options that can be used by Parks and other users and stakeholders in the future management of the Kakadu National Park. The key outputs were presented in the report including:

- a risk register which outlined key risks to the South Alligator River catchment under the provided climate change scenarios
- a list of adaptation option which aimed to treat the risks
- potential qualitative indicators that can be used to determine when adaptation options may be implemented
- an initial assessment of the indicators in terms of the constraints/barriers to implementation and the possible organisations involved in implementation
- a preliminary economic assessment of adaptation options in the form of a multiple criteria analysis to determine relative costs and expected benefits of implementing each of the options.

Multiple Criteria Analysis – Final ranking of adaptation options

The final ranking of adaptation options is provided in Table 1 and demonstrated that the equally best performing options, given the criteria adopted for the assessment, were to:

- promote new forms of tourism at existing sites
- maintain access to priority sites
- manage crocodile numbers and minimise contact with humans (Figure 3)
- manage key ecological sites to build resilience.

The trade-off matrix identified that the major differences in the performance of these options was between the cost of implementation and the benefits to regional economy.

Table 1: ***Prioritisation of Options****. Aggregate scores represent the performance of each option against the five criteria used in the multiple criteria analysis (cost of implementation, level of risk mitigated, efficacy, feasibility to implement and benefits to regional economy). The rank represents the prioritisation of options based on the aggregate score. Source: BMT WBM 2010. © Commonwealth of Australia, Department of Climate Change and Energy Efficiency, 2011.*

OPTIONS	AGGREGATE SCORE	RANK
Tourism		
Promote new tourism at existing sites	7	**1**
Open new sites	8	**2**
Replicate sites and/or create 'Living Museum'	18	**9**
Maintain access to priority sites	7	**1**
Maintain infrastructure at priority sites	10	**4**
Manage crocodile numbers and minimise human contact	7	**1**
Maintain World Heritage listing	9	**3**
Mining		
Rehabilitate past mining facilities	16	**8**
Upgrade infrastructure for proposed mines	14	**6**
Health and Safety		
Prevent introduction of tropical diseases	15	**7**
Develop incidence response plan	9	**3**
Upgrade safety communication	9	**3**
Ecology		
Educate visitors and residents and businesses	10	**4**
Manage extractive uses for the Park	11	**5**
Manage key ecological sites to build resilience	7	**1**
Structural protection of priority sites	11	**5**
Transport and Communication		
Develop alternative forms of transport into and within Park	10	**4**
Construct all weather road access	9	**3**

Options that were ranked highly were opening new sites to visitors and two options put forward to maintain access to sites within the Park, despite the relatively high cost of implementation. Interestingly, the options ranked highest were those which facilitated the continuation of tourism activities within the catchment (e.g. access, swimming, wildlife viewing – Figure 3) rather than options requiring major infrastructure to secure sites of high ecological and or cultural value. Assigning weights or an order of importance to criteria might well have resulted in a different ranking. Hydrological modelling together with ecological response modelling would assist in more accurately estimating the cost of implementation which may result in a more robust and reliable ranking of possible options.

As this analysis was undertaken to inform an initial assessment of adaptation options, the results suggest that more resources are required to determine a set of performance criteria against which options can be measured and with which stakeholders are comfortable. More importantly, to implement any of these options, further research, in particular development of a Digital Elevation Model (DEM), is required to identify specific sites at risk and to enable the relocation of infrastructure, including access roads, to be located in areas identified as secure from sea level rise, flooding and/or storm surge. In addition, more reliable rainfall data, maps showing where cultural and anthropological sites of significance are located (where appropriate) together with an ecological response model would enable a more robust assessment.

Figure 3: Crocodile in the South Alligator River catchment spotted from the air. Photo: © Lyn Leger.

Limitations to study and implementation of findings

Based on the key findings, the following issues and opportunities were identified in the context of future planning, management and policy responses.

Key information gaps and refinement of numerical models

Timely adaptation to climate change will depend on the ability to identify areas that may be significantly impacted through sea level rise, storm surge from more frequent and intense cyclones and changes to rainfall, and being able to confidently predict the likelihood and severity of such changes.

A hydrodynamic numerical model of the tidal channel and floodplain was developed as part of the study, with inputs from coastal and catchment models, for existing and future climate change scenarios at 2030 and 2070. The hydrodynamic modelling undertaken showed that under the 2030 and 2070 scenarios, more frequent and longer periods of saltwater inundation of freshwater floodplains could be expected when compared with the existing scenario. The development of these models used the best data available to the study team. However, some key datasets were not available for the study. These included:

- A digital elevation model (DEM) for the area. The DEM provided for the study was not of sufficient resolution/accuracy to be able to provide accurate and reliable results in the modelling.
- Sediment characteristics for the floodplain and the estuary which are essential for geomorphological modelling. This also includes delivery of sediments (fluvial and marine) and the tidal zone dynamics (flocculation and levee building/scouring).

These significant data gaps meant that only qualitative assessments could be made of the impacts to the values of the South Alligator River catchment. Similar issues were experienced with the catchment model due to a lack of stream gauging within the catchment.

The lack of an established survey datum in the region has also restricted the collection of reliable elevation data for modelling and other purposes.

Acquisition of a quality DEM and sediment characteristic data for the floodplain and estuary may allow for future use of the existing tidal and floodplain model created as part of the study, including in a predictive capacity. In particular, the model has the ability to take the subtle detail on an essentially flat floodplain and simulate water flow into and out of the billabongs, paleochannels and other water retaining features. In this case, the impacts of sea level rise could be modelled in a more accurate way. In addition, the model is capable of simulating the sedimentation processes associated with increased channel flow, increased sediment inflow from the catchment and flocculation.

These processes are essential for levee building and, with appropriate data, the ability of the system to respond to sea level rise could be modelled. The model would also be applicable for use in sensitivity analyses including the likelihood of cut road access, the incidence of flooding in developed/important areas and similar uses which would be of benefit in the investigation and implementation of future adaptation actions.

Limitations of park management

The study aimed to provide an assessment of potential climate change impacts and identification of potential adaptation options that can be used by Parks and other users and stakeholders in the future management of the Kakadu National Park. However, a number of factors have affected the uptake of reporting findings and recommendations by Park management:

- **Misalignment of study scope and boundaries, and jurisdiction of Kakadu National Park:** The study area boundary was within the Kakadu National Park. However, the study addressed values and impacts and identified adaptation options that are not within the direct jurisdiction of management of Kakadu National Park (e.g. impacts to tourism values and small businesses), and require consistency with management approach from outside the Park. Despite this, many of the cultural and socio-economic values of the catchment depend on the maintenance of ecosystems and the conservation of biodiversity. By using available funding to manage the natural values of the Park, park managers have the best chance to build resilience of Kakadu's wetlands to climate change, and protect and enhance the non-natural values of the Park.

- **Misalignment of study timeline and Park planning timeframes:** At the time the study was undertaken, the Kakadu National Park Management Plan 2007-2014 was halfway through its tenure, and the *Kakadu National Park Climate Change Strategy* was in the process of being drafted by Park management, but was completed prior to the publication of the BMT WBM study. This meant that the BMT WBM (2010) report was not available to the Parks staff at a critical time in the development of the Kakadu National Park Climate Change Strategy 2010-2015. It is noted however that some actions within the *Climate Change Strategy* are similar to those identified during the study, and may have resulted from the involvement in Parks staff in the study consultation processes.
- The recently approved Kakadu National Park Management Plan 2006-2026 acknowledges that "a vulnerability assessment of the South Alligator River catchment was completed in 2011", suggesting that this Plan has considered the findings of BMT WBM (2010). Policies within the Plan also include implementing adaptation measures to maximise the resilience of Kakadu, and working with communities, industries and stakeholders to adapt to climate change. However, the lack of reference to BMT WBM (2010) may mean the reader does not have access to the appropriate tools to reconsider the climate change risks and options outlined in the BMT WBM report, and the processes used throughout the study.
- **Availability of funding and staff resources for Park management:** During the years following the publication of the BMT WBM (2010) report, funding constraints have led to the following issues.
  - Loss of some staff with knowledge of land management practices and past research conducted in the Park (including the BMT WBM [2010] study)
  - The need to focus on immediate priorities (i.e. onground management of fire, pests and weeds). This has, in turn, has had an impact on the ability of Park's staff to consider and respond to any additional climate change adaptation measures, particularly ones focused on forward planning. However, recent increases in staff and funding may create opportunities for additional planning and adaptation responses in future.

Conclusion

BMT WBM (2010) and other previous research conducted suggest that climate change is likely to impact on coastal and lowland areas of Kakadu National Park through rising sea levels and saltwater inundation. Key opportunities exist to use the methodologies and processes from this study, and capture the findings in future planning and government decision making processes.

A revised Kakadu National Park Climate Change Strategy will be developed in 2016. This provides an opportunity for Park management to revisit the study approach and reassess the risks and adaptation options to determine the most efficient and cost effective adaptation options that can be implemented as actions under the Strategy, and to build resilience of Kakadu National Park's low-lying coastal wetlands to the impacts of climate change.

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Please cite as: Leger, L., and G. Fisk, 2016: Kakadu - Vulnerability to Climate Change Impacts. Case Study for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

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